Cost management of modular products: An interventionist research study

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1 Introduction

This introductory chapter serves several purposes. First, we motivate our research, and explain our intended contribution to academic literature. This also entails a short explanation of the research design. And second, we aim to explain the structure of the thesis to provide guidance to the reader.

Two research topics are central to that dissertation. As a first research focus, we explore *cost impacts and cost management strategies in the context of modularity*. The topic of modular designed products received much attention in the innovation and operations management literature (for example, Cebon, Hauptman, & Shekhar, 2008; Chakravarty & Balakrishnan, 2001; Ro, Liker, & Fixson, 2007; Ulrich, 1995), but this is not too extensively researched in the management accounting and control literature. We do not know much about how companies coordinate their decisions and manage costs when dealing with a modularly designed product portfolio. One of the few studies that focus on cost management issues that arise during the execution of a modular strategy is Israelsen & Jørgensen (2011).

For empirically investigating practical cost management approaches and challenges in this field, we conducted an interventionist research study in cooperation with a car manufacturer. The company was well known for following a modular strategy since decades. The key aspect of such an interventionist research design is that the researcher is directly involved in the action and uses intervention as one of the research assets, and he therefore contributes both to theoretical knowledge and practice improvements (Jönsson & Lukka, 2006). The author of this thesis was full-time on site for three years. He was a member of the car manufacturer's controlling department that was responsible for new product development (NPD) projects. In that position, he was able to identify research opportunities that contribute to academic literature and he could also improve the company's cost management abilities to solve new challenges. Simply said, he aimed at "solving some ill-defined problem which goes beyond present knowledge and has as its output both a 'solved' problem and a contribution to theory" (Berry & Otley, 2004, p. 232).

Our second research focus investigates the question: *how can providers of management accounting technology increase its persuasiveness?* The accounting literature recognizes that accounting numbers are inherently soft and incomplete (Jordan & Messner, 2012). Their role during decision making is socially constructed, depending on beliefs about the future, perceptions about a calculation's adequateness, further discussions, negotiations, and personal interests (Andon, Baxter, & Chua, 2018; Briers & Chua, 2001; Quattrone, 2017; Rowe, Shields,

& Birnberg, 2012). In the context of strategic decision making for modular product design, we investigate how the provision of details and explanations may enhance a calculation's persuasiveness, and therefore actors' comfort to act on it.

This second research topic evolved in the course of the research project. Some other topics, thought to be relevant for the company during earlier discussions, turned out to be not a fertile area to work on, because it was unlikely to get on the company's agenda at that time. However, other research opportunities appeared that we had not thought of before. In particular, the company was estimating the financial consequences of product development decisions for a modular architecture. These calculations were surrounded by enormous uncertainty and the controllers were trying to make their calculations more persuasive. This illustrates another characteristic of longitudinal field studies—researchers have low control over the empirical space (Ahrens & Chapman, 2006). This research is therefore inspired and motivated by challenges and requirements we found in practice. However, the dissertation transports complex practical cost management challenges into scientific discourses and contributes to a more nuanced understanding how management accountants may increase their calculations' persuasiveness in uncertain contexts.

The thesis comprises five chapters as shown in Figure 1. Besides the introducing and concluding chapter, the thesis' three main studies are presented in chapter two, three, and four. We will shortly explain and summarize the three studies in the following. The second chapter of the thesis is a literature review which focuses on the modular design of products and the purpose of cost management. Modularity essentially involves mechanisms for coordinating technical design decisions across a large portfolio of products, with the aim of reducing total costs and maximizing total profit of that portfolio. Thus, it goes beyond target costing, which typically focuses on costs of only one product. However, in the management accounting and control literature, there has been only limited attention to modularity, whereas much research on this topic has been published in the innovation and operations management literature.

We look at various literatures, and organize, analyze, and discuss existing knowledge about cost impacts and cost management aspects of modular strategies. We systematically

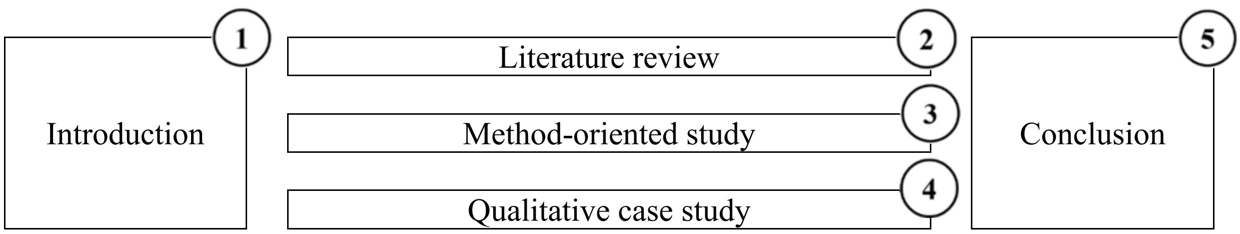

Figure 1. Five chapters constitute the dissertation

review 41 accounting journals and 32 journals in innovation and operations management. We aim to create a detailed and differentiated review of the literature to get a better understanding of the multiple facets of modular design, component commonality, and product platforms as cost management strategies during the entire product life cycle.

The third chapter provides a method-oriented study. We extend the scope of target costing, and present a method to determine fixed cost targets for a modularly designed product portfolio. Existing target costing literature pays significant attention to managing single product's manufacturing costs, but almost ignores target setting procedures for research and development (R&D) and investment costs of modular designed product families.

Triggered by the practical requirements of the car manufacturing firm, we conceptualize a method to determine R&D and fixed manufacturing cost targets for a modularly designed architecture that provides the basis for a whole product portfolio. The method enables the user to generate fixed-cost specific cost targets for the architecture's individual elements (for example, a particular platform or group of modules and components). We present the method's implementation, and illustrate how cost targets were established in the company to realize significant fixed cost reductions.

In chapter four, we present a qualitative case study and examine how the provision of details and explanations helps to harden soft accounting information. The author of this thesis was actively involved during several strategic decisions for a modular product architecture. These decisions were surrounded by a significant amount of uncertainty. The chapter conceptualizes a theoretical framework to explain how the provision of details and explanations helps to strengthen soft calculations' persuasiveness. We base this chapter on studies that show how the role and use of uncertain numbers and calculations depend on actors' perceptions, beliefs, and interests, and how their comfort to act on these numbers is impacted by discussions and negotiations.

We postulate that management accountants are not "neutral" or "objective" providers of information, but have an agenda, too. With our theoretical framework, we provide several means and instruments accountants may apply in order to achieve that their calculations become more influential. *Expressing* and *enabling scrutiny*, *enabling comparisons*, *reversing* respectively *focusing the burden of proof*, and *opening and closing the window of opportunity for challenge* are key aspects of our framework. Furthermore, we provide extensive empirical evidence to illustrate and substantiate our theoretical framework.

Major parts of this thesis are written in the first-person perspective. In sections where we present empirical evidence from the case study (mainly Section 3.4 respectively 4.5), we use the third-person perspective to also talk about “the controllers”. This helps to differentiate between the author of the thesis (first-person perspective) and him as one of the actors in the car manufacturer’s controlling team that was responsible for the particular tasks (third-person perspective).

2 Cost management and modular product design strategies

Abstract

Companies that follow strategies such as modularity, component commonality, and product platforms aim to offer a wide assortment of end products to their customers, while simultaneously reducing total costs and maximizing total profit of that portfolio. The mentioned approaches are complex phenomena, and a large number of studies use a multitude of deviating conceptualizations. Modularity requires mechanisms for coordinating technical design decisions across a whole product portfolio, but the management accounting literature has paid only scarce attention to that topic. With the current study, we present existing knowledge of cost impacts of modular strategies from various literature streams, and provide an overview of modularity for cost management purposes. We understand modularity as a deliberate cost management strategy, and show the multiple facets and partly ambiguous effects (also beyond costs) such approaches have during the different stages of a product's whole life cycle. Moreover, we differentiate modular approaches from target costing, and discuss behavioral aspects, such as incentives as well as challenges and limitations of accountability that arise during its implementation in practice.

Keywords: *Modular design, cost management, literature review, target costing, component commonality, product platform*

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2.1 Introduction

This chapter discusses the use of product modularity for cost management purposes. We consider the context of firms offering a wide assortment of end products to their customers and which need to manage their costs to be able to offer such diversity efficiently. For example, German car manufacturers sell many different car models and individual configurations to customers, and managing the costs of that diversity is a big challenge. Modular design of products is a key approach they employ to be able to utilize economies of scale in development, purchasing, and manufacturing.[1] As we will discuss below, modularity essentially involves mechanisms for coordinating technical design decisions across a large portfolio of products, with the aim of reducing total costs and maximizing total profit of that portfolio. Thus, it goes beyond target costing, which typically focusses on costs within the scope of only one product.

However, in the management accounting and control literature, there has been only limited attention for modularity, whereas much research on this topic has been published in the innovation and operations management literature (Wouters & Morales, 2014; Wouters, Morales, Grollmuss, & Scheer, 2016). Many management accounting techniques are not necessarily compatible with modularity as a cost management approach. For example, Taipaleenmäki (2014) investigated the role of management accounting in new product development (NPD) based on several case studies. One of the companies used a product life cycle profitability calculation, which aimed to reflect the NPD process and to cover the full product life cycle. However, "[product life cycle profitability] was seen as an insufficient model for analyzing product variants, and no suitable method was available for *supporting modular development decisions*" (Taipaleenmäki, 2014).

The purpose of this chapter is to look at various literatures and to provide an overview of our current understanding of modularity for cost management purposes. So, even though the concept of modularity may also relate to organizational design or educational programs (Schilling, 2000), we will focus on modularity in the design of products and for the purpose of cost management.

[1] For example, Volkswagen, BMW and Mercedes-Benz talk about their various platforms as a key strategy for managing costs. Wikipedia, *Volkswagen Group MQB platform*, http://en.wikipedia.org/wiki/Volkswagen_Group_MQB_platform, (accessed 11 January 2016). Herbert Diess, *R&D: Future-proofing the BMW group*, presentation dated March 20, 2013, downloaded from http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/investor_relations/downloads/_pdf/BMW_Group_AIC2013_Presentation_R-D_Dr_Diess.pdf (accessed 11 January 2016). Autoevolution, *Mercedes-Benz will switch to just four car platforms*, http://www.autoevolution.com/news/mercedes-benz-will-switch-to-just-four-car-platforms-78508.html (accessed 11 January 2016).

2.1.1 Modularity and cost management in prior literature reviews

Several literature reviews have examined modularity from different points of view. Labro (2004) reviewed the operations management literature with respect to the effects of common components on various levels of cost divers, according to activity-based costing. Wouters & Morales (2014) and Wouters et al. (2016) addressed modularity, but not in that much detail, as this was one of many other cost management methods reviewed. Several other literature reviews concentrate on R&D and manufacturing aspects of modularity, but do not focus on cost management. Campagnolo & Camuffo (2010) reviewed 125 papers about modularity in a management or business context from a product design, process design, and organizational point-of-view. Fixson (2007) identified 160 studies within the engineering and management literature dealing with commonality and modularity and analyzed these with respect to topic, investigated effects (such as costs), and applied research methods. Jiao, Simpson, & Siddique (2007) identified research and reflected on the current knowledge on product platforms and product family design. Their objective is to give a broad overview over the topic, and cost aspects are only briefly mentioned. Salvador (2007) screened management and engineering journals with the intention to discuss different definitions of modularity.

It is understandable that most of these prior reviews have not focused specifically on cost management, because most research does not go into much detail regarding cost impact. In some cases, general assumptions such as “manufacturing costs always decline with the use of commonality” (Desai, Kekre, Radhakrishnan, & Srinivasan, 2001) are too imprecise to capture the complex and sometimes opposed effects of modularity. Additionally, many studies mention the (supposed) benefits of modular design, platform usage and common components rather broadly and not explicitly in financial terms, such as flexibility, risks, lead times, quality, or product variety (Henke, 2000; Mahmoud-Jouini & Lenfle, 2010; Robertson & Ulrich, 1998). These effects are important, so we consider them and try to bridge their impact on costs, even if such effects are hard to quantify in some cases.

2.1.2 The current literature review

The contribution of the present literature review is that we focus on modularity and consider this as a *deliberate cost management strategy*. We extend the earlier literature review by Labro (2004) by reviewing later studies from similar journals, and also by including several other aspects around modularity as cost management strategy. Our objective is to create a detailed and differentiated review of the literature to get a better understanding of the multiple facets of modular design, component commonality, and product platforms as cost management strategies during the entire product life cycle.

2.1.3 Research method

We have included studies published in accounting as well as in innovations and operations management on the use of modularity for cost management purposes. We focus on all phases of a product life cycle, and thus on various kinds of costs (such as development costs, manufacturing, inventory holding, and after-sales service). There are many tradeoffs involved when applying these methods, because cost savings in one phase of the life cycle or in one functional area can entail extra costs in another phase or area. The selection of sources has been a diverse process. We were aware of relevant literature through earlier research projects and structured literature searches we had been involved in, and so we realized in advance that the amount of research on modularity is very extensive.[2] A main challenge was to identify studies that specifically focus on cost management.

Keyword searches have been conducted to identify additional sources.[3] This included journals in accounting (the 37 journals listed by Bonner, Hesford, Van der Stede, & Young (2006) complemented by *Advances in Management Accounting, Journal of Cost Management, European Accounting Review, and Management Accounting Research)* as well as journals in innovation and operations management (32 journals, consisting of the 23 journals listed in Wouters et al. (2016) plus *Production and Operations Management, Journal of Purchasing & Supply Chain Management, International Journal of Operations & Production Management, Engineering Management Journal, European Journal of Operational Research, Organization Studies, Journal of Management Studies, Journals of Management, and European Management Journal*).[4] Additional studies were found through the lists of references in key papers. The topic of modularity is huge, and the number of papers found quickly rose to an unmanageable number, even though many could very quickly be excluded because they were not addressing cost management and NPD. Gradually, we formulated the topics that are covered in this paper and selected papers based on these. So, we do not claim to cover *all* papers on the intersection of modularity, cost management and NPD, but we believe we are including a significant part

[2] Some examples of well-known papers on modularity that we already knew are Feitzinger & Lee (1997), Fisher et al. (1999), Fixson (2005), Labro (2004), and Ulrich (1995).
[3] Examples of keywords used are modularity, modularization, module, modular design, delayed product differentiation and the abbreviation DPD, component commonality, part commonality, material commonality, component sharing, common component, shared component, product platform, and product family.
[4] Note that the journals *Management Science* and *Decision Sciences* could also be considered as innovation and operations management journals, but these were already included on the Bonner et al. (2006) list.

of the studies published in reputable academic journals for the specific topics covered in this review.

The remainder of this chapter is structured as follows. Section 2.2 discusses the relationship between cost management and modularity and compares this to target costing. Section 2.3 goes into some of the terminology around modularity to become more specific on what this means for the scope of this chapter. The main section follows thereafter, looking at literature on the various ways in which these cost management methods have an impact on an organization's costs. Section 2.5 considers a topic that has received far less attention in prior literature but that are vital for cost management purposes, namely the role of cost allocation and other incentives for modularity. Section 2.6 considers the organizational context of using modularity, in particular the problematic nature of accountability in this context.

2.2 Cost management through modularity: Going beyond target costing

The management accounting literature has mainly addressed the topic of product design and cost management by looking at target costing (Wouters & Morales, 2014), and overall, management accounting research and practice have not focused that much on product development (Taipaleenmäki, 2014).

Target costing means that the allowable manufacturing costs of a product and of its components are determined at the beginning of a NPD project (Ansari, Bell, & Okano, 2007). Starting point is to consider what kinds of products will be offered, at what sales price, and how these compare to competitors' products that are expected to be available, and the assumed sales prices of those. So, targets do not only relate to sales prices and costs derived from those, but also to the whole spectrum of functionality and performance of the product. Next, elements such as import duties, taxes, costs and profit margins for various participants within the supply chain (for example, for car dealers and importing companies) are subtracted in order calculate the actual net earnings the manufacturer will receive. Deducing the target profit margin gives the allowable total unit cost for the manufacturer, from which the non-manufacturing costs (such as, marketing, distribution, warranty, or development) need to be deducted to get to the allowable manufacturing unit cost. This allowable cost can be broken down to obtain target costs for the major systems or even single components of the product.

Target costing can also be extended towards suppliers. The target cost of a component provides the maximum purchase price for the manufacturer. The manufacturer and supplier may also talk about the supplier's detailed cost breakdown for manufacturing the component (open book accounting). Moreover, if product development requires significant resources and lead time, there will also be targets for the cost and lead time of that NPD project as such, potentially broken down into several stages (milestones) and cost categories.

Later into the NPD project, the maturing design of the new product can be reviewed after completion of each development phase. A design review is a milestone within a product development process whereby a design is evaluated against its requirements in order to verify the outcomes of previous activities and identify issues before committing to—and possibly re-prioritize—further work. The manufacturing cost of the product and the components will be estimated, based on what is known about the semi-finished design. However, "does the estimated product cost meet the target cost?" is not the only question during these reviews. Similarly, the proposed product design will be examined in terms of the other targets for functionality and performance. Moreover, the cost and progress of the NPD project as such will be reviewed. Therefore, target costing should be seen in the wider context of stage-gate reviews (Hertenstein & Platt, 2000).

Thus, target costing is more elaborate than how it is often represented as "maximum allowable cost = attainable selling price – required profit margin" (Dekker & Smidt, 2003). Inherently, several stages of the supply chain and various kinds of costs are involved. Clearly, there are multiple targets—not just costs—so there are complex tradeoffs to be made among these targets. Obviously, all this planning needs a lot of forecasting, at least beyond the development time of the new product, so target costing is surrounded with considerable uncertainty. Evidently, with multiple models of the product, multiple sales channels, price erosion, and learning curves, these targets involve approximations, such as weighted-average sales prices and costs, and moreover, the targets will be dynamic (i.e., defined for several points in time). Understandably, estimating the cost of a product during the NPD project, when not everything has been determined, is challenging.

But apart from such complexities, the fundamental issue of target costing in the context of modularity is the focus on the product manufacturing cost within the *scope of one NPD project*. This is less relevant, or anyway not the whole story, in the context of modularity, because there the focus is on the costs and profitability of a *portfolio of related products*. In other words, "modular design […] entails a situation where the traditional product costing targeting at *product-level* (here meaning one good produced) cost information may become irrelevant. Instead, the focus seems to be frequently directed to the total profitability of technology or solution based *product lines* or profit responsible business units" (Granlund & Taipaleenmäki, 2005).

2.2.1 Beyond target costing

When a company is producing and selling a large number of different products and serving a large number of different customers, some costs are determined by the combined effect of design choices made in separate NPD projects. For example, the costs of warehousing products may be driven by the breadth of the product assortment (measured by the number of different stock-keeping units, or SKUs). The firm's R&D costs may be driven by the total number of different elements (i.e., parts, modules, designs, patterns, or versions) that need to be designed for all products. Or, purchasing transaction costs may be driven by the number of different suppliers the firm is doing business with for all its products. Purchase prices may be affected by the number of units purchased for all products in which a particular part is used. Similarly, manufacturing costs may be affected by the number of units produced per part and the number of production runs needed for producing that number of units. However, simply reducing the number of different parts, suppliers, or production batches may not result in lower costs, as the cost per part, supplier, or production batch may go up due to increased difficulty (Labro, 2004).

The point is that many of these "complexity-driven costs" can hardly be addressed within the scope of a single NPD project for developing only one product. Structural cost management is required, that considers organizational design, product design and process design, in order to create an appropriate cost structure (Anderson & Dekker, 2009). For example, a car company will have, next to target costing for each new model, also programs in place across different car models to develop engines and other systems that are jointly used, and it will also develop platforms on the basis of which subsequent new car models need to be based.

As another example, consider Unilever in fast moving consumer goods, such as home and personal care products, or ice cream. Different European country organizations within Unilever carried many local brands, developed their own new products, created marketing campaigns only for use in their own countries, and had their own manufacturing sites. The company went for a cost management strategy of complexity reduction. It decreased the number of different brands, formulations, packaging materials, suppliers, etc. that were used across Europe.[5] Also, new global brands were introduced, such as Magnum ice cream. As a result,

[5] For example, Unilever introduced the "Heartbrand" as a new symbol for their various existing ice cream brands around the world. The new logo replaced the previous design in most countries, but the local names (such as Wall's, Langnese, Frigo, Ola, Streets, and Algida) were carried on. However, packaging of products often does not have these local names on it, and consumers in different markets will "automatically" associate the Heartbrand logo on the product with their local brand name. Therefore, the same item can be sold in different markets. It is a very subtle form of creating more commonality of products across markets. See, for example,

fewer brands can be supported with larger budgets for product development and marketing (think of the very expensive commercials for Magnum ice cream). More commonality of products also allows lower inventories and better customer service, because a particular product can be sold in various countries, depending on actual demand. The company created more commonality across products as a deliberate cost management strategy, and this did not happen through target costing within separate NPD projects.

These examples illustrate that managing complexity-based costs requires additional cost-management methods besides target costing.[6] That is the focus of methods such as component commonality, modular design, and product platforms, which, for brevity, we will simply refer to as "modularity."

2.3 Conceptualizations of modularity

Since modularity is a complex phenomenon, understood in many different ways, this section discusses various conceptualizations of modularity. The objective is to get confusion about the concept of modularity "out of the way" before we get to the heart of this literature review.

A NPD project concerns a distinct activity for the development and introduction of one or several new products that are added to the portfolio. The term "products" will refer here to the firm's market offerings that may consist of a combination of products and services that the firm offers to its customers (Ulaga & Reinartz, 2011). For example, a truck may be the core product, and additional services include financing, training, and maintenance. A company will regularly develop and introduce new products and phase out old products, and so at any point in time it offers a portfolio of products that are in different stages of their product life cycles. The NPD project requires various kinds of R&D costs, for internal resources such as staff and equipment, and for external contributions, such as additional staff on a temporary basis, licenses and other intellectual property, and services (such as conducting tests or building prototypes). These R&D costs comprise one focus of the company's cost management efforts. The new product itself will require various kinds of manufacturing as well as non-manufacturing costs, and these product costs are the other focus of the company's cost management efforts.[7]

Wikipedia, *Wall's (ice cream)*, https://en.wikipedia.org/wiki/Wall%27s_(ice_cream) (accessed 11 January 2016); Louise Lucas and Barney Jopson, *The complexities of simplifying*, *Financial Times* (accessed 7 January 2016).

[6] Bayou (1999) and Bayou and Reinstein (2003) are some of the earlier works that started to address the complexities of costing to support design decisions during NPD.

[7] Beyond these costs, the company could also consider in its cost management efforts the costs its customers will incur when using the product and how these costs compare to competing products. This focus on "customer value" (Anderson, Narus, & van Rossum, 2006; Wouters & Kirchberger, 2015) is beyond the scope of this chapter.

Several approaches to modularity can be distinguished, such as component commonality, modular design, and product platforms. Collectively, these are mechanisms for coordinating technical design decisions during NPD across a portfolio of products, with the aim of reducing total costs over the total volume of these products (i.e., concerning all products, and over their entire life cycles) or maximizing total profit for the firm. This is particularly relevant in the context of bringing a large portfolio of different end products to the market in a cost-efficient way. However, the terms modular design, commonality, and product platforms are often used in the literature without clearly defining or distinguishing them (Gershenson, Prasad, & Zhang, 2003). For example, after reviewing about 100 papers dealing with product modularity, Salvador (2007) found about 40 different definitions. Also, a standard and accepted definition of the term "module" does not exist (Henke, 2000).

The close connection and difficulty of a clear distinction between these cost management method becomes obvious in the attempt by Christopher (2000) who includes all three concepts in one definition. He defines postponement or delayed configuration as "the principle of seeking to design products using common platforms, components, or modules, but where the final assembly or customization does not take place until the final market destination and/or customer requirement is known." Voss & Hsuan (2009), on the other hand, include commonality in their definition of modularity as the "scheme by which interfaces shared among components in a given product architecture are standardized and specified to allow for greater reusability and commonality (or sharing) of components among product families."

We will compare and differentiate between several definitions and conclude with the definitions that are the basis for this chapter.

2.3.1 Component commonality

Labro (2004) and Mirchandani & Mishrah (2009) define component commonality simply as the usage of a same version of a component in the assembly of more than one different type of end product. This is comparable to "the replacement of several different components […] by one component" (Eynan & Rosenblatt, 1996). These definitions are more referring to the static condition than on the dynamics of a NPD process, what is actually our focus. Therefore, Wouters & Morales (2014) define parts commonality as "limited sets of allowed materials, parts, components, packaging etc. that act as constraints during product design, in order to share these across a range of final products." This definition focusses on the NPD processes to enhance commonality among the product portfolio. When we talk about component commonality, we mean both the application of the same components of multiple products within a time period, and the application of the same components from one product generation to the other, also called *re-use* (Ramdas, Fisher, & Ulrich, 2003).

2.3.2 Modular Design

Although modular design promotes the application of the same component in several products, we will not equate the two methods. Modular design is a design philosophy, meaning that "products are designed in such a way, that a wide variety of final products can be produced using a limited number of modules that are adjusted and/or combined with different parts and other modules" (Wouters & Morales, 2014). Schilling (2000) describes modularity quite similarly as a general concept of a system, and its ability to separate and recombine its components.

Ulrich (1995) is one of the first researchers dealing with modularity from a technical point of view. He conceptualized the one-to-one mapping of functions to physical components as a fundamental characteristic of a modular product architecture. For an integral architecture, this mapping is complex and not one-to-one. If a functional feature of a product is executed by one specific component, and no interaction with other components is required to perform this function, we talk about a full modular product design. Another important technical key characteristic of modularity are standardized interface specifications, which minimize the interactions among the individual modules, and create independence between them (Sanchez & Mahoney, 1996). Going into the same direction, Baldwin & Clark (2000, p. 63) define a module as "a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units."

This characteristic of modular design—it facilitates the decomposition of a modular system (Mikkola, 2007) due to standardized interfaces and therefore breaking the complex system down into smaller and simpler subsystems (Fine, 2000)—entails two important benefits. On the one hand, a product can be broken down into its functional components, and "single components can be developed and manufactured independently of what occurs in respect of other components" (Galvin, 1999). The second important benefit is that exactly these standardized interfaces enable firms to reuse existing modules and built up a huge variety of different products: "Modularity […] allows […] creating product variety by changing some of the features of individual modules, while the basic architecture and relations among components are standardized" (Fredriksson & Gadde, 2005).

Fixson & Clark (2002) go further and define modularity as "a bundle of product characteristics rather than a single dimension." They unbundle modularity in a multidimensional product architecture construct in order to measure differences in product architecture and operationalize modularity. As major dimensions of this construct, they identify the function-component mapping, i.e., the way functions are allocated to components, and interfaces, as the relations between the different components.

Pandremenos, Paralikas, Salonitis, & Chryssolouris (2009) distinguish between three fields of modularity: modularity in use, modularity in design, and modularity in production. This distinction deals with the various motives a firm has when applying a modular strategy. Modularity in use focuses on the customer's perspective (satisfying needs through individualization), modularity in design emphasizes the architectural dimension, and modularity in production underlines the flexibility for the manufacturing process.

The importance of the modules' independence grows with the complexity of the product. Langlois (2002, p. 19) describes modularity as a "set of principles for managing complexity." Standardized interfaces might be easier to implement in IT and software, or in a simple product, for example a chair or furniture, because the designer can overlook a manageable number of interdependencies. Yet, for a complex product such as a car, many physical and spatial restrictions reduce possibilities to implement standardized interfaces, so considerable coordination costs are unavoidable. Persson & Åhlström (2006) criticize that the literature focuses on rather simple products, and they conducted a case study at Volvo. Their key findings about difficulties of modularizing complex products concern the coordination process and the appropriate degree of modularity, and they suggest it would be impossible to create a very complex product with a fully modular design.

Adding the term *mass customization*, also often mentioned in this context, "mass customization appears to presuppose product modularity, and the benefits heralded by move to modularity would likely be realized in a move to mass customization" (Ro et al., 2007). Duray, Ward, Milligan, & Berry (2000) develop a conceptual typology about this topic and reason in a similar way. They define the term mass customization as "a paradox-breaking manufacturing reality that combines the unique products of craft manufacturing with the cost-efficient manufacturing methods of mass production" and "building products to customer specifications using modular components to achieve economies of scale" (Duray et al., 2000).

As shown above, the term modular design is multifaceted and can be defined in varied ways. Recognizing this ambiguity, Salvador (2007) screened management and engineering journals and identified five definitional perspectives of the term product modularity: component commonality, component combinability, function binding, interface standardization, and loose coupling.

2.3.3 Product platform

A common example for product platforms is the automotive industry. Nowadays, many volume and premium car manufacturers create platforms as specific wheel bases on which several derivatives are based, such as a sedan, a station wagon, and a cabriolet. Probably the most widely known example is the Volkswagen group that also applies platforms across its brands (Paralikas, Fysikopoulos, Pandremenos, & Chryssolouris, 2011).

Robertson & Ulrich (1998) give a general definition of platforms when they talk about a "collection of assets [i.e., components, processes, knowledge, people and relationships] that are shared by a set of products." Lehnerd & Meyer (1997) talk about a core technology, consisting of a set of subsystems and interfaces. This core technology results in a common structure that enables firms to develop and produce a stream of derivative products in an efficient way. Baldwin & Clark (1997) mention three aspects of product platforms: architecture (what modules with which function will be part of the system?), interfaces (how will the individual modules interact?), and standards (is the module conform to the system's design rules?).

Thus, a platform defines the core of a product and constitutes the physical base of a product family. It is a specific architecture that allows the shared use of processes, components, and knowledge among product sets (Davila & Wouters, 2004). Halman, Hofer, & van Vuuren (2003) link platforms to product families and define a platform as the "common basis of all individual products within a product family. As a consequence, a platform is always linked to a product family."

Wortmann & Alblas (2009) discuss three types of platforms in their work: a *modular platform* reconfigures existing modules for a new variant. A *scalable platform* is variable with respect to the capacity, so deriving a product with the same function but a divergent performance level is eased. The focus of a *generational platform* lies on the time dimension, when deriving following product generations from an existing platform accelerates the product development process.

2.3.4 Modularity in this chapter

From our point of view, the perspectives of modularity and commonality are different. While modular design seems to be a more strategic and long-term orientated approach when a product family is conceptualized in an early development stage, the idea of component commonality is based on already developed and applied components used in existing product variants. When

Table 1. Definitions used for this review

Component commonality	A constraint or requirement to use already developed components without adjusting or modifying them in a NPD project in order to increase the number of carry-over-parts.
Modular design	An architectural and strategic design philosophy that enables a firm to separate and recombine components within a product family or among products. Technical implementation is realized through functional independence and standardized interfaces among modules.
Product platform	A specification of a common technical base from which a high number of products with different performance characteristics and features are derived.

planning or developing a new derivative product, the question is this: are there already developed components existing products use that can be (re-)used for the new derivate product? So, commonality is medium-term orientated and focusses on the component: is a component particularly designed for and used in only one product, or is it used among a whole family of products? In contrast, modular design is long-term oriented and focusses on the design of a whole product family: if a modular approach is chosen, how can individual components be used and replaced independently among different derivative products?

Nonetheless, the two terms are closely connected: when a new derivative product is planned, and developers are willing to (re-)use already existing components developed for a present product, this product has to be constructed in a modular way. Otherwise, if products have an integral design, it becomes much more difficult to adopt components for the new derivative product. We argue therefore, that component commonality is a consequence of modular design, or even modular design is a precondition to enable component commonality.

In addition, a product platform concerns the basic architecture of a product by describing the physical implementation of a functional design, and this becomes the basis for a series of derivative products.

For the purpose of this literature review, we developed the definitions shown in Table 1. These are based on common threads in the various definitions mentioned above and include the key characteristics of each method from our point of view.

2.4 Impact of modularity on costs

In this section, we review literature dealing with the impact of modularity on costs. First we review some cases that describe modularity as an overall, strategic approach for NPD and cost management. Then we look at studies that cover more detailed and specific design choices, for example, whether it would be better for a company to stick to the prescribed database of common parts, or to allow an exception and develop an individualized component for a particular product. We will also discuss that this literature implicitly assumes some form of centralized decision-making.

2.4.1 Holistic cases of cost management and modularity

Some of the empirical literature has studied the implementation of modularity in actual cases and describes quite comprehensive and pragmatic examples of how modularity can be implemented. A classic example of modularity implementation is IBM in the 1960s, described in Harvard Business Review (Baldwin & Clark, 1997). It describes how IBM introduced its first modular computer in 1964 and discusses the consequences for competitors, suppliers, innovation in general, and for IBM itself. Another classic example is Black & Decker in the 1970s, described in a book on product platforms (Rosenau & Rothberg, 2003). It tells the story of the big challenges regarding cost pressure and competiveness for Black & Decker in the 1970s, and how they solved it through a modular strategy. This led to large savings in material and labor costs, and it also brought considerable benefits in cycle time and new product introductions, which enabled Black & Decker to dominate the market for many years. Sanderson & Uzumeri (1995) describe how Sony handled variety of its products, and one of the elements was modularity. Sony minimized its design costs by "building all of their models around key modules and platforms. Modular design and flexible manufacturing allowed Sony to produce a wide variety of models with high quality and low cost." It also enabled Sony to introduce many new products and achieve rapid model turnover. Hewlett-Packard is the focal example in the paper by Feitzinger & Lee (1997). The paper describes the effects when HP postponed "the task of differentiating [the] product for a specific customer until the latest possible point in the supply network" (p.116) and reduced the number of different components in its LaserJets (a cost reduction in manufacturing, stocking, and delivering) and DeskJets (slightly higher material costs, but a considerable reduction in manufacturing, shipping, and inventory costs). Further examples talk about the development process of the "smart" by Daimler (Stephan, Pfaffmann, & Sanchez, 2008) and more broadly about the U.S. auto industry (Ro et al., 2007).[8] Other field studies address the limitations of modularity concepts and the problems and risks related to implementing these, for example based on case studies of the three

[8] As a side remark, there are also many papers that introduce methods, models, or processes, how modularity can be developed and implemented, and illustrate this with a specific example (Martin & Ishii, 2002; Simpson, Maier, & Mistree, 2001; Suh, De Weck, & Chang, 2007). These examples are not based on empirical studies reporting findings from an actual application in an organization, but they are realistic, fictitious illustrations inspired by an earlier example reported in the literature or the authors' general knowledge. Some studies are based on actual cases, but without going into much detail of the field work—it's still about illustrating the model (Caux, David, & Pierreval, 2006; Krishnan et al., 1999).

technology-driven companies ASML, Skil, and SDI (Halman et al., 2003), the automotive industry (Mahmoud-Jouini & Lenfle, 2010; Persson & Åhlström, 2006; Sköld & Karlsson, 2012), and other empirical settings (Lau, 2011; Muffatto & Roveda, 2000).

2.4.2 The implicit assumption of centralized decision-making

Before going into more detail regarding the costs that are involved in specific design choices, it is helpful to consider the assumption that is implicit in the literature reviewed below. Moving from an integral to a modular approach entails shifts in processes and organizational infrastructure, which requires additional costs the organization should be aware of. That these organizational costs are worth investing is shown by Ramdas et al. (2003), who investigate *centralized versus decentralized decision-making*.

Their model considers a situation in which a firm offers a fixed and known number of products that are concurrently developed, and it includes two kinds of decisions: (1) which versions of each component should be developed for this defined product line, and (2) which version of each component should be used by each model in the line. Of course, there are all kinds of technical constraints, such as which components can be used together in a module, and which modules can be used for a particular product. Obviously, a lot of information is required, such as sales for each product, all feasible component versions (the existing versions and the versions that might be under consideration by any individual project team), the fixed costs of introducing a particular component version (such as for design, tooling, and after-sales support) and the variable costs when using a particular module on a particular product (such as for materials). The model assumes *centralized decision-making*, i.e., a cost minimization objective for the entire organization. Using the model, cost minimizing at the portfolio level can consider the cost trade-offs across all products (Ramdas et al., 2003).

Yet, often such an overall optimization may not be realistic, because not all information is available in one place at the same time, and not all decisions are taken simultaneously based on an overall cost minimization objective. *Decentralized decision-making* means that each project team independently (project-by-project) decides which components to develop for their product and which existing components to use, which have already been developed by another team. This approach results in higher costs for the entire portfolio. However, decentralized decision-making is not considered in Section 4. Here we review research about the impact of modularity on different types of costs, so as to better understand the trade-offs involved when using modularity as a cost management method. Implicitly, we consider centralized decision making with an overall optimization objective. The issue of decentralized decision making comes back in Section 5.

Table 2 illustrates the structure of the remainder of this section. We will deal with the numerous effects (mainly cost impacts) of modularity during the different life cycle phases of a product. The table aggregates the effects we found, whereby we distinguish between cost rate and driver use regarding the several cost effects, as applied by Labro (2004). *F* indicates a favorable impact, so a cost reduction, and *U* means an unfavorable impact, so a cost increase. Please note some papers discuss cost impact of modularity that can be either favorable or unfavorable, depending on the individual circumstances. Additionally, some papers deal with specific effects that cannot be categorized as favorable or unfavorable.

It is our intention to offer a holistic view of the effects a modular strategy can have on a firm's costs, so we also discuss two effects that are not mentioned in Table 2. These two effects cannot be clearly assigned to a specific life cycle stage, or even arise in several stages.

Table 2. Effects of modularity on various kinds of costs

Cost rate		*Driver use*		*Effects besides costs*	
Design, development, and innovation					
Initial development costs		**Number of development events**		**Individualization of components**	
Mahmoud-Jouini & Lenfle (2010)	U	Mahmoud-Jouini & Lenfle (2010)	F	Fisher et al. (1999)	-
Krishnan & Gupta (2001)	U	Fisher et al. (1999)	F	Davila & Wouters (2004)	-
Davila & Wouters (2004)	U	Krishnan & Gupta (2001)	F	Chakravarty & Balakrishnan (2001)	-
Krishnan, Singh, & Tirupati (1999)	U	Krishnan et al. (1999)	F		
				Manageability	
				Baldwin & Clark (1997)	F
				Langlois (2002)	F
				Innovation Level	
				Kamrad et al. (2013)	F
				Garud & Kumaraswamy (1995)	F
				Ramachandran & Krishnan (2008)	F
				Miozzo & Grimshaw (2005)	U
Sourcing, manufacturing, and logistics					
Purchase pooling		**Manufacturing investments**		**Agility**	
Fisher et al. (1999)	F	Fisher et al. (1999)	F	Watanabe & Ane (2004)	F
Hu et al. (2013)	F,U				

Cost rate		*Driver use*		*Effects besides costs*	
Inventory costs		**Number of set-up**		**Outsourcing**	
Thomas & Warsing (2007)	F	Thonemann & Brandeau (2000)	F	Anderson & Parker (2002)	F
Hillier (2002)	F			Miozzo & Grimshaw (2005)	U
Variable production costs					
Ramdas et al. (2003)	U				
Krishnan & Gupta (2001)	U				
Fisher et al. (1999)	U				
Marketing, sales, and distribution					
				Sales	
				Nobeoka & Cusumano (1997)	F
				Marketing research	
				Sanchez (1999)	-
				Pricing and cannibalisation	
				Fisher et al. (1999)	-
				Robertson & Ulrich (1998)	-
				Desai et al. (2001)	U
				Subramanian (2013)	F
				Kim & Chhajed (2000)	F
				Quality	
				Fisher et al. (1999)	F
				Ramdas & Randall (2008)	F,U
				Flexibility	
				Cebon et al. (2008)	F
				Asan et al. (2008)	F
				Imitation	
				Ethiraj (2008)	U
Product use and maintenance					
Warranty costs				**Upgradeability**	
Murthy & Blischke (2000)	F			Ramachandran & Krishnan (2008)	F
				Ülkü et al. (2012)	F
Remanufacturing, recycling, and disposal					
Retirement costs				**Waste reduction**	
Zhang & Gershenson (2002)	-			Kamrad et al. (2013)	F
Remanufacturing costs				Fernández & Kekäle (2005)	F
Abbey et al. (2013)	F			Sharma et al. (2010)	F
Maslennikova & Foley (2000)	F				
Subramanian et al (2013)	F				

A first aspect is *complexity costs*: because the total number of different components to develop, purchase, manufacture and store decreases, modularity reduces complexity (Davila & Wouters, 2004; Persson & Åhlström, 2006). Moreover, the disparity of processes declines (Garg & Tang, 1997). Furthermore, *coordination costs* affect several life cycle stages, too. We argue that a higher coordination effort is needed almost throughout the whole life cycle when implementing a modular design strategy: in the development phase, when requirements of all products have to be considered or combined during products' conceptualization; during supplier negotiations, when an intensive coordination among the individual projects seems also important to realize economies of scale; and during manufacturing, when production systems are jointly used among several products. Fredriksson (2006) emphasizes the importance of coordination mechanisms for the efficient implementation of a modular strategy. Although both *complexity* and *coordination efforts* are hard to quantify in monetary terms, they have a fundamental impact an organization has to be aware of when pursuing a modular strategy.

2.4.3 Impact on design, development & innovation

One of the most examined life cycle stages concerning the effects of modularity is the product development phase. The literature has investigated multifaceted effects which will be discussed below.

One argument is that a modular product architecture causes higher **initial development costs**. At the beginning of the development activities, when a component or a product platform is designed, additional costs arise to enable reusability for further product derivatives, compared to the development of a specific component or integral product. The requirements for a jointly used component are higher (or at least not lower) compared to a product-specific solution (Davila & Wouters, 2004; Krishnan & Gupta, 2001; Krishnan et al., 1999; Mahmoud-Jouini & Lenfle, 2010). We compare two alternatives at this point: the development costs of a component suitable for one (integral) product, versus the development cost of a component that can be used in more than one product. From our point of view, the firm increases its investment in product development at this stage to realize future development cost savings. The objective is to derive several products from the same platform in a cost-efficient way and consequently to avoid large development efforts for every single product.

Another argument deals with the **number of development events**: if components or platforms are shared among different products, fewer parts have to be designed and tested in total, which decreases overall development costs (Davila & Wouters, 2004; Fisher et al., 1999; Krishnan & Gupta, 2001; Krishnan et al., 1999). Therefore, even if the development effort for a platform might exceed the expenses for the development of the technical base of just one product, total development costs may decrease and lead times may be reduced when applying product platforms (Mahmoud-Jouini & Lenfle, 2010; Muffatto & Roveda, 2000).

The practical challenge lies in the assessment of the technical feasibility, as well as in the estimation of the development expenses for each option, in order to handle this trade-off before taking the final decision. Krishnan & Gupta (2001) create a mathematical model to examine under which conditions a platform strategy outperforms an individual product development approach. They conclude that product platforms are appropriate when performance levels of derivative products are not too different, and customers' valuation and requirements for different market segments are not extremely diverse.

The factors that influence the decision to standardize and share a component or to go for a product-specific solution (in the sense of an **individualized component**) have received much attention in the academic literature. While Fisher et al. (1999) distinguish between components with *strong* and *weak* influence on quality, Davila & Wouters (2004) separate the components in *core* and *non-core* modules, and Toyota categorizes their parts into *aesthetic* and *functional* components (Fisher et al., 1999). Both studies conclude that the aesthetic parts are appropriate candidates to individualize. Consequently, the development team can focus on these components, as they are directly responsible for the products' perceived value. Moreover, imposing restrictions to the development team might inhibit their creativity NPD requires, especially at the beginning.

The degree of modularity can also be interpreted as a property of a product. An interesting question concerns the appropriate or optimal number of product variants a common technical base should be designed for, and how many module modifications are needed for a specific range of product variety. In other words, how high should the degree of modularity within a product family be? Chakravarty & Balakrishnan (2001) try to answer that question and develop a mathematical model to determine the optimal variance in order to maximize firm's profits.

One of a modular strategy's main benefits is the assembly of small, independently developed subsystems to a final product with extensive functionality (Baldwin & Clark, 1997). This characteristic (breaking down a complex product into smaller, individual modules) is a way to maintain **manageability** (Langlois, 2002). As a consequence, each subsystem can be processed individually. As we already mention in Section 3, the development of complex products, for example cars, is not feasible in another way, as these kinds of products consist of many and still very complex subsystems.

This decomposing aspect of modularity (a complex product is divided up into smaller and simpler subsystems) allows a shift from radical to incremental innovation, which can accelerate further development in the next step. Therefore, a firm applying modularity can enhance the **innovation level** of its products, as new technology can be integrated faster. Developers can improve the product step-by-step via replacing technological obsolete modules with new ones (without changing the remaining product). Only the internal content and performance of the replaced modules change. This allows a firm's products to remain technologically up-to-date in a cost-efficient way, which becomes even more important if a complex product entails technologies with deviating life cycles and if redesigning costs for integral products are high (Kamrad et al., 2013).

The decision whether it is a better idea to reuse a component for the product's next generation or to redesign/upgrade it, should be made against the backdrop of how the redesigned component can be priced (Wu, De Matta, & Lowe, 2009). Balancing these opportunity costs (if the additional profits outweigh the redesign costs) of several component upgrades can be helpful when budget restrictions exist, but sometimes also strategical considerations force these decisions: if a component's functionality does not meet to the current basic customer expectations or legal requirements anymore, a firm simply has to update or exchange the component. We found manifold terminology for this incremental "step-by-step" innovation. Garud & Kumaraswamy (1995) talk about *economies of substitution*, referring mainly to associated cost savings, Cebon, Hauptman, & Shekhar (2008) use the term *modular innovation* as one of four innovation types, and Ramachandran & Krishnan (2008) talk about *modular upgradeability* referring to rapid sequential innovation in their study about software.

On the other hand, we can also think about difficulties in the context of modular innovation. Yet, negative cost effects of platform based development have received far less research attention (Krishnan & Gupta, 2001; Persson & Åhlström, 2006). Miozzo & Grimshaw (2005) contradict the claim that modularity is beneficial for and accelerates the innovation process. Dealing with IT outsourcing in knowledge-intensive business services, they examine 13 IT outsourcing contracts and report difficulties concerning the cooperation between the firms and their suppliers. Though the study deals with the quite specific topic of IT services, it seems plausible that practical problems, such as maintaining standardized interfaces or cooperation between firms in general, can be responsible for barriers in the innovation process.

2.4.4 *Impact on sourcing, manufacturing & logistics*

Other areas that have received much research attention in the context of modular design, component commonality, and product platforms are sourcing, manufacturing, and logistics. Probably the most common argument for benefits of component commonality are economies of scale (Fisher et al., 1999). With larger quantities, the sourcing department can achieve better conditions in price negotiations with their suppliers – we refer to this effect as **purchase pooling**. This applies when a customer firm is able to purchase its desired quantity and quantity discounts are offered. Hu, Duenyas & Beil (2013) contradict this widespread argumentation and base their study on powerful suppliers that can define price and quantity conditions. Developing a mathematical model, they conclude that firms can even harm themselves when pooling their purchases at a more aggregated level, as the powerful supplier can adapt the contract, benefits from the reduced demand variability, and extracts profits from the buying firm.

Furthermore, modularity also impacts logistic and **inventory costs**. Researchers often report a positive effect on inventory system performance (Thomas & Warsing, 2007). Based on mathematical models and numerical simulations, a risk pooling effect can be identified, as it is easier to forecast demands on a generic than on a specific level. And because modularity allows firms to use component variants in higher quantities, fewer components in total have to be kept in stock, i.e., lower inventory is needed and therefore, capital employed is reduced (Davila & Wouters, 2007; Hillier, 2002).

Another, but potentially unfavorable effect of modular components concerns higher **variable production costs** (compared to individualized components) (Fisher et al., 1999; Murthy & Blischke, 2000). This seems plausible if we talk about material costs: Modular parts need to fit in several end products that might have different requirements. Therefore, it might be more complex than an integral part that is specifically designed for just one end product. Or, a common component is used both in a low-quality version and a high-end version of a product, and if the component has to meet the high-quality product's requirements, it will be over-specified (i.e., better than adequate) for some versions within the product family (Krishnan & Gupta, 2001; Ramdas et al., 2003). Fisher et al. (1999) develop an analytical model dealing with the key drivers of a component sharing strategy. The model focuses on components with a weak influence on product quality. They test this model in an empirical study with data from six OEMs about automotive front brakes. They conclude that if components are downward compatible, manufacturing costs increase with the performance of the component, and economies of scale concerning production costs exist. Additionally, they observe a positive correlation between component and product variety. For example, a specific rotor is developed for every two additional platforms. As this is exactly the trend modularity wants to counteract, they relate this observation to individual teams' autonomy and the absence of a centrally coordinated component commonality policy.

Modularity also impacts **investments for manufacturing**. In many industries, specific machines and tools are needed to produce certain components. As fewer component variants have to be produced, also the investments in these production systems and tools may be less (Fisher et al., 1999).

Another, closely related impact of commonality refers directly to the manufacturing process, more specifically to the **number of set-ups**. As the total number of component variants decreases, the quantity of each produced component increases (if we assume a firm that applies a modular strategy will not produce a lower total volume of end products), and so the number of set-ups and related set-up costs in the production process decreases (Thonemann & Brandeau, 2000).

As already mentioned, some impacts are hard to quantify in monetary terms. The most common impact of modularity (besides costs) concerns increased flexibility or ***agility*** if modularity enables delaying the point of product differentiation, which means that prepackaged modules are hold in stock till their final utilization is known (Christopher, 2000). Watanabe & Ane (2004) use simulation and find that a modular product architecture leads to an increasing manufacturing agility, which reduces the manufacturing lead time in a next step.

Another way to reduce costs is to ***outsource*** several production steps, e.g., if hourly rates of suppliers or firms in other countries are lower. Anderson & Parker (2002) deal with the make or buy decision in their analytical study, and they find a connection between the degree of modularity and outsourcing: increasing modularity leads to more outsourcing. Although modularity can be an enabler for cost savings through outsourcing, one should also consider difficulties in this context, which we already mention in an earlier section (Miozzo & Grimshaw, 2005).

2.4.5 Impact on marketing, sales & distribution

We did not identify literature about the effects of modularity on costs and cost driver use in marketing, sales, or distribution. Nonetheless, modularity may impact the firm's image and the products' reliability, and so it is a significantly impacted area, mainly on the revenues side. We will discuss some implications and new challenges for the marketing activities and sales, because this is also an important part to get a holistic understanding of the topic.

If a modular strategy (increasing the number of derivative products for appropriate costs) is properly executed, ***sales*** volume, revenue and market share will increase, because more market segments can be served (Nobeoka & Cusumano, 1997). Additionally, customers may be more satisfied with a customized product compared to a standardized mass product, which may lead to a greater willingness to pay and more buy decisions. Or, like in today's automotive industry, many markets are developing towards a personalized environment, so there is no choice but to offer customized products in order to stay competitive. "Today, we are witnessing customer-driven strategies instead of product-driven strategy" (Kucuk & Krishnamurthy, 2007). In other words, the product differentiation decision is, at least in parts, relocated from the firm to the customer. Or, you could also say that giving the customer the possibility to customize his product is a product differentiation feature per se.

Moreover, modularity influences **marketing research**. While the conventional marketing research process identifies consumer preferences to optimize a product's attributes according to a specific target segment, marketing research for modular products has to take the variances of these consumer preferences into account. So, it is less a task of identifying the specific needs a product has to satisfy in a particular market, but more about figuring out a whole range of several required product manifestations. In a next step, these are used to create a modular architecture that is able to serve the most profitable market segments. Additionally, the marketing department is required to position the firm via a relational marketing strategy. For example, working out the benefits of the new product architecture for the customer, like scalability, upgradeability, or improved serviceability (Sanchez, 1999).

As we already mentioned before, the whole approach of modularity will only work in the long term if the derivative products, though they share common components, are well distinguishable for the customer. This has both **pricing and cannibalization** impacts: if a premium-priced product variant seems similar in appearance and functionality, the customer has no reason to buy it and may choose the cheaper derivative. So, in order to realize premium prices, it makes sense not to share the components that have a direct impact on the product's quality from the customer's point of view, and therefore only share components the customer does not know or perceive as important (Fisher et al., 1999; Robertson & Ulrich, 1998).

Desai et al. (2001) also discuss the effect that commonality may hinder a firm to extract premium prices for the better product due to reduced differentiation. They develop an analytical model to examine the trade-off between manufacturing benefits of commonality for these marketing challenges. Additionally, they develop an index to operationalize the attractiveness of "making a component common" compared to other components. While there is a general agreement that different products should be well distinguishable in order to reduce cannibalization, Subramanian, Ferguson, & Toktay (2013) argue in a different way. Developing a mathematical model and illustrating its implementation with two Apple iPads, they conclude that the cannibalization effect can also be beneficial for a firm when a third-party remanufacturer exists.

Kim & Chhajed (2000) argue in their study that a too noticeable application of commonality, such that a clear distinction of different products from a customer's point of view is not given anymore, impacts a product's utility in the eyes of the customer. They develop a mathematical model and examine how modularity and prices should be designed to reduce cannibalization and maximize profits when different product qualities are offered. As one result, they conclude that target segments' quality valuation is crucial when considering the usage of common components among segments. While most studies justify the commonality approach with cost savings, they reason that, if a firm is able to price the valuation change, commonality can even be beneficial without these savings. Otherwise, if customers do not perceive any additional value, they will not necessarily pay price premiums for common components in their cheaper product variant (derived from the premium product) (Desai et al., 2001).

Besides the purchase price, the **quality** of a product and its components can be a key criterion for customer's buying decision and willingness to pay. The key question is, if and how modularity affects product quality. We argue that generalized statements, such as that an increasing product quality and reliability always follows from a product platform strategy (Mahmoud-Jouini & Lenfle, 2010), are not necessarily correct. Therefore, we want to discuss a quality tradeoff.

On the one hand, due to a learning effect, the quality of a component applied in multiple products can be higher than a newly developed and individualized component. Additionally, if a company plans to utilize a component in more than one product, it might be willing to spend more money on development activities for this particular, shared component. This can also be a reason for a better quality compared to components developed for just a single product, where, just because of the lower total number of parts needed, less development budget is available. And, if different quality levels of products use the same component, the component might exceed the quality requirements for a range of the product family, except for the high-end product (Fisher et al., 1999).

On the other hand, a decreasing quality due to component commonality may occur if a component is not exactly designed and customized for the specific requirements of a single product. If the functional performance of a component is not only scalable, but differs with respect to requirements, architecture, or other characteristics, the approach to replace several components by one shared component may lead to unfavorable quality effects because of several compromises. Ramdas & Randall (2008) study this quality tradeoff of component commonality, and define reliability as one dimension of quality. They conduct an empirical study and analyzed 693 observations from a data set of break rotor failures from Ford. While they establish that the optimal technical fit of a component to a product's requirements improves quality, they also conclude that the experience effect is beneficial for quality (based on only one component in one company, which limits empirical generalizability). They reason that the relevance of this learning or experience effect decreases as a component is applied in more and more products over time (the marginal value of experience when going from 1 to 2 products is much larger than, for example, going from the 10th to the 11th product also adopting that same component).

Another important impact of modularity that is also hard to quantify is increasing **flexibility**. Modularity entails the chance to react to technological changes, to deal with market uncertainty (Asan et al., 2008; Wouters, Workum, & Hissel, 2011), and it increases the number of market niches that can be occupied (Cebon et al., 2008). These strategic benefits might be hard to assess in cost savings, but they can be very valuable to a firm: if the marketing department detects a new market niche for a new derivate product, the development process needs not to start from the beginning. If modularity is implemented in an efficient and clever way, a platform and many components exist, and the new product can "help itself," so the new market can be served in a short period of time, and sales may increase (compared to an integral strategy). Additionally, as requirements for a product differ from one market to another, fulfilling the different regional customer expectations is eased.

Ethiraj, Levinthal, & Roy (2008) examine the trade-off of modularity on **imitation** and innovation. As we already discussed the innovation benefits of this product architecture in one of the previous paragraphs, they conclude via simulation that the innovation gains of a complete modular design include the risk of imitation. They summarize that a nearly modular architecture dominates both a fully modular approach (due to reduced imitation risk) and a non-modular architecture (due to enhanced innovation opportunities).

2.4.6 Impact on product use & maintenance

In this section, we want to discuss the effects of modularity after product development, so when the product has already been sold to customers. We focus on the impacts for the firms, but also include the customer's perspective.

If we think about the one-to-one mapping from functions to components (Ulrich, 1995) we mentioned in the previous section, modularity eases the identification of a defect module if a certain functional performance is not given anymore. Instead of disassembling a whole integral product, damage diagnosis as well as repair work or replacement is accelerated. Therefore, modularity reduces **warranty costs**, as repairing or maintaining a product is facilitated (Murthy & Blischke, 2000). Additionally, due to the lower number of total components, service costs may decline (Robertson & Ulrich, 1998).

If we adopt the customers' perspective now, they can just exchange an obsolete module if a product is built up of independent functional units. Thus, the customer gets easier access to **upgrades**, what seems preferable from a customer's point of view, especially when a product's technology improves in a short period of time (Ramachandran & Krishnan, 2008). This might be a buying argument and therefore increase sales, as the upgradeability option extends the value of the customer's investment. On the other hand, this updateability might extend the period of use, and reduce additional sales. Depending on a firm's sales strategy (e.g., if a firm focuses on revenues from product sales, or more on additional functions and updates), harmful impacts on sales seem possible, too.

Ülkü, Dimofte, & Schmidt (2012) investigate consumers' reactions and valuation of modular products in three experimental studies. They report decision biases for modularly upgradable products. Counterintuitively, the research participants undervalued future savings of rapidly improving products through upgrades, and overvalued upgrade-savings of products with a long life cycle.

2.4.7 Impact on remanufacturing, recycling & disposal

A firm's decision which product architecture to apply has an influence even at the end of a product's life cycle, involving four different processes: remanufacturing, reuse, recycling, and disposal (Zhang & Gershenson, 2002), briefly summarized as "retirement costs." In order to emphasize the importance of considering recycling and disposal aspects already in the development stage, Tseng, Chang, & Cheng (2010) develop an algorithm to assess the costs and benefits of modularizing a product.

The cost-reducing impact of modularity in this last life cycle stage is also hypothesized by Zhang and Gershenson (2002) (mainly because of the simplified update and decomposition characteristics). They examine the direct relationship between modularity and **retirement costs**. But, after analyzing 14 different products with varying degrees of modularity (captured by a modularity measure) and calculating the several retirement costs for these products, they could not find a statistically significant relationship between the degree of modularity and retirement costs.

In contrast, Abbey, Guide, & Souza (2013) argue that the easy-to-disassembly characteristic of modularity facilitates **remanufacturing** and reduces the separation time and cost at this stage. Maslennikova & Foley (2000) examined this issue during a case study at Xerox, selling printers, among other things. They found the modular design of products enabled the company to implement an end-of-life take-back program. The company created 400 reprocessing and remanufacturing jobs, and it reused over 3.8 million components that fit into their quality criteria within one year. Not only did the company save the disposal costs, which many governments impose to these kind of manufacturers; altogether, the net savings in one year were over 80 million dollars, also through reduced raw-material purchases and energy savings.

Subramanian et al. (2013) deal with the topic of including remanufacturing considerations into component commonality decisions. They argue that profits can significantly increase when remanufacturing is considered already at the beginning of NPD projects. They criticize that many firms base their component commonality strategy only on manufacturing and sales, and ignore the changes of cost reduction and cannibalization effects of remanufacturing processes.

Replacing only a few broken or obsolete components can significantly **reduce waste**, in comparison to integral designed products where the whole product has to be disposed of (Kamrad et al., 2013). While for integral products, scrapping or material recycling is often the most adequate approach at this stage, modules offer the chance to be repaired, refurbished, or reused (Fernández & Kekäle, 2005). For this reason, modularity promotes the sustainability idea firms focus more on in recent years. The idea to offer consumers the possibility to renew only the defect part instead of discarding the complete product (Sharma et al., 2010) can also be valuable in the sense of a green image. Environmental friendly manufacturing technology becomes more and more important, and firms spend large budgets on green marketing campaigns.

2.5 Cost allocation and modularity

The previous section implicitly addressed centralized decisions on modularity that consider a wide range of tradeoffs for the entire organization. Two issues were not addressed: can accounting systems provide information to support such decisions? And, what incentives do accounting systems provide to decentralized decision makers who are responsible for separate products, because of cost allocations? These issues are reviewed in this section.

2.5.1 Costing allocations for a centralized decision on modularity

Let's start with a simple example. Suppose there are three products that if designed independently generate a profit of 310 monetary units. It is technically possible to design a common module and use this for two or even all three products. How can the accounting system provide information on the cost consequences of more modularity? We could not find many papers that explicitly address this issue, especially not in the accounting literature.

Park & Simpson (2005, 2008) use an activity-based costing (ABC) system to estimate the cost implications of design alternatives regarding which parts are based on the same common part. Although the paper is not always as clearly written as we would like from an accounting perspective, it is interesting to see how their ABC system includes detailed activities, including allocation of costs to those activities, to be able to estimate and compare the cost of parts when produced independently and also when produced as a common part.

Thyssen, Israelsen, & Jørgensen (2006) discuss ABC and modularity based on a case study. Many costs that are common to a number of products will be, in ABC-terminology, at the level of company-sustaining activities, product-line sustaining activities, or module-sustaining activities. They argue that any allocation of such costs to cost objects for which these are common "(based on revenue, number of units, direct labour hours, etc.) is bound to be arbitrary insofar as there is no cause and effect relation between the costs and the objects. Instead, one should summate the contributions from all the relevant products and deduct the common cost as an aggregate figure" (Thyssen et al., 2006). The latter recommendation is also common in German costing systems of the multi-stage contribution costing (Ewert & Wagenhofer, 2006; Kloock & Schiller, 1997).

Johnson & Kirchain (2010) also consider cost allocations of common components. First, they determine the costs of all product variants as if each variant were produced independently, so without the benefits of sharing. The "standalone" cost of a product variant is calculated by adding the costs of all components that are needed for the product. Then the costs of all product variants are calculated with considering the benefits of sharing. The “shared cost” of a product variant is the sum of the costs of unique components and a slice of the shared costs for common components, whereby a product’s cut of the shared costs is determined based on the production volume of that part that the product consumes relative to the total production volume of the part. So in this study, the role of cost allocations is to have a more comprehensive calculation of the full cost of a product, including a share of common costs for the common components that are used for the product.

2.5.2 Cost allocations as incentives for decentralized decisions on modularity

Continuing the simple example with three products, suppose if two of these use the common module, the profit from those two products is 300 and the profit from the third product is 40, so 340 from all three products together. If instead all three use the common module, costs decrease and total profit is 400. How should the development costs and unit costs of the common module be allocated, such that it is attractive for the managers who are responsible for these products to adopt the common module?

More generally formulated, assuming it is possible to decide on a modularity strategy that creates most advantages for the entire product portfolio (Ramdas et al., 2003), the question arises how to translate this into cost allocations for separate product-level decisions that will actually implement that chosen modularity strategy. Benefits for the entire portfolio such as greater purchasing or manufacturing volumes and lower inventory holding costs for the entire organization (i.e., for all products together) do not necessarily make modularity attractive at the product level. For example, the development of a part just for one particular product may be relatively straightforward and inexpensive, but the development costs of a more broadly applicable part may be significantly higher. As another example, there could be a part that is exactly right for a particular product, but having to choose a part from the database of allowed parts may lead to overspecification and higher material costs, or it may result in performance degradation, negative customer reactions, and revenue losses. The system for the allocation of joint costs resulting from modularity to multiple products may or may not make it attractive to adopt modularity at the product level.

Yet, perhaps somewhat surprisingly, the issue of cost allocation and cost savings associated with modularity to products has not received that much explicit attention in the literature. Two related papers on remanufacturing illustrate this lacuna. The first study (Subramanian et al., 2013), also mentioned earlier in this chapter, addresses the question of the optimal component commonality decision for the entire organization when also considering remanufacturing of products. Examples are machine tools, consumer electronics, and tires. The second study (Toktay & Wei, 2011) explicitly considers that different divisions within the organization may undertake manufacturing and remanufacturing operations, and so incentives must be considered. The study analyzes the decisions of both divisions *on sales prices and production quantities* and develops cost allocation mechanisms of the initial manufacturing cost between the two divisions to achieve that the decentralized decisions lead to the optimal result for the entire company. However, what is *not* addressed is the decentralized decision on *component commonality*: if the manufacturing division makes that product design decision, how can cost allocations be used to achieve that the decentralized component commonality decision also leads to the optimal result for the entire company?

Cost allocation may not be needed when the implementation of a chosen modularity strategy is implemented through action controls and/or performance measures that are not based on costs. To some extent, firms will probably use action controls to simply force the implementation of a chosen modularity strategy. For example, there could be a database with allowed parts, there could be rules regarding modules that have to be incorporated into the product design (Davila & Wouters, 2004). Result controls may also directly focus on the implementation of a chosen modularity strategy by requiring progress on certain performance measures reflecting the level of modularity, which have been developed in various studies (Hölttä-Otto, Chiriac, Lysy, & Suk Suh, 2012; Johnson & Kirchain, 2010; Thevenot & Simpson, 2006).

However, the interesting question concerns the “voluntary” adoption of a modularity strategy, simply because the common parts and modules enable the realization of target costs. Cost allocation for modularity is understood here as the allocation of the development costs of technology to products that use this common technology and the allocation of unit costs of modules to products that use these common modules (whereby module is meant to generally refer to parts, components, subassemblies, modules, or software—basically anything built into a product). In other words: what does a product pay for technology and modules that are used together with others, instead of just developing and buying on its own? How do these internal prices affect decision-making at the product level?

Israelsen and Jørgensen (2011) discuss this setting, drawing on Ramdas et al. (2003), and develop a model for the allocation of costs to products that use a common module. They present the example already introduced above: suppose three products can use a common module. If only two use this module, the profit from those two is 300 and the profit from the third product is 40. If instead all three use the common module, costs decrease and total profit rises is 400. For the manager responsible for the third product to adopt the common module, the cost allocation system should result in profit of at least 40 for that product. Their model does not consider revenue effects, and it requires cost allocations in such a way, that none of the managers are less well off (i.e., have higher costs for their own product). This implies that if the contributing projects are arranged in descending order of contributing profit, then at any given point, the marginal project incorporating the common module cannot have more profit increase allocated to it than the marginal profit increase of the portfolio of all participating projects.

A first rule they suggest is to *allocate the marginal profitability of a participating product to that particular project*. In the example above, the profit increase with the third product is 60, and that would be allocated to that third project. However, to achieve this end result for each product, the distinction between unit-level costs and development costs is considered. The overall profit increase is the result of lower unit-level costs and development costs, but at the product level, it may not work out that well. The unit cost of the common module is allocated to the products based on the number of units used by each product. Because of overspecification, that may lead to too high unit-level costs for some products, which can be corrected with a so-called lump sum credit. After this, the development costs are allocated to the products in such a way, that the intended profit effects are achieved. They present a numerical example based on a case study of a company that develops high-tech, analytical instruments. In this example of 6 products that can all adopt a common module, the 6th product offers a marginal profit increase of 10,000 for the entire company if it also adopts the module. Just looking at this product, however, gives a different picture: when not taking the common module, the unit costs are 350,000 and the unique development costs are 100,000 (so 450,000 costs in total); when taking the common module, the unit costs increase to 472,500 in total. So rather than allocating some of the development costs for the joint module to this product too, instead, a lump sum credit of 32,500 is "allocated" to this product, so that the costs are reduced to 440,000 and it enjoys its marginal profit increase of 10,000 that it contributes for the entire company. The paper also discusses various practical challenges with the proposed solution, drawing on the case study experiences.

Bhaskaran & Krishnan (2009) discuss a different but related context. The issue is again decentralized decision-making in the context of product development and the impact of financial incentives, but different firms are involved and different mechanisms than cost allocations are investigated. Starting point for this paper is that by working together on product development, the development costs are lower compared to the situation when the innovation would to be done by a single firm. Beyond simple revenue sharing, these firms can decide on sharing of the development work and/or development investments if one firm conducts most of the development work. The paper investigates which cost and effort sharing mechanism is better, depending on a variety of conditions.

2.6 Modularity, implementation, and accountability

The review of the literature on modularity so far has, hopefully, made it clear that these cost management strategies involve a lot of incompleteness—as in calculations and performance measures that do not capture all the relevant dimensions of performance (Jordan & Messner, 2012). In practice, targets for manufacturing costs in the context of target costing and modularity are based on an endless number of assumptions about future sales prices, required features, and other product attributes, future costs and margins downstream in the supply chain, the firms' own margins and nonmanufacturing costs, breakdowns of overall manufacturing cost targets, etc.. Having a manufacturing cost target for, say, the navigation system of a car of € 87.34 looks incredibly "precise" and "objective" but is actually extremely arbitrary. Or, an organization may not break down cost targets to such a detailed level, thereby leaving much uncertainty for decision makers at that operational level (Jørgensen & Messner, 2010). Similarly, there are likely to be many issues with performance measures that are supposed to reflect the level of modularity, which were briefly mentioned in Section 2.5, or with performance measures in NPD more generally (Hertenstein & Platt, 2000). Moreover, the way in which costs of common modules are allocated (see the discussion in Section 2.5) is probably creating some strange incentives in many practical situations. Also, estimates of the costs of product designs that are still work-in-progress during the NPD project, for comparison with cost targets, will be flawed with uncertainty.

The point is this: accountability based on target costing and modularity can be very real—there might be all kinds of pressures, bad consequences, rewards, etc. connected to these targets—but those targets and supporting data will typically be highly arbitrary and artificial. Yet, it all looks terribly objective and factual. How does accountability come about? What role do incomplete performance measures, targets and calculations have in NPD? When and how are people committed to work towards such soft but also hard targets? Several studies have looked at such issues in the context of NPD and the use of modularity.

Mouritsen, Hansen, & Hansen (2001, 2009) present several case studies on management accounting around NPD projects in technology companies. These studies demonstrate that we should not think about the usefulness of management accounting for NPD (only) in terms of how “accurate” those techniques are. “The primary quality of management accounting calculations in relation to innovation activities is hardly that they describe innovation activities and make them increasingly transparent” (Mouritsen et al., 2009). In their LeanTech case, the company had outsourced a large part of its production processes. Having activity-based costing information from its suppliers strongly influenced the company’s development activities, in the sense that they wanted to use fewer different components to save adjustment time and costs. Consequently, the range of components was reduced from 15,000 to 5,000 (Mouritsen et al., 2001). Also, the large number of different intermediate products, such as printed circuit boards, used for assembling products was now seen as too costly. There was a push towards products that needed less physical adaption, combined with the development of fewer modules but with more potential functionalities and software solutions for customer adaptation.

In this LeanTech case, costing information impacted product development, but not because the costing information would be “perfect.” The calculations disregarded the additional costs due to the increasing average cost per unit on inventory, the risks and possible costs due to the increased waiting time for critical components, as well as the higher R&D costs because of increased complexity of technical development (Mouritsen et al., 2009). LeanTech and the other case companies made or considered particular extensions that could be claimed to make the existing calculations more complete. But that was not the crux. “Sales performance, contribution margin and ABC margin are powerful because they can motivate actions to be performed by innovators. This translation, rather than represent the innovation choices, creates a context for innovation activities to occur” (Mouritsen et al., 2009). Management accounting calculations may be needed to make ideas visible and credible, and it can challenge managers to relate their ideas and concerns about innovation to other important considerations, such as strategic objectives, profitability of products, and operational constraints in their own organization or elsewhere in the value chain.

The research of Jørgensen & Messner (2009, 2010) focusses even more specifically on modularity. They report a case study on the introduction of a new product strategy in a medium-sized, family-owned Danish company. The study demonstrates the limitations of accounting calculations to analyze decisions and accountability. It suggests that the various models mentioned above in Section 2.4 are most often very difficult—if not impossible—to implement because of lack of clarity of the modular concept itself in a particular situation, the complexity of modelling the concept, and the lack of required data. We will summarize these two papers (Jørgensen & Messner, 2009, 2010) quite extensively, because this research is one of the few examples of research addressing accountability for modularity and costs in such depth, and it is thus particularly relevant for our review.

The initial decision in the case company (Jørgensen & Messner, 2009, 2010): The company they investigated wanted to achieve various strategic objectives through a modular product strategy, which involved investing in platform development from which technology and even physical modules could be reused. The study shows how different people had different ideas about what modularity would be and the effects it would have. For example, marketing people were thinking of modularization as something that would enable them to sell any customization the customer would want, mainly through software configuration. The service engineers from sales and marketing were concerned with what effect the proposed modular architecture would have on customers' cost of ownership. The manufacturing people wanted modules that were physically manageable, and hoped modularization would enable faster production and separately testable modules. The quality manager wanted a design that would increase the number of instruments that pass the quality tests in the first attempt, etc.

Also, it becomes clear these very diverse benefits (and costs) of modularity were difficult to calculate. Top management wanted to achieve higher efficiency in product development and greater flexibility in offering new products. Modularity intuitively seemed a good idea to achieve this. They were aware of the kind of complex effects and tradeoffs we have also reviewed in Section 2.4, but these could not be fully quantified.

Moreover, the calculation tool for evaluating the profitability of a new product was, principally, not geared to capture the effects of modularity, but rather to evaluate products separately. The company "used a spreadsheet model that required engineers or managers to fill in estimated unit costs in production, as well as material and labor costs for the development of the product." (Jørgensen & Messner, 2009). Understandably, "the existing spreadsheet model was designed to handle only one product at a time, while in the case of modularity, there would be several products or product variants that had to be evaluated in tandem because they would share one or more modules." (Jørgensen & Messner, 2010). "When modularity was introduced, the representational limits of the earlier mentioned calculation model became apparent" (Jørgensen & Messner, 2009). Still, the CEO made the decision to go modular, because, as said above, intuitively it seemed a good idea, and many people also expected they would learn much from the new project and then better understand the consequences.

Next, they present and discuss findings regarding the company's first two projects for developing modular products. The company's stage-gate system played an important role. A company manual specified the different stages, the responsibilities, the desired outputs, the required documentation, etc. Although this control system was quite detailed, it was also explicitly stated the described processes should be regarded as guidelines and could be adjusted to suit individual projects. This formalized control instrument was generally perceived as helpful in maintaining a certain level of efficiency.

Accountability at the gates: The evaluation process worked basically the same at the start of a new development project (i.e., the first gate) and at later gates. The calculation model that focused on the contribution margin ratio and payback ratio was revised based on new information obtained during the development project. Engineers and project managers had the opportunity to introduce add-on spreadsheets and they could, to some extent, repair the calculation model with such technical solutions. An example is that the spreadsheet calculation model did not include indirect variable production costs, which the company's accounting ERP system actually added to the product cost based on a percentage of the direct variable costs. This could be corrected in the calculation model. Still, severe limitations remained, and managers in the case study mentioned that the implications of reuse, project lead time, and economies of scale were still not reflected in the calculation model.

So, accountability was *not* created through detailed cost and profitability targets and rigorous estimates of to what extent those were achieved. Instead, the management board focused on high-level targets and on coordination. Strategic objectives were not translated into numbers, but they were discussed together with financial arguments. Although strategic objectives, such as quality, lead time, or production efficiency could not be fully quantified, the calculation model provided a starting point to talk about how design choices and tradeoffs affected these strategic objectives. "The management board drew from their own practical expertise in order to 'see through' numbers that featured in the project reports" (Jørgensen & Messner, 2010). "Strategic concerns were regarded as means to profitability that had to be balanced in a reasonable way" (p. 201). The management board focused its inquiry to emphasize that the integration of different concerns by different parties was important at any stage during the NPD project. They "used the meetings at the gate to ensure that there was local communication and coordination" (p. 202). These findings are related to how Mouritsen et al. (2009) discuss their cases and suggest that financial numbers can influence NPD because "the calculation connects the innovation activity to other concerns."

Accountability at the stages (between the gates): Anticipation of the discussions with the board that project managers knew would take place at the gates also influenced how accountability was created between the gates (during the NPD stages). It made project managers think about how they could explain how their actions might impact overall profitability—even if such arguments could often not be translated into hard calculations. It made them consider how they could argue their decisions supported strategic objectives, and it let them engage in horizontal information sharing so they would be able to show a wider perspective. "The enforcement of financial accountability at the gates can be seen as a means to remind managers of the importance of accounting numbers—even if these are only imperfect representations of the decisions and practices in NPD" (Jørgensen & Messner, 2010). These practices are understandable, and they not claimed to be optimal.

These studies convey a more realistic notion of accountability for modularity in NPD. While models in the literature depict optimal decisions for stylized settings (see Section 2.4) and we can imagine a refined, "ideal" system with target costs and clear guidelines for the use of modularity (as described earlier in this chapter), these empirical studies show this may be illusory. "It was clearly impossible to decide upon every detail in advance" (Jørgensen & Messner, 2010). The role of financial goals and calculations to create accountability for modularity can only be understood by seeing those goals and calculations in combination with other information and practices, such as: focusing on high-level financial goals, discussing how calculations of financial goals are related to strategic goals that are not part of the calculation, and probing how actions have wider impact for various activities inside the company and for external parties. Financial goals and calculations can be a starting point, but managers will combine those with insights that are not compounded in financial models.

2.7 Conclusion

The purpose of this chapter was to provide an overview of our current understanding of modularity for cost management purposes based on various literatures. Our literature review shows that NPD and the use of modularity for cost management purposes are complex phenomena. Much more of the research reviewed here has been published in innovation and operations management than in the management accounting literature.

The purpose of modularity in the context of NPD and cost management is to coordinate design decisions across a portfolio of related products, in order to provide product variety in an efficient way. As such, it goes beyond target costing that focusses on the costs of products within the scope of a single NPD project. Within the overall idea of modularity, we mentioned three concepts. Component commonality has the perspective of existing components and concerns the use of these for products that are newly developed or redesigned. Modular design looks at the strategic design of a product family by defining building blocks and interfaces, such that individual components and modules can be used and replaced independently among different derivative products. Finally, a product platform is a basic architecture of the physical implementation of a functional design, which becomes the basis for a series of derivative products.

Our review of empirical research showed there are several holistic case studies that are intended as inspirational and pragmatic illustrations of modularity. We also reviewed a large stream of literature that analyzes some of the impacts and tradeoffs involved in using modularity for cost management purposes. Much of this research is not empirical and uses quantitative models that necessarily address rather stylized settings.

The two final topics identified in this literature review start to look at behavioral aspects. One is the design of allocation of costs that are shared across different products. How can these cost allocations provide incentives for product managers to adopt modularity and to accept more commonality across products, if that would be beneficial for the entire organization? The other topic is the question how accountability for modularity comes about. One could imagine a refined system with accurate models that guide optimal decisions about modularity, detailed targets for costs and profitability of products and product groups, and accurate measurements of achieved modularity, costs and profitability. However, the complexity of the decision models already suggests that such an approach may be naive, and several empirical studies described more realistically how modularity was achieved.

We suggest the following ideas for future research: one avenue would be to conduct field research and investigate if and how quantitative models capture cost management issues around modularity in a real organization. Some research could focus on adjusting such models to much more complex settings, where decisions on products are not made simultaneously (so there is a mix of “old,” current, and future products) and that involves much more complicated products and many technical constraints. Quantitative models for such settings will likely be less comprehensive and elegant from a mathematical point of view but might, on the other hand, include more of the multifaceted aspects that are involved in many real-world situations.

Another topic for future research concerns cost allocations to influence decision-making at the level of target-costing processes for individual NPD projects. On the one hand, this could investigate which modularity strategy the firm would provide and analyze cost allocations that stimulate behavioral congruence. But even more subtle: it is unlikely that the perfect and encompassing modularity strategy can be defined ex ante. Given an overall modularity strategy, it may still be optimal to sometimes allow exceptions. Cost allocations could provide the information and incentives to the responsible product managers for such decisions.

Decisions on modularity and cost allocations could also be explicitly embedded in a hierarchical planning process. The basic design of a hierarchical planning system includes the partitioning of the overall planning problem, and the linkage of the resulting subproblems (Hax, 2013). This means the overall planning problem is decomposed and first some "hierarchical" or broader decisions are made, for example about the basic architecture of a product family in terms of shared systems, unique systems, and interfaces. These decisions create constraints for later and more detailed decisions, for example about specific modules to be developed. In a context of multiple products that are developed after each other and evolving information, such an approach might be useful.

Although not modularity per se, we believe future research could also fruitfully investigate how firms deal with complexities of target costing systems. For example, how do they understand costs throughout the value chain? How do they set targets for initial development costs? How do they analyze tradeoffs between initial development costs and later manufacturing costs? How do they analyze tradeoffs between costs and other targets?

Perhaps one of the poorest understood topics is accountability when modularity is used for cost management purposes. There are huge complexities and uncertainties of modularity, so the supporting management accounting tools will only very incompletely be able to analyze tradeoffs, provide targets, and measure results. Given these circumstances, we need to understand more realistically how modularity, cost management, and accountability work in practice, and what this means for management accounting and management accountants.

3 Extending the scope of target costing: An approach to determine fixed cost targets for a modularly designed product portfolio

Abstract

Target costing as a cost management method is applied in a single product's development stage and considers all costs that accrue during its lifecycle. The academic target costing literature focuses on cost management efforts for manufacturing costs, such as material and labor costs, and provides methods and instrument to determine cost targets. But we have scarce insights how targets for other costs that come up during a products' lifecycle, for example, R&D or investments in tools and machines, are determined during that process. This is understandable, as managing these kind of costs for a single product seems not too challenging. However, strategies that focus on managing a firm's whole product portfolio received increasing relevance and attention in recent years – both in academia and practice. If a firm follows strategies such as modular design, component commonality, or product platforms, managing R&D costs and other investments may become more complex. We present a method to determine a fixed costs target for a modularly designed architecture a whole product portfolio is based on. Next, we break fixed cost targets down to elements and fixed cost types. We provide empirical evidence and illustrate the method's implementation with data from a three-year case study we conducted at a car company. On site, we could substantiate and enforce a significant fixed cost reduction as a mean to ensure future products' profitability. In order to realize the fixed cost target, architecture's variety and complexity was significantly reduced. With this study, we also aim to illustrate and address challenges for cost management practice that arise in the context of a modularly designed product portfolio.

Keywords: *Target costing, modular design, R&D costs, manufacturing investments, case study, interventionist research*

3.1 Introduction

Target costing is the cost management method for new product development (NPD) that has received most attention in academia, and its practical relevance increased during past decades (Wouters & Morales, 2014). It aims to reduce a product's manufacturing costs already during its R&D stage, while other methods, such as Kaizen costing or Just-in-time, focus on an improvement of a product's cost performance after its start of production (SOP). This seems reasonable, as approximately 80% of a product's costs are determined before the first unit is produced (Anderson & Sedatole, 1998; Carr & Ng, 1995; Cooper & Slagmulder, 2004a; Davila & Wouters, 2004; Kato, 1993; Kee, 2010).

Although some authors mention or emphasize how target costing considers the full product life cycle (Agndal & Nilsson, 2009; Bjøornenak & Olson, 1999; Cadez & Guilding, 2008; Ewert & Ernst, 1999; Guilding, Cravens, & Tayles, 2000; Kato, 1993; Tanaka, Yoshikawa, Nines, & Mitchell, 1994), we found that the target costing literature's major focus is on *manufacturing costs* (Carr & Ng, 1995; Cooper, 1996; Sakurai, 1996; Wouters & Morales, 2014). This makes sense, as approximately 60-80% of a product's costs are determined by direct materials and component costs (Al Chen, Romocki, & Zuckerman, 1997; Anderson & Dekker, 2009; Carr & Ng, 1995; Lee & Monden, 1996). Nonetheless, there is scarce insight how targets for other kinds of costs, such as R&D or investments in manufacturing systems, are determined. For example, Lee & Monden (1996, p. 202) casually state that "[t]he target cost reduction figure for fixed costs is not calculated in the same manner as variable costs. The budget amount for each fixed cost element is regarded as target. The actual performance is compared to the budgeted cost for evaluation." Filomena, Neto, & Duffey (2009) separate development costs from 'other costs', and subtract R&D costs from a product's target price to finally calculate targets for indirect, direct, and raw material costs. But, they give no detailed information about how the R&D cost targets were determined. We were surprised that this issue has not received much attention in the academic literature so far, as Tani et al. (1994) found that new investments and development costs were object of target cost management for over 80 % respectively 60% of the surveyed firms.

Furthermore, we found that the focus of the target costing literature is typically limited to cost management activities of a *single product*. The target costing literature does not address how design choices across multiple development projects can be coordinated for cost management purposes. As presented in the previous chapter, modularly designed components are a strategy to handle increasing product variety in a cost-efficient way (Ramdas, 2003), and the literature documents several benefits of modular strategies, for example development cost savings or scale effects (Fisher et al., 1999; Krishnan & Gupta, 2001; Mahmoud-Jouini & Lenfle, 2010), as well as some negative effects (Labro, 2004). We can conclude that the overall cost effect of a modular approach is not straightforward, but there is a lack of understanding of suitable approaches for cost management in the context of strategies such as modular design, product platforms, or common component use.

Therefore, we propose an approach to extend the scope of target costing as the first contribution of this paper. We present a method to determine market-based cost targets for product-specific fixed costs. R&D costs or investments for manufacturing systems are part of the full costs products have to cover, and, in contrast to other costs like overheads, are often directly triggered by them. Consequently, if products' profit margins are to be realized, early cost management activities that focus on these kind of costs are mandatory. Furthermore, this method concerns the development of a portfolio of products, based on a modular product strategy. In this case, a firm's product portfolio is interwoven, and components need to satisfy the requirements of more than one product. This entails potential for conflict. As a portfolio's variety and customizability directly impacts its R&D costs (Ramdas & Sawhney, 2001), we argue that such cost targets can be an effective cost management tool to impact complexity. For example in the car industry, where modular strategies' importance increased during the past decades, these kind of costs add up to several billion dollars per year. We argue that the philosophy of target costing helps to derive R&D and investment budgets for a complex modular product architecture, and do not exclusively agree with the statement made by Kato (1993) which says that "R&D is essentially a process of trial and error."

As a second contribution, we illustrate the method's implementation and provide empirical evidence about its practicality from a three-year case study we conducted at a car company. Extending target costing's scope by incorporating practical evidence seemed appropriate to us, as "academic research on target costing lags practice" (Ansari et al., 2007, p. 508). The case company's products were based on a modular designed architecture, and both its complexity and R&D costs significantly increased in the past. This happened because products were equipped with a large spread of characteristics and functionalities, and consequently, products' realized profit margins eroded. Implementing the presented method was a way to manage and impact fixed costs for the future modular architecture. To the best of our knowledge, this aspect has not received much attention in the literature so far.

In addition, our case study addresses and illustrates challenges that arise if target costing is combined with cost management strategies that focus on a whole product portfolio. Davila

& Wouters (2004) discuss the topic of product platforms, modular design, and parts commonality, and raise the question if there are cost management practices that complement or supplement to target costing. A better understanding of management processes in the context of modular strategies is needed to comprehend how conflicting objectives within product families are considered and solved, and how promised benefits of such a strategy can be achieved. With this study, we aim to link target costing and modular design strategies for cost management purposes. Providing practical challenges that arise in a complex product setting, we also contribute to the understanding of how an organization's movement towards a more modular product architecture impacts its management systems (Ro et al., 2007).

The remainder of the paper is structured as follows: In the next section, we summarize and discuss the academic target costing literature. We give an overview of the cost categories and methods it focuses on, and also link target costing to interdependencies between several products. In Section 3.3, we formally introduce the method that derives a fixed cost target for a modular product architecture. We start Section 3.4 by introducing our research approach, and present empirical evidence that gives detailed insights into the method's implementation at our case company. We close the paper with a concluding discussion.

3.2 Literature review

While the literature review in Chapter 2 also takes aspects of target costing into account, the focus of the current literature review section is specifically on that particular cost management method. We reviewed additional literature and aim to answer more nuanced questions about target costing like: how does target costing work? Which cost types does target costing literature consider? What do we know about the way the method is executed? And, to which extend does the target costing literature consider interdependencies within a firm's portfolio?

We started our literature analysis with target costing studies that have been identified in earlier literature reviews by Wouters & Morales (2014) and Wouters, Morales, Grollmuss, & Scheer (2016). Those authors investigated the relevance of 15 cost management methods, and analyzed publications from 1990 – 2013 and 1990 – 2014, respectively, in 63 academic journals in total. Target costing was one relevant cost management method in their research, and they found 18 papers in the innovation and operations management literature (Wouters et al., 2016) and 38 studies in the management accounting literature (Wouters & Morales, 2014) which dealt with that topic. For the current paper, we added studies we were already familiar with (for example, Ansari et al., 2007) or found in key papers' reference lists (for example, Kee & Matherly, 2013). In order to capture also recent research, we did a literature search via Google scholar to identify studies which were published in academic accounting journals between 2014 and 2017 and have the word ‘target costing’ in their title (for example, Navissi & Sridharan, 2017). In total, this approach resulted in a set of 64 papers that are part of this literature review.

There is a variety of different perspectives in the field of target costing. Therefore, we organized our literature set in three panels, which we will present in the following sub-sections. In Section 3.2.1, we give a summary of our first panel that includes studies that describe target costing’s general concept or emphasize particular perspectives. For example, we identified many papers that look on target costing from an (inter-)organizational or (inter-)cultural point of view. In Section 3.2.2, we explore our second panel, and examine which explicit cost categories the target costing literature pays attention to. In Section 3.2.3, we show methodical knowledge about how cost targets are specified and achieved. This sub-section does not refer to a particular panel, but is based on our whole set of literature. Section 3.2.4 is based on papers of our third panel, and we examine how target costing considers interdependencies among products. Finally, we conclude the literature review and motivate the identified research gap in Section 3.2.5.

There is only little overlap between the studies that are included in the three panels, as most papers take one of the perspectives mentioned. For example, many papers listed in the first panel talk about the general term ‘costs’ or ‘product costs’ without specifying which kind of costs they refer to. Sometimes these studies superficially mention cost categories, but do not provide much detail. In many cases, the focus of these papers is to examine if and in which context target costing is applied, or how collaborating firms’ cost management activities are affected if target costing is executed. Therefore, we incorporated studies that deal with specific cost categories in a target costing context in our second panel. Finally, papers that clearly focus on cost management activities for a whole portfolio of products form panel three. The three panels are shown in Table 3.

3.2.1 General characteristics & literature emphases of target costing

We first present papers listed in panel one that **describe the target costing process** or discuss **general characteristics** of it. The target costing process entails the observation or estimation of a realizable market price for a product with a specific set of characteristics and functionalities. Subtracting the aspired margin a firm plans to realize with the product, the allowable total costs to “create” the product remain. Subtracting overheads, R&D expenses, and manufacturing investments that are needed before a product’s actual manufacturing starts

Table 3. Literature set for the current study

Panel one: Diverse emphases of TC studies					
Article	*Describing TC process/ general characteristics*	*(Inter-) organizational focus*	*(Inter-) cultural focus*	*Literature review*	*Other foci*
Afonso, Nunes, Paisana & Braga (2008)	X				
Agndal & Nilsson (2009)		X			
Agndal & Nilsson (2010)		X			
Al Chen et al. (1997)		X	X		
Albright & Kappel (2003)					X
Anderson & Dekker (2009)		X			
Ansari et al. (2007)			X	X	
Ax, Greve, & Nilsson (2008)	X				
Baines & Langfield-Smith (2003)		X			
Bjøornenak & Olson (1999)	X				
Cadez & Guilding (2008)					X
Caglio & Ditillo (2012)		X			
Carr & Ng (1995)		X			
Chenhall & Langfield-Smith (1998)			X		
Chenhall (2008)					X
Cooper & Slagmulder (1999)	X				
Cooper & Slagmulder (2004a)	X				
Cooper & Slagmulder (2004b)		X			
Cooper & Yoshikawa (1994)		X			
Cooper (1996)	X	X	X		X
Dekker, Sakaguchi, & Kawai (2013)		X			
Duh, Xiao, & Chow (2008)			X	X	
Ellram (2006)	X		X		
Everaert & Bruggeman (2002)					X
Ewert & Ernst (1999)	X				
Fayard, Lee, Leitch, & Kettinger (2012)		X			
Gopalakrishnan, Libby, Samuels, & Swenson (2015)					X
Guilding et al. (2000)			X		
Hopper, Koga, & Goto (1999)			X		
Hoque, Akter, & Monden (2005)					X

Article	*Describing TC process/ general characteristics*	*(Inter-) organizational focus*	*(Inter-) cultural focus*	*Literature review*	*Other foci*
Hyvönen (2003)					X
Ibusuki & Kaminski (2007)	X				
Jun Lin & Yu (2002)			X		
Kato (1993)	X				
Kee (2010)	X				
Lee & Monden (1996)	X		X		
Li, Wang, Yin, Kull, & Choi (2012)		X			
Liker, Kamath, Wasti, & Nagamachi (1996)		X	X		
Mihm (2010)					X
Monden & Hamada (1991)	X		X		
Mouritsen, Hansen, & Hansen (2001)		X			
Navissi & Sridharan (2017)					X
Petersen, Handfield, & Ragatz (2003)		X			
Plank & Ferrin (2002)					X
Rabino (2001)			X		
Roslender & Hart (2003)					X
Seal, Berry, & Cullen (2004)		X			
Scarbrough, Nanni, & Sakurai (1991)			X		
Tani et al. (1994)	X	X	X		
Wagenhofer (2006)			X	X	
Wijewardena & De Zoysa (1999)			X		
Wouters & Morales (2014)	X			X	
Wouters et al. (2016)	X			X	
Wu, Boateng, & Drury (2007)			X		
Yazdifar & Askarany (2012)	X		X		

Panel two: TC studies explicitly mentioning specific cost categories [*]

<table>
<tr><th></th><th></th><th></th><th colspan="3">Non-manufacturing costs</th><th colspan="2">Manufacturing costs</th></tr>
<tr><th>Article</th><th>External costs/ margins</th><th>Margin</th><th>Overhead</th><th>R&D</th><th>Variable</th><th>Fixed</th><th>Variable</th></tr>
<tr><td>Anderson & Sedatole (1998)</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">X**</td></tr>
<tr><td>Ansari et al. (2007)</td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Bhimani (2003)</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">X**</td></tr>
<tr><td>Carr & Ng (1995)</td><td></td><td></td><td>X</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Cooper & Slagmulder (1999)</td><td></td><td>X</td><td></td><td></td><td></td><td colspan="2">X**</td></tr>
</table>

			Non-manufacturing costs			Manufacturing costs	
Article	*External costs/ margins*	*Margin*	*Overhead*	*R&D*	*Variable*	*Fixed*	*Variable*
Cooper & Slagmulder (2004b)						X**	
Cooper & Yoshikawa (1994)						X	X
Cooper (1996)							X
Ellram (2006)		X	X			X	X
Everaert & Bruggeman (2002)						X**	
Filomena et al. (2009)				X		X**	
Hoque et al. (2005)							X
Ibusuki & Kaminski (2007)		X					X
Jun Lin & Yu (2002)		X	X				X
Kato (1993)		X					
Kee (2010)	X	X	X	X		X	X
Lee & Monden (1996)	X	X	X			X	X
Li et al.(2012)		X				X**	
Monden & Hamada (1991)		X				X	X
Nixon (1998)				X		X	X
Tani et al. (1994)		X	X	X		X	X
Woods, Taylor, & Fang (2012)		X		X		X	X
Wouters & Morales (2014)							X
Zengin & Ada (2010)		X				X	X
***Panel three:* TC studies with focus on products' interdependencies**							
Davila & Wouters (2004)							
Kee & Matherly (2013)							
Ro et al. (2007)							

* Sometimes it was difficult to cluster the studies in these categories. We did not include a study in a specific cost category if these costs were only briefly mentioned and obviously not in the focus of the paper.

** Does not explicitly distinguish between fixed and variable costs results in the variable manufacturing costs per unit (Cooper & Slagmulder, 1999; Ibusuki & Kaminski, 2007; Lee & Monden, 1996; Wouters & Morales, 2014). These remaining costs are available to equip the product with properties that are needed to realize the ex-ante observed or estimated market price. The target costing method is implemented during the development process and its key idea is to focus on low costs while meeting customer requirements with respect to quality and functionality (Afonso et al., 2008). The reciprocal relationship between costs, realizable price, and a product's attributes means that costs are not determined within the firm—a characteristic for a cost-plus strategy—but allowed by the market (Ewert & Ernst, 1999).

During the development process, market changes or product property adjustments can affect the achievable market price and might therefore also impact the allowable costs. Therefore, target costing is more than market price minus aspired margin—it is an iterative process between a product's properties and their technical realization, related costs, and market price. Cooper (1996) talks about the *survival triplet* of product price, quality, and functionality that determines a firm's success. Bjøornenak & Olson (1999, p. 332) emphasize the *normative* or *ex-ante* perspective of target costing—"it says something about how it should be, and not how it has been"—and Afonso, Nunes, Paisana, & Braga (2008) call target costing a "strategic weapon" to ensure suitable market introduction.

The process of target costing entails several steps. Wouters & Morales (2014) distinguish between two major purposes of target costing: *setting the cost target* and *early cost estimation.* The first aspect refers to the basic idea of target costing to calculate the allowable costs by subtracting the aspired margin from the estimated sales price, and break it down to the whole supply chain. This part of target costing is executed right at the beginning of the development process, while the other essential part, *early cost estimation*, is performed during the development process: assessing to what extent the components, and ultimately the whole product design, meet the outlined costs. Cooper & Slagmulder (1999) divide the target costing process into three iterative steps: *market-driven costing* focuses on deriving the market price and setting the target margin, to calculate the allowable costs. *Product-level target costing* then forces the development and design team to meet the target costs with their technical concepts – for example with methods such as value engineering (VE). Finally, *component-level target costing* sets targets for individual parts or components. With this last step, a buying firm is able to address components' target costs to their suppliers.

A second stream of literature listed in panel one focuses exactly on this (**inter-) organizational** application of target costing for cost management purposes and how cost management cooperation beyond organizational boarders enhances cost reduction possibilities (Agndal & Nilsson, 2009, 2010; Al Chen et al., 1997; S. W. Anderson & Dekker, 2009; Baines & Langfield-Smith, 2003; Caglio & Ditillo, 2012; Carr & Ng, 1995; Cooper, 1996; Cooper & Slagmulder, 2004b; Cooper & Yoshikawa, 1994; Dekker et al., 2013; Fayard et al., 2012; Li et al., 2012; Liker et al., 1996; Mouritsen et al., 2001; Petersen et al., 2003; Rabino, 2001; Seal et al., 2004; Tani et al., 1994). Close cooperation with suppliers during the development stage promotes the integration of development efforts of the firms involved, and leads to more substantive discussions to finally meet target costs (Cooper, 1996).

The third perspective studies of our first panel adopt are target costing issues in an (**inter-) cultural contexts**. Target costing has its origin in Japanese firms (Al Chen et al., 1997; Ansari et al., 2007) and there are studies that examine timely or cultural differences of target costing application. Al Chen et al. (1997) investigate the adaption and transferability of strategic cost management practices of Japanese subsidiaries in the United States compared to their parent company. Guilding, Cravens, & Tayles (2000) examine the use of 12 strategic management accounting practices in New Zealand, the U.K and the United States. Jun Lin & Yu (2002) examine how western management accounting practices in the developing Chinese economy have spread. Wijewardena & De Zoysa (1999) compare management accounting practices in Australia and Japan and find that Japanese companies focused their cost management activities much more towards the design and development stage, for example, through target costing. Wu, Boateng, & Drury (2007) discuss the adoption and benefits of western management accounting practices in China and discovered that target costing is more beneficial for state owned enterprises than joint ventures. Finally, Chenhall & Langfield-Smith (1998) examine to what extent target costing and other cost management methods are applied in Australian manufacturing firms.

Furthermore, some papers of panel one are **literature reviews** about management accounting methods in which target costing plays an important role. As already mentioned above, Wouters & Morales provide comprehensive summaries of literature that deal with management accounting methods during NPD in management accounting journals (Wouters & Morales, 2014) and in the innovation and operations management literature (Wouters et al., 2016). Ansari et al. (2007) analyze target costing literature published from 1995 until 2005 and also examine differences of English and Japanese studies. Duh, Xiao, & Chow (2008) examine the management accounting research in China between 1997 and 2005 and find a relatively high attention to target costing during that period. Wagenhofer (2006) reviews management accounting practices, such as target costing, in German-speaking countries.

We could not cluster studies with diverse **other foci** in one of the mentioned perspectives. Even as these studies do not capture the focus of the current chapter, they provide interesting insights and additional understanding of the target costing topic. Mihm (2010) investigates incentives for individual engineers in complex NPD projects that require an extensive split of the design task. He concludes that emerging information asymmetries, lack of transparency, or career concerns may lead to an overestimation of parts' importance by the responsible engineers. This 'internal cost gaming' can finally result in product overdesign, project delay, and, as a last consequence, in project termination. Other studies focus on goal setting and found that assigning a specific cost target to design engineers leads to lower-cost products than under general ("do your best") cost goals (Cooper, 1996; Everaert & Bruggeman, 2002; Gopalakrishnan et al., 2015). For example, Everaert & Bruggeman (2002) examine the impact of specific cost targets on quality, costs, and development time under low respectively high time pressure during NPD. Executing a laboratory test, they found that specific cost targets lead to lower product costs without harming development time or quality. Cooper (1996, p. 238) states that "designing to a specified low cost appears to create more intense pressure to reduce costs than designing to an unspecified minimum cost".

To conclude, many studies exist that consider different target costing aspects. For the current chapter, we will pay limited attention to target costing's inter-organizational characteristic or its deviating application, but focus on cost types and instruments considered in the literature.

3.2.2 Specifying the term costs: Cost types considered by target costing literature

For the current chapter, we are interested in which types of costs the target costing literature considers during new product development (NPD). Figure 2 illustrates a product's cost structure and we cluster the studies of panel two according to the major cost type they consider. Of course, this is a simplified illustration and does not contain particular aspects, such as capital costs as discussed by Kee (2010) or Woods et al. (2012).

A significant share of a product's sales price does not arrive at a company. These **external costs and margins**, such as sales taxes or distribution fees, vary from market to market and might change over time.[9] Even as these costs might not directly influence a product's development stage, they may affect either an organization's margin or its product's target cost structure. Lee & Monden (1996) illustrate that the firm in their study would not change sales

[9] In practice, there might not always exist a separate and independent importing company, but this may be owned by the company. For simplification, here we generalize this distinction.

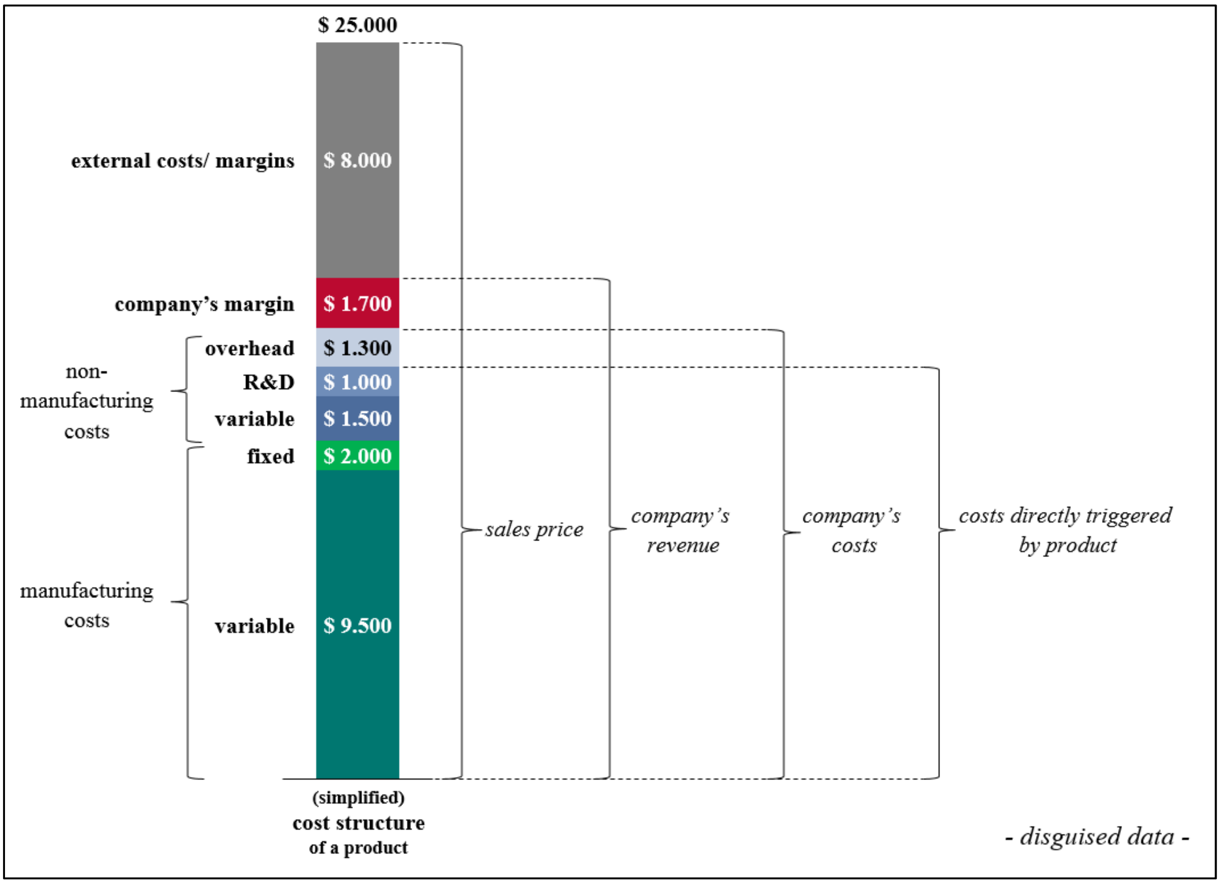

Figure 2. Exemplary breakdown of a product's sales price into cost types

prices because of sales tax changes. But in general, we found almost no references to these kinds of costs in the literature. Some studies only superficially mention to subtract "any uncontrollable allocations, such as taxes[…]" (Ibusuki & Kaminski, 2007) and Hoque et al. (2005) implicitly consider these costs by distinguishing between retail price and wholesale price.

The way a company determines a single product's aspired **margin** can be done in different ways. We found that plenty of target costing studies mention that aspect, but only a few describe or discuss it in more detail. Cooper & Slagmulder (1999) emphasize to set realistic margins, as too ambitious target costs might lead engineers' conclusion that these costs are not achievable, so they would resign and not try to achieve the target costs anymore. The authors mention two ways of defining target margins: first, comparing a new product with its predecessor and adjusting the margins due to specific circumstances. Second, breaking a firm's total profit claim down to individual products or sectors. A firm has to manage its product portfolio in a way that it meets the organization's target profit each year. Consequently, an organization should derive a product's target profit margin by corporate strategic profit planning considerations (Kato, 1993). Important aspects to consider are the future product mix, their variations and the individual products' sales volume (Kato, 1993). Monden & Hamada (1991, p. 19) describe in their empirical study that "profit plans for the whole company are established and the overall target profit for each period is determined for each product". Additionally, Cooper & Slagmulder (1999) shortly discuss the connection of margins to other costs and state that a company has to adjust its target profit margins if market prices change or additional investments become known. In the next step, a company has to take additional measures in order to compensate the profit. Once a product's target profit is set, the context and method how it has been determined should be communicated in an objective and comprehensible way communicated. This increases its acceptance within an organization (Cooper & Slagmulder, 1999).

There are different ways of measuring margins. In the car industry, the target profit is normally set by using the return on sales ratio (Lee & Monden, 1996). In a study about considering capital costs during the target costing process, Woods et al. (2012) discuss different measures of profitability, such as return on sales, return on assets, return on equity, residual income, economic value added, or net operating profit after tax. Firms usually cannot determine their profit claim without any constraints, as it is, at least to a certain extent, exogenously defined by capital markets (Ansari et al., 2007) or competitors' profit margins.

For the actual costs that accrue in-house, we distinguish between non-manufacturing and manufacturing costs. Non-manufacturing costs that are not directly caused by a product are a firm's **overhead costs**, such as the costs for buildings or administration. These costs are not in the focus of NPD, so there was only superficial information in the literature. At Nissan, overhead costs make up about one fifth of the manufacturing costs (Carr & Ng, 1995), and these were distributed to products on the basis of different logics. Possible methods to allocate these overhead costs to products can be based on sales volume, revenue, or number of used parts, for example. Without further discussing the proceeding, Ellram (2006, p. 18) mentions that target costs have to be "apportioned among the internal cost centers" and general and administrative costs are one cost type besides others. Jun Lin & Yu (2002) already explicitly subtracts the corporate overhead costs from the estimated sales price in order to calculate the total target costs by product. They mention the budgeting process of these overhead costs, and state that "a detailed analysis of each expense item is applied" (Jun Lin & Yu, 2002, p. 455)

Non-manufacturing costs that are directly caused and assignable to individual products can be both variable and fixed. We categorize **R&D costs** as non-manufacturing fixed costs, and in some target costing studies, these costs are only briefly mentioned. For example, Cooper & Slagmulder (1999) state that the target margin should be high enough, so it can compensate large upfront investments. Ibusuki & Kaminski (2007) explicitly set the assumption that fixed costs are uncontrollable. Al Chen et al. (1997) argue that the focus of these cost elements is basically achieved through budgets for the several functional departments, and reductions (or restrictions) lead to an overall cost improvement. In the context of service-providers that develop parts on behalf of OEMs, Cooper & Slagmulder (2004b) superficially discuss R&D outsourcing. Kato (1993) mentions that target costing also aims to reduce fixed costs, not only variable costs. In the study by Roslender & Hart (2003), a pharmaceutical company applying target costing was challenged to manage its R&D activities in a cost-efficient way. Monden & Hamada (1991) mention that during the corporate planning stage, facility and development costs are allocated to the several products in order to calculate the operating profit. Mouritsen et al. (2001) mention that it is obviously difficult to set target costs for the development processes of a product.

Besides these papers that mention R&D costs only casually, we also found a few target costing studies that discuss R&D costs in a more profound way. In a survey-based study, Tani et al. (1994) review the state of the art of target costing and present that 60% of the consulted firms consider development costs as an object of target costing management. Moreover, 40% of the firms included development costs in cost tables as applied tools during the target costing process. Filomena, Neto, & Duffey (2009) explicitly consider development costs in their target costing operationalization model. They divide the target costing process during NPD in four stages and state that development costs can be forecasted with historical data. Divided by the forecasted demand, they subtract the *cost share related to the costs incurred to develop the product* to calculate the allowed variable costs. In their study, R&D costs are a means to calculate the allowable variable costs, but these costs are not in the focus of cost management efforts itself. Kee (2010) incorporates the costs of capital in a target costing model and considers the time value of large investments necessary to manufacture a product. Even as the author does not explicitly mention development costs, this is, of course, also true for R&D costs. Nixon (1998) discusses R&D costs in the context of measuring productivity and effectiveness, and states that the R&D literature is more ex-post oriented than putting emphasis on a lead perspective. He also talks about how customer requirements can be integrated during the development stage, but not how development costs should reflect the market situation.

Within the studies included in the sample, none explicitly discusses **variable non-manufacturing costs** (costs for sales support activities, for example).

Finally, we distinguish between fixed and variable manufacturing costs, but both are directly caused and assignable to individual products. In some studies, authors do not clearly distinguish between fixed and variable manufacturing costs, but refer to manufacturing costs in general (for example, Anderson & Sedatole (1998)).

For the purpose of this chapter, we refer to costs for investments in production systems, tools, or machines as **fixed manufacturing costs**. Studies that explicitly mention these kind of costs were, for example, Lee & Monden (1996, p. 200), who summarize that "[p]roduction engineers […] evaluate resource requirements and manufacturing processes". Kee (2010) explicitly considers investment costs, but similar to R&D costs, the reader does not gain detailed insights how targets for this cost category are determined. Zengin & Ada (2010) consider manufacturing overhead costs in their cost calculation, and Woods et al. (2012) refer to tool costs respectively tool budgets in their study about incorporating economic value added into the target costing system.

A major focus in target costing literature is on **variable manufacturing costs**, such as material costs, labor costs, or direct conversion costs (Ibusuki & Kaminski, 2007; Lee & Monden, 1996; Zengin & Ada, 2010). Most of the studies in panel two deal with these kind of costs, and even as many authors emphasize that target costing has a full life cycle perspective, the focus of the target costing literature with respect to target setting is quite narrow. Wouters & Morales (2014) emphasize to subtract both the margin and nonmanufacturing costs from the market price to get to the focus of target costing processes: manufacturing costs. S*etting the cost target* is the first step, while es*timating the actual costs* of a proposed technical solution is the follow-up process (Wouters & Morales, 2014). Woods, Taylor, & Fang (2012, p. 268) state that "traditional target costing focuses on seeking cost reductions through changes in the type/source of materials[…]". Carr & Ng (1995) focus in their case study on materials and components that represent over 80% of the costs their case company has to deal with. Other studies describe the target costing process between a firm and a supplier, and it becomes obvious that a component's price represent variable manufacturing costs for the firm, while the supplying firm has to take a full-cost perspective (Cooper, 1996; Cooper & Yoshikawa, 1994). Cooperating with its suppliers, a firm may adjust a component's specifications and "engineers can design […] lower cost parts" (Cooper & Yoshikawa, 1994, p. 60). Ellram (2006) compares the theoretical target costing model with practice of U.S. and other Western firms, and also focuses on material respectively component costs. In the case of decreasing plant utilization, the focus on variable manufacturing costs becomes even more important – to ensure that sold products make at least a positive contribution, and are not sold below their variable costs (Cooper, 1996).

In conclusion, there is consensus that target costing is a full-cost approach that takes a product's whole life cycle into account: "Target cost targets, derived from market considerations and systematically disaggregated by the finance function […] do provide the essential focal point coordinating all cost reduction efforts" (Carr & Ng, 1995, p. 362). The several cost types, in combination with the achievable market price, sales volume, intended product characteristics, and aspired margin, build a complex system that needs to be balanced. The interdependencies between different cost types (material, labor and overhead costs) are shortly discussed by Carr & Ng (1995), but scarcely in the focus of target costing literature per se. While there exist many studies that are not explicit about which costs they refer to, a major focus is on target setting and cost estimation for manufacturing costs.

3.2.3 Methods to specify cost targets

The target costing literature provides several methods for determining cost targets. The subtraction-method, or market-into-company, is probably the most known methodical aspect of target costing. An aspired profit margin is subtracted from the market price to calculate the allowable costs. Cooper & Slagmulder (1999) use the term "market-driven costing" as the first of three elements of the target costing process.

In a next step, the overall cost target has to be broken down in a continuous process: "When the allowable costs are considered too far below the estimated cost, the appropriate price range and functionality are reviewed until an achievable allowable cost is identified." (Cooper & Yoshikawa, 1994). Cooper & Slagmulder (1999) use the terms "product-level target costing" respectively "component-level target costing". Quality function deployment (QFD) is a method to break the cost target down towards components or functionalities, and therefore helps to incorporate the customer's requirements during the development process (Wassermann, 1993). QFD is a cross-functional method to ensure quality and functionality, and it links customer requirements and their technical implementation. It is a tool to prioritize design requirements during NPD in order to ensure or improve customer's value. Even QFD does not focus on cost reduction goals, it helps to efficiently allocate costs to parts and components. Therefore, QFD is helpful to achieve cost optimal products (Wouters & Morales, 2014).

To manage and estimate a product's manufacturing costs during the development stage, value engineering (VE) is a method closely connected to target costing (Anderson & Sedatole, 1998; Ibusuki & Kaminski, 2007). It links a product's functionalities, the price the customer is willing to pay for the product, and the product's costs (Al Chen et al., 1997). From the customer's perspective, a product represents a bundle of functionalities and characteristics he is willing to pay a specific price for, and the idea of VE is to allocate manufacturing costs towards functionalities the customer receives high value from. In other words, VE guides a product's redesign and lowers costs through changing technical concepts where a customer receives low value. The outcome of a successful VE process is a product that fulfills customer's requirements at lower costs.

Even it does not represent costs, a product's market price is a major input for the target costing philosophy, and the literature does also provide methods for determining market prices, for example via market research (Cooper, 1996; Kato, 1993; Lee & Monden, 1996). Estimating a market price for a product at the beginning respectively during its development stage may be a complex and uncertain task. A firm needs to estimate current market circumstances and competitors, prospect that into the future, and anticipate potential change. The sales price estimated at the beginning of the development process may be different from the finally realized market price when the product is actually sold (Lee & Monden, 1996). Jun Lin & Yu (2002) talk about a firm's price setting practices that applies the moving market price averages that are forecasted two times a year. Additionally, there is always a trade-off between price and sales volume – both normally set by the sales division (Cooper & Slagmulder, 1999).

Besides the methods presented above, target costing literature tends to simplify things and scarcely discusses challenge firms face in practice. A firm may need to consider many issues during the development stage, but this is not included in typical descriptions of target costing systems which include a strong aggregation across product variants, markets, and time. Complex products (for example, products with a high variety of attribute combinations) may complicate the target costing process even further, and it might be easier to implement and probably more appropriate for routine than for novel products (Mihm, 2010). For example, globally operating firms are confronted with a variety of deviating customer- or legal requirements. Consequently, at least for some industries, there is not *one* particular market with customers the firm aims to offer *the* product to, but a large variety of markets that impact products' specifications. Target markets, anticipated customers, a firm's image (and therefore its opportunity to realize premium prices), or competitors influence the sales price, total sales units, and the products characteristics (Kato, 1993). Furthermore, a product may be sold over a large period of time (for example, the life cycle of a car usually lasts between 5-10 years) what might cause price changes as well (Cooper, 1996).

In sum, there exist partly simple, partly sophisticated methods to estimate a product's expected sales price, calculate allowed costs, or break them down and allocate them on the component level. But so far, methods to determine cost targets for R&D or manufacturing investments are not in the focus of target costing literature.

3.2.4 Interdependencies among products

So far, we understand target costing as a cost management method that focuses on one product. It is a cost management technique that is applied during a single product's development stage, and simplified, a product manager does not need to worry about other things and products besides the one he is responsible for. Depending on attributes the product should possess, the product manager may manage and decide which materials, components, and parts to use, and which may be too costly or inadequate. Besides target costing, other cost management methods for product development focus on coordinating design decisions across a portfolio of products. Key examples are component commonality, modular design, and product platforms (Davila & Wouters, 2004). These strategies may help firms to manage its whole product portfolio, and cost reduction goals may be one motivation among others (see Chapter 2 of the thesis).

Research that combines these two perspectives, namely **target costing studies with focus on products' interdependencies,** are rare, and our third panel comprises only three studies. In their work about modularity and supply chain coordination, Ro, Liker, & Fixson (2007) illustrate that target costing can be a barrier for an effective cooperation between OEM and suppliers. Kee & Matherly (2013) show that, if products share constrained resources (i.e. production capacities), an isolated target costing logic that focuses on single products can lead to sub-optimal decisions. And Davila & Wouters (2004) argue that target costing has several limitations, and introduce cost management approaches such as modular design, parts commonality or product platform planning as appropriate alternatives if time-to-market, technology or customer needs are critical factors.

In order to provide additional insights into firm-wide and portfolio-oriented strategies (Ramdas et al., 2003), we present few papers beyond panel three. Cooper & Slagmulder (1999) mention to consider a firm's portfolio right at the beginning of the target costing process, namely when the products' individual margins are set. They argue that a firm needs to "[s]et the company's long-term sales and profit objectives […and s]tructure the product lines to achieve maximum profitability" (Cooper & Slagmulder, 1999, p. 24 f.). Several studies argue that a modular strategy can be a mean for individual product managers to reach the target margin, for example via sharing development costs or realized scale effects (Fisher et al., 1999; Hu et al., 2013; Krishnan & Gupta, 2001; Krishnan et al., 1999; Mahmoud-Jouini & Lenfle, 2010; Ramdas et al., 2003). For example, Ibusuki & Kaminski (2007) mention modularity as a means to reduce costs during the target costing process. But there may be also dysfunctional effects if product-oriented (for example, target costing) and portfolio-oriented (for example, modular design, component commonality, and product platforms) cost management efforts coincide. Israelsen & Jørgensen (2011) identify a coordination problem if a product manager's and the firm's agenda are not congruent. Simply said, we can think of situations when it may be beneficial for an individual product manager, but adverse for the firm, to develop and apply an individual component, and not to use an existing one. To overcome this problem, the authors develop a cost management system which distributes cost savings in a way that products' local goals are in line with a firm's global optimum.

3.2.5 Summary of target costing literature's focus

For the purpose of this chapter, we have extensively reviewed the existing academic target costing literature, and found that its major focus is on managing variable manufacturing costs of single products. It tends to simplify practical challenges, scarcely discusses other kinds of costs, such as R&D costs or investments in manufacturing systems, and also ignores cost interdependencies within a product portfolio that emerge if a firm follows strategies like modular design. We aim to close this gap, and introduce a method to determine fixed cost targets for a modular product architecture.

3.3 Extending the scope of target costing: A method to determine fixed cost targets for a modular product architecture

As shown in the previous section, we have almost no insights how targets for R&D and fixed manufacturing costs can be set in the context of target costing for a modularly designed product portfolio. So, the focus of this section is to introduce a method for determining such cost targets. We will use the term "fixed costs" to refer to R&D and fixed manufacturing costs, in line with Fisher et al. (1999, p. 299) who state: "Investment in new products includes the costs of product development and the fixed costs of production." We focus on these costs not for an individual product, but for a portfolio of products that share a common architecture.

This focus is illustrated in Figure 3. Vertically, it shows the time cost management activities are actually performed. While cost management methods like Kaizen costing or KANBAN are executed after start of production (SOP), target costing is performed beforehand. Horizontally, Figure 3 shows the time when costs actually arise. While R&D costs and investments into production systems arise before SOP, variable manufacturing costs arise after

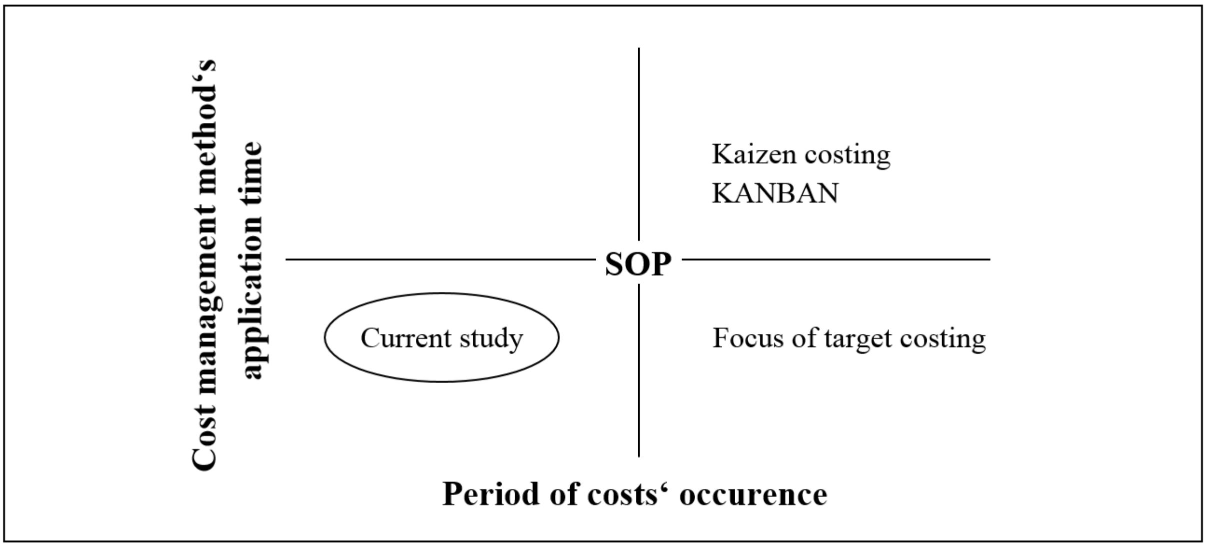

Figure 3. Focus of the target costing extension of the current study

SOP.[10] Even target costing is a full-cost approach, we found in the literature that its main focus is on variable manufacturing costs, so on costs that arise after SOP. The same applies to cost management methods such as Kaizen costing or KANBAN. We focus on managing fixed costs that actually arise before products' SOP.

3.3.1 Coordinating a whole portfolio provides more benefits than a project-by-project approach

We refer to a modular product architecture as a technical base from which a firm derives a multitude of products. These products are consecutively brought to market, maybe even with a time horizon of several years. We assume that one major motivation for the implementation of a modular product architecture is to reduce costs, as "it is evident that product modularity is supported by an economic rationale" (Israelsen & Jørgensen, 2011, p. 453). Excellent product variety management may be a competitive advantage, but entails also challenges for a company's cost management activities: "Managing product variety requires decision making at different organizational levels, over different time horizons, within and across functional and organizational boundaries, before and after product launch" (Ramdas, 2003, p. 80).

Based on Ramdas et al. (2003), we distinguish three different approaches to manage a modular strategy. In a *project-by-project approach*, a firm focuses on the requirements of the first product that is going to use the common technical base and conceptualizes components and technologies accordingly. Follow-up products can go back to these existing parts and may

[10] We focus on initial R&D and fixed manufacturing costs, but some R&D and fixed manufacturing costs may arise after SOP, for example, for products upgrades.

apply them, too. But in the case of varying or exceeding requirements, engineers have to conceptualize additional variants, new components, or further technologies. In other words, each single project independently evaluates and decides to which extent existing components are used. This procedure may entail challenges particularly for complex products that require a precise interplay of many components and systems. Over time, the "shelf" that entails existing components becomes larger. And although follow-up products may use some carry-over-parts (COP), many potentials for cost savings, scale effects, and other synergies are not realized. Ramdas et al. (2003, p. 151) state: "In practice, a history of low coordination across individual projects often results in an explosion in the number of component versions."

Second, in a *coordinated projects approach* (Ramdas et al., 2003), a company considers and anticipates the requirements of all products which it plans to derive from a modular architecture. The development of components is fully focused on modular design and scalability to ensure a broad range of application and reusability, leading to significant synergies between the products. Besides higher coordination efforts needed, this strategy entails additional challenges, for example anticipating long-term trends and their impact on the portfolio. Some product requirements may be highly uncertain during the conceptualization stage of the modular architecture, and future market situations may be hard to estimate. Because of such difficulties, a *coordinated projects approach* may be not the natural approach to follow and "there may be an organizational tendency to 'start from scratch' in designing a new product, perhaps because of the costs of finding and testing an existing component." However, Ramdas et al. (2003, p. 151) found that "the performance of the project-by-project approach deteriorated significantly relative to the coordinated projects approach."

The third approach is a hybrid form of the former two. Ramdas et al. (2003) describe the *partially coordinated approach* as a procedure in which some decisions are centrally coordinated, but other decisions made for each product separately. The first two approaches seem to mark radical endpoints in the range from "perfectly coordinated" product development to "no coordination at all" and this third approach may be of the most practical relevance. The extent to which a firm incorporates requirements of all products already during the modular architecture's conceptualization stage may vary within these boundaries.

We argue that the method which is developed in the current paper is a means to stimulate activities for a cost-efficient conceptualization, and to put great effort in coordinating the whole portfolio's requirements. Having a target for fixed costs of the entire modular architecture stimulates that engineers cannot proceed step-by-step but need to consider all relevant product requirements. We introduce a method for determining such a cost target, which serves as an influential constraint for engineers, intensifies coordination efforts, and enables management accountants to evaluate to which extent a modular product architecture's concept meets financial requirements. Summarized, an objective and concrete cost constraint is useful (Cooper, 1996), also for a modular architecture's fixed costs, and a "do your best" strategy (Gopalakrishnan et al., 2015) misses precise control effects.

3.3.2 Determining a target for the fixed costs of a modular product architecture

The method helps determining a target for the fixed costs for a modular architecture, which is subsequently allocated to the individual products that apply this common technical base. We assume that this allocation is based on a costs-by-cause principle, at least to a certain degree. Consequently, each product's cost structure entails not only its individual fixed costs, but also an allocated share that covers the architecture's fixed costs to a certain extent. This full-cost logic implies that an individual product's profitability is also affected by the modular architecture's fixed costs.

First, it needs to be clarified which products *i* are going to be based on the modular architecture. Similar to classic target costing, we need estimates for the sales prices, sales units, as well as the major attributes of each product. The latter information give an orientation what kind of products will belong to the relevant portfolio. The breath of product requirements impacts the technical complexity of the modular architecture.

The modular architecture's fixed cost target, $A_{t,}$ is described in equation (1). This account represents a reasonable amount that can be afforded in relation to the revenue the firm will realize with the derived products, and consequently, individual products' profitability will not be eroded by too high allocated fixed costs.

$$A_t = \sum_{i=1}^{n} (x_{i,t} \times y_{i,t} \times z_{i,t}) \qquad (1)$$

Notation:

A	*fixed cost target for modular product architecture [$]*
i = 1…n	*products derived from the modular product architecture*
t	*generation index*
x_i	*sales units*
y_i	*net revenue per unit [$]*
z_i	*cost ratio [%]*

The generation index *t* refers to the presumption that there are consecutive product generations, and values for a future generation may be based on data of the current or past generation. The expected sales units x are included, because in a full-cost logic, the burden caused by fixed costs depends on the number of total units sold. So, if a modular product architecture enables a firm to sell more (less) units, the fixed cost target ceteris paribus increases (decreases) accordingly. Estimating future sales units may be challenging, and one way to do so is by relying on past or current data. Sales unit information about a previous or current product can be combined with anticipated future market trends, see equation (2). Of course, if a planned product has no predecessor, information has to be gathered in other ways, for example via market research or expert consultations.

$$x_{i,t} = x_{i,t-1}(1 + \alpha_{i,t}) \tag{2}$$

Notation:
α_t *anticipated sales unit change from t-1 to t;* $\alpha \in [-1;\infty)$

Expected net revenues y_i is the second factor.[11] The basic idea of target costing is that the allowable costs depend on a product's market price, and this also applies to fixed costs. A product sold for \$ 100.000 is, ceteris paribus, able to cover higher costs than a product sold for \$ 30.000.[12] Equivalent to sales unit forecasts, we expect firms to base their estimates about future product's net revenues on information from previous respectively current products, and combine it with a factor that represents future changes, as shown in equation (3):

$$y_{i,t} = y_{i,t-1}(1 + \beta_{i,t}) \tag{3}$$

Notation:
β_t *anticipated net revenue change from t-1 to t;* $\beta \in [-1;\infty)$

The third factor is a cost ratio z. This represents the net revenue's share every single product can afford to cover the modular architecture's fixed costs. Again, we could think of different ways these cost ratios can be set for every product i, for example, by managerial judgment or detailed cost analysis of how much fixed costs were allocated to each product in the past or current product portfolio. These values may be adjusted due to strategic considerations or future expectations. We define the cost ratio's calculation in equation (4).

[11] As shown in ***Figure 2***, we refer to a firm's net revenues as market price minus taxes and fees, because these taxes and fees are not in the focus of internal cost management activities during NPD. If the calculation would be based on market prices, cost ratios z decrease.
[12] Of course, this statement is simplified, and ignores aspects like divergent aspired profit margins or the relationship between costs a product triggers in order to realize particular attributes that enable the firm to realize the sales price.

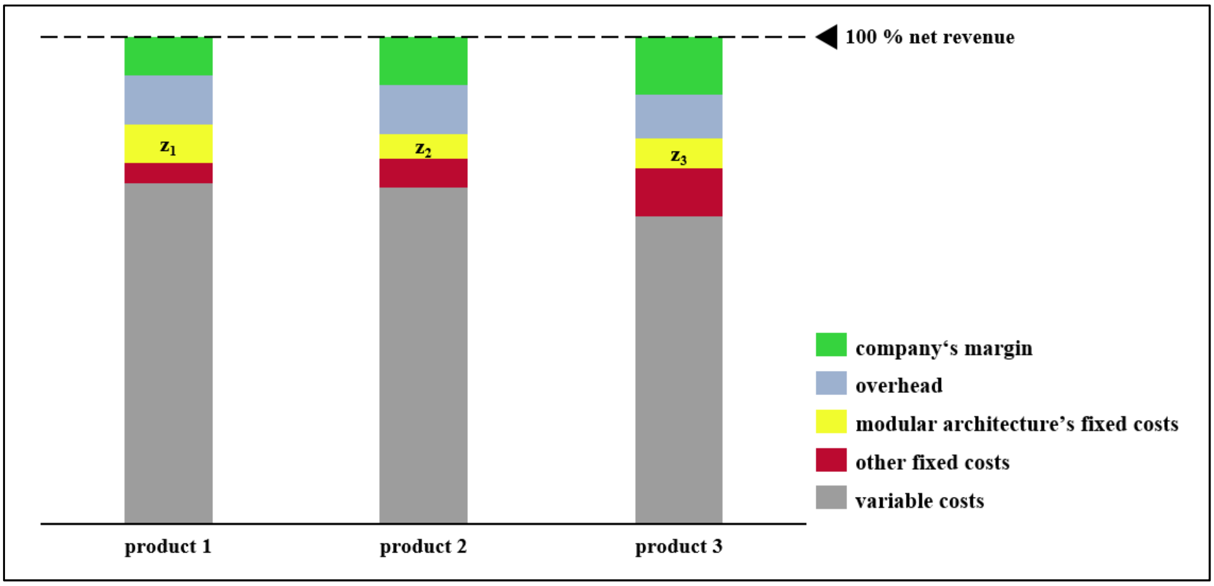

Figure 4. Illustration of products' cost ratios

$$z_{i,t} = \frac{c_{i,t-1}}{x_{i,t-1} \times y_{i,t-1}} (1 + \gamma_{i,t}) \quad (4)$$

Notation:

γ_t *adaption of cost ratio from t-1 to t; $\beta \in [-1;\infty)$*

c_i *costs for modular product architecture allocated to product i [$]*

We include the cost ratio as a percentage for two reasons. Profitability targets are often expressed in percentage figures, too (Lee & Monden, 1996). It also enables comparisons among a whole product portfolio with significant deviating sales units and net revenues. Overviews such as in Figure 4 entail all relevant products and are helpful to explain the method to managers.

Summarized, with data about planned products, and estimations about their net revenues, sales units, and cost ratios, A_t can be determined. Table 4 shows an overview.

Table 4. Overview of required input data & calculation of the fixed cost target

Product (i)	*Sales units (x_i)*	*Net revenue (y_i)*	*Cost ratio (z_i)*	*Affordable fixed costs*	*Fixed cost target*
Product 1	x_1	y_1	z_1	$x_1 * y_1 * z_1$	
Product 2	x_2	y_2	z_2	$x_2 * y_2 * z_2$	
Product 3	x_3	y_3	z_3	$x_3 * y_3 * z_3$	$\boldsymbol{A_t}$
…	…	…	…	…	
Product n	x_n	y_n	z_n	$x_n * y_n * z_n$	

3.3.3 Going further: Breaking cost targets down

So far, we determined an overall fixed cost target for a modular product architecture, which serves as a budget constraint for such an architecture. In the context of complex products with diverse managers being responsible for separate products, modules, and components, the overall cost target seems too unspecific and, therefore, breaking it down to elements and cost types is the subsequent step. In other words, A_t is an important constraint and starting point, but in order to impact individual interest groups' work, it needs to be broken down and, for example, allocated to individual development efforts (Ansari et al., 2007).

3.3.3.1 Determining fixed cost targets for elements

We assume that a modular product architecture consists of elements *j*. Depending on how granular the cost targets are set, such an element may comprise a whole product platform, a group of modules, or just one component, for which individual fixed cost targets are needed. A_t remains as the budget constraint for the sum of all elements' fixed cost targets. This is defined in equation (5).

$$\sum_{j=1}^{m} a_{j,t} = A_t \tag{5}$$

Notation:
j = 1…m *elements the modular product architecture consists of*
a_j *fixed cost target for element j*

For breaking down A_t to elements, we assume the following: first, an element's fixed costs are allocated to products that use this element (costs-by-cause principle). Second, probably not every product will apply every element. Consequently, not every product "helps to fund" every element's fixed costs. Analogue to the logic presented in the previous section, we define cost ratios each product can afford for individual elements. Again, past or current product generations may provide a base for information, which could be further adapted. This results in equation (6).

$$z_{i,j,t} = \frac{c_{i,j,t\text{-}1}}{x_{i,j,t\text{-}1} \times y_{i,j,t\text{-}1}} \left(1 + \gamma_{i,j,t}\right) \tag{6}$$

Obviously, a product cannot spend more money on the architecture's elements than it can afford for the modular architecture as a whole. Therefore, equation (7) needs to be true for all products *i* and elements *j*.

$$\sum_{j=1}^{m} z_{i,j,t} = z_{i,t} \tag{7}$$

Determining the fixed cost target for a specific element *j* is formulated in equation (8). This equation is similar to equation (1), but on the level of elements. For all products *i*, estimated sales units are multiplied by the estimated revenues and by the element-specific cost ratios. Determining the sum of these values results in the fixed cost target for an individual element.

$$a_{j,t} = \sum_{i=1}^{n} (x_{i,t} \times y_{i,t} \times z_{i,j,t}) \tag{8}$$

3.3.3.2 Splitting fixed cost targets for elements into targets for various cost types

We distinguish between manufacturing and non-manufacturing fixed costs. If a fixed cost target for a concrete element (a_j) is determined, we assume that this element may trigger different kinds of fixed costs, for example R&D costs as well as manufacturing investments (machines, tools, etc.). In practice, engineers may be responsible to conceptualize, design, and develop an element, while production managers implement the firm's production system. Therefore, we argue that these people need to be confronted with fixed cost targets for the scope they are responsible for. Equation (9) divides an element's fixed cost target into fixed cost types.

$$a_{j,k,t} = \delta_k \, a_{j,t} \tag{9}$$

Notation:
$k = 1 \ldots l$ *fixed cost type*
δ_k *cost share for fixed cost type;* $\delta \in [0;1]$; $\sum_{k=1}^{l} \delta_k = 1$

Table 5. Break-down of modular architecture's fixed cost target on elements & fixed cost types

Element (j)	*Element's fixed cost target*	*Fixed cost type 1 (f_1)*	*Fixed cost type 2 (f_2)*	…	*Fixed cost type k (f_k)*
Element 1	$a_{1,t}$	$\delta_1 * a_{1,t}$	$\delta_2 * a_{1,t}$	…	$\delta_k * a_{1,t}$
Element 2	$a_{2,t}$	$\delta_1 * a_{2,t}$	$\delta_2 * a_{2,t}$	…	$\delta_k * a_{2,t}$
Element 3	$a_{3,t}$	$\delta_1 * a_{3,t}$	$\delta_2 * a_{3,t}$	…	$\delta_k * a_{3,t}$
…	…	…	…	…	…
Element m	$a_{m,t}$	$\delta_1 * a_{m,t}$	$\delta_2 * a_{m,t}$	…	$\delta_k * a_{m,t}$
Sum	$\sum = A_t$	$\sum f_1$	$\sum f_2$		$\sum f_k$

An element's fixed cost target may not be exceeded, and therefore cost shares δ_k need to sum up to one. Again, a firm may have various possibilities to set these individual cost shares, and we expect that cost data from previous projects serves as a valuable source of information. Table 5 shows the method's final outcome: the modular architecture's fixed cost target, as well as its break down to elements and fixed cost types.

3.4 A case study

This section describes the implementation of the method in a case study. This gives an example for illustrating the method and provides empirical evidence of the method's practicality. We describe the research method, introduce the case company, describe the conceptualization and implementation of the method, which involved gathering data, making assumptions, and processing the data, and finally report reactions to the method and its impact during the modular architecture's development stage.

3.4.1 Research method

We conducted a three-year research study at a car manufacturer, *AutoCompany*, which had followed a modular strategy for more than a decade. It also shared the technical base of its cars with several other car companies that belonged to the same group. *AutoCompany* had significantly expanded its product portfolio and built new plants, resulting in a strong growth of R&D costs and production investments. As this chapter's focus is on practical cost management challenges a modular strategy implies during the development of complex and R&D intensive products, the cooperation with *AutoCompany* offered a fruitful and promising research opportunity.

In order to gather detailed and rich insights, we conducted a long-term interventionist research study (Jönsson & Lukka, 2006). During the three years, the researcher was full-time on-site, and part of the controlling department responsible for NPD projects' cost management. More specifically, the researcher was a member of the team that coordinated *AutoCompany's* modular product architecture. We used intervention as one of the research assets (Jönsson & Lukka, 2006), and aimed to "solving some ill-defined problem which goes beyond present knowledge and has as its output both a 'solved' problem and a contribution to theory" (Berry & Otley, 2004, p. 232).

During the project, the researcher accompanied, supported and impacted the transition period between two consecutive modular architectures. Besides taking intensive notes, conducting interviews, and collecting various kinds of data (such as company documents, presentations, and emails), the researcher contributed to cost management activities in the context of *AutoCompany's* modular architectures. To keep track of processes, events, and record other detailed information, the researcher kept a research diary, as suggested by Jönsson & Lukka (2006). Two times a year, the researcher, his supervisor, and a top manager of *AutoCompany's* controlling department met in order to review and manage the research project. Meetings between the researcher and his supervisor respectively the researcher and *AutoCompany's* controlling top manager were more frequent, approximately one to two times per month.

3.4.2 Research site

AutoCompany had introduced target costing for managing its NPD projects decades ago, but the modular strategy was implemented much later. At the time the research project started, *AutoCompany's* previous modular architecture's development process had lasted for several years and was nearly done. Products based on this modular architecture started to reach SOP and *AutoCompany* started to think about concepts for the subsequent modular architecture. *AutoCompany* planned to cooperate intensively with another firm of the group, *CarEnterprise*, for developing the next modular architecture. The method described in the previous section was developed and tested by gathering and analyzing data about the previous modular architecture, as the basis for an improved cost management strategy for the next generation. For reasons of confidentiality, we present disguised and simplified data in the following sections.

3.4.2.1 Cost management of modular architectures & products at AutoCompany

Figure 5 illustrates the intersection of car projects and a modular architecture. At *AutoCompany*, the structure was slightly more complex than introduced in Section 3.3. The term *car project* referred to a complete car model *AutoCompany* finally sold to its customers, and it consisted of the following four kinds of parts: hat, platform, modules, and cross-architecturally used parts. Hat-parts were car project-specific, but the latter three kind of parts were shared among car projects and brands. In the following, we describe these kinds of parts in more detail. The *modular architecture* consisted of platforms and modules, and it comprised shared components and technologies, such as axles or an air conditioning unit. Not much of these parts were visible from the outside. At *AutoCompany*, a modular product architecture was described as

> *"overall guidelines for the utilizing car projects with the goal to realize synergies as well as master and reduce complexity over cars and car segments."*

The car's *hat* referred to parts and components that shape the car's specific appearance, for example the chassis or interior. A *platform* referred to the bottom group of a car with similar dimensions, and the functional interaction of the parts located in cars' lower area (see Fisher et al. (1999) who use the term "wheelbase"). If cars' requirement and proportion differences exceeded a certain degree, *AutoCompany* created another platform (variant) to obtain desired properties. Examples for such properties were cars' height (sedan or SUV), length, or applied range of powertrains. *Modules* were defined as

> *"technical group of components that form a functional and logic unit, which is completely interchangeable."*

These components were installed in all car projects that were part of the same modular architecture. Finally, the scope of *cross-architecturally used parts* was broader, and they were meant to be installed in cars regardless from which of the group's modular architectures it was derived from. These parts were of a particular strategical or technological relevance, and examples for such investment-intensive components were engines or electronic architectures. Per definition, they were not part of a modular architecture.

At the time the research project began, *AutoCompany's* cost management activities were focused on car projects, and the main financial KPI was projects' return on sales (ROS). An internal cost allocation system, particularly based on car projects' expected sales units, distributed the modular architecture's accrued fixed costs to the individual car projects. This procedure was yearly updated, and accountants incorporated allocated costs in the full cost calculations of the car projects. Therefore, car projects that were based on the same modular architecture were interwoven, as already mentioned by Israelsen & Jørgensen (2011, p. 455): "[S]haring of modules creates cost interdependencies among participating products".

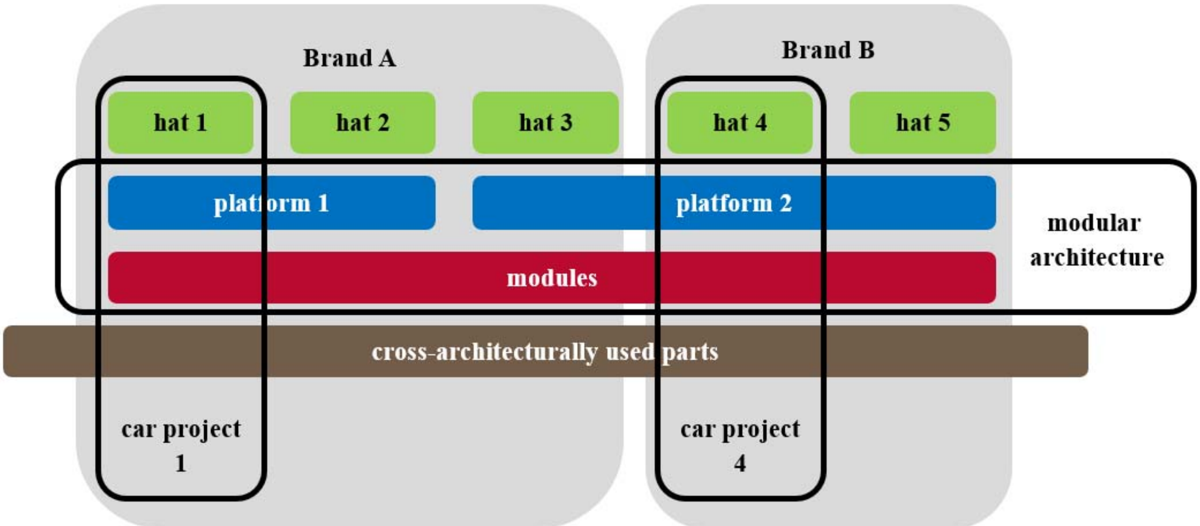

Figure 5. Scheme of elements a car project consists of at AutoCompany

3.4.2.2 Motivation for change: Challenges caused by current product generation

AutoCompany's current modular architecture comprised several platforms and hundreds of modules and variants. In total, it was the base for approximately 40 car from five brands. All car models were equipped with a combustion engine, and the modular architecture was the basis for five to ten million units over its whole lifecycle. The fixed costs of the whole modular architecture summed up to several billion dollars, comprising R&D expenses (both in-house development as well as external service providers), investments in production systems (machines and tools for in-house production), investments in purchasing (machines and tools to manufacture components at suppliers), and investments in quality efforts. Approximately 85% was invested in platforms and 15% in modules. Moreover, 60% were caused by R&D, 20% by production investments, and 20% in purchasing investments. The share of quality investments was below 1%.

As development of the current modular architecture was nearly done, *AutoCompany* was confronted with an unsatisfying cost performance: almost every car project based on the current modular architecture was estimated to fail its target profitability, and one major reason was that the fixed costs were far too high. Consequently, cost allocations to car projects eroded their margins. There was only a weak link between projects' affordability and decisions about the modular architecture's concept and variety. Decisions that had an impact on the modular architecture's fixed costs were made by managers of many different departments, projects, and brands, but there was no central authority that was responsible for managing the fixed costs and coordinating decisions for the modular the architecture. Controllers included a lump sum for cost allocations in their projects' target cost structure, but in many cases, decisions in the modular architecture's context were made without considering the financial consequences for the projects. The internal allocation procedure was opaque and delayed, and therefore, car projects were partly charged for decisions made by themselves, but also by others, a long time ago. These decisions were made step-by-step, financed in advance by many different car projects, and partly re-allocated afterwards. A controller at *AutoCompany* said:

> *"During the past ten years, it was established in the company that everybody wants to realize the optimum for his car project. Nobody was willing to compromise in favor of the total optimum. Like this, you will never get a lean solution for the modular architecture."*

This proceeding was further facilitated by a poor target discipline. While the target costing philosophy promotes the idea of finding technical concepts that fit target costs (Cooper & Slagmulder, 1999; Zengin & Ada, 2010), we often experienced at *AutoCompany* that target setting was afterwards adapted to concrete technical concepts. In many cases, engineers worked on technical concepts, and after estimating its costs, a slightly reduced figure was defined as cost target. For the current modular architecture, no fixed cost target existed that could have impacted its concept.

3.4.2.3 Expectations for the upcoming modular architecture

AutoCompany's management was aware of the current product generation's fixed cost overruns and profitability problems, and an additional cost management instrument was required to improve management of fixed costs for the next generation of the modular architecture. Key actors in this case study were the researcher, as well as colleagues and managers from *AutoCompany's* controlling department, in the following referred to as *the controllers*. Sales managers were involved during the data gathering process. The controllers presented and discussed the approach also with controlling colleagues of *CarEnterprise*. At later stages, they explained and justified the approach also to group's management, car project managers, as well as managers of *AutoCompany's* development and production department.

During the early stage of the next modular architecture's concept stage, uncertainty was significantly high, and some managers were quite 'greedy' for fixed cost targets. Discussing various future concepts, one general manager said towards the controllers:

> *"But then, finally, please give us targets!"*

On the other hand, there were also managers that doubted the usefulness of such a target at the beginning. A top manager of *AutoCompany's* controlling department was quite skeptical about the determination of a modular architecture's fixed cost target. His doubts were based on the significant uncertainty about required platforms, technologies, components, and variants, and he reasoned that fixed costs for these elements would be hard to estimate. And also *CarEnterprise's* controllers struggled with the idea of setting a fixed cost target without being able to estimate costs of concrete technical concepts:

> *"So, without any technical specifications, we cannot estimate [the modular architecture's fixed costs]."*

Nonetheless, the controllers went on to discuss the idea and potential approaches. During several meetings, experienced controlling managers agreed that "sending financial messages" would be important to impact the modular architecture's concept, and that projects' affordability should be a crucial input parameter. But ideas for a methodology were scarce. Two controlling managers commented on the current situation:

"So far, there is no method to derive a financial [fixed cost] target for a modular architecture."

"When we are talking about cost concepts of modular architectures, we are completely blank."

3.4.3 Implementing the method in practice

This section describes the development and implementation of the method presented in Section 3.3. It involved gathering information about future portfolio, projects' sales units, revenues, and cost ratios, which is described in the following three sub-sections. The calculation of the fixed cost target and its subsequent disaggregation is described in three further sub-sections.

3.4.3.1 Gathering information about future product portfolio & sales units

The information which products would be sold for how many times was crucial in order to estimate how many units in total were able to fund the modular architecture's development costs and investments. Managers of *AutoCompany* and *CarEnterprise* went through a strategic portfolio planning process of several months, but estimating total sales units of these future car projects remained challenging. *AutoCompany's* sales managers were used to forecasting sales units for a time horizon of ten years and since SOP of the first car project was planned in six years, forecasts for the next 15 years were required. Obviously, this was surrounded by significant uncertainty and it required many discussions over several months for the controllers to convince sales managers to provide those estimates. For the major market segments, they based their estimations on current sales units, and anticipated future market trends (see equation (2)). Unfortunately, *CarEnterprise* did not provide such estimates, and the controllers made their own assumptions. Specifically, they set α in equation (2) equal to zero, assuming that *CarEnterprise's* next product generation's sales units would be equal to the current generation.

3.4.3.2 Gathering information about future net revenues

Estimates for future car projects' net revenues were the second input factor the controllers needed to apply equation (1). After several discussions, and in cooperation with the sales department, the controllers made assumptions to forecast future net revenues. Similar to the sales units' forecasts, the controllers took current car projects' net revenues as a baseline and defined factors to adapt these figures for future car projects (see equation (3)). For example, if a current combustion car would be replaced by an electric variant in the future, the controllers set β equal to 0.05. This implied that an electric car's net revenues were expected to be 5% above the net revenues of a similar combustion car.

3.4.3.3 Gathering information about appropriate cost ratios

As additional input for equation (1), the controllers aimed to answer the question: which share of the car projects' net revenues is appropriate to fund the modular architecture's fixed costs? As there was no cost information about future car projects in that early stage, controllers analyzed current car projects' cost structures. Besides analyzing quarterly updated intern cost reports for the current product generation, the controllers consulted several cost experts and conducted further cost analysis with excel to see through the opaque cost situation: first, elements' fixed costs were financed in advance by many different car projects, and at a later stage, these costs were re-allocated to other car projects. Figure 6 shows an exemplary calculation of current car's cost ratio (see equation (4); no generation index).

To explain the method to others, the controllers provided illustrations such as shown in Figure 7. These illustrations were helpful to embed the idea of cost ratios into the logic of target costing. The controllers generated these figures both to show the projects' current cost situation, as well as to transparently display deviations from the projects' target cost structure. They set all cost types in relation to the car projects' net revenues. This enabled the controllers to identify patterns among the car projects and increased comparability.

Comparing the two data sets, controllers found out that, on average, current car projects were charged for 30% more fixed costs than assumed in the initial business cases. These additional costs directly eroded car projects' profitability. This was an important result, as different concepts for the future modular strategy were discussed during that stage. For example, engineers argued that additional requirements and increasing complexity might cause

Input data	
sales volume of car project 0	x_0 = 500.000
net revenue per unit of car project 0	y_0 = 20.000 €
platform's fixed costs (financed in advance by car project 0)	$ 700 Mio.
platform's allocation credit (by other car projects that use the same platform)	$ 250 Mio.
modules' fixed costs (financed in advance by car project 0)	$ 90 Mio.
modules' allocation credit (by other car projects that use the same modules)	$ 50 Mio.
allocated costs for modules financed in advance by other car projects & used by car project 0	$ 10 Mio.

$$z_0 = \frac{\$\,700\,Mio. - \$\,250\,Mio. + \$\,90\,Mio.\; - \$\,50\,Mio. + \$\,10\,Mio.}{500.000\; x\; \$\,20.000}$$

$$= \frac{\$\,500\,Mio.}{\$\,10\,Bn.}$$

$$= 5\%$$

- disguised data -

Figure 6. Exemplary calculation of car project 0's cost ratio

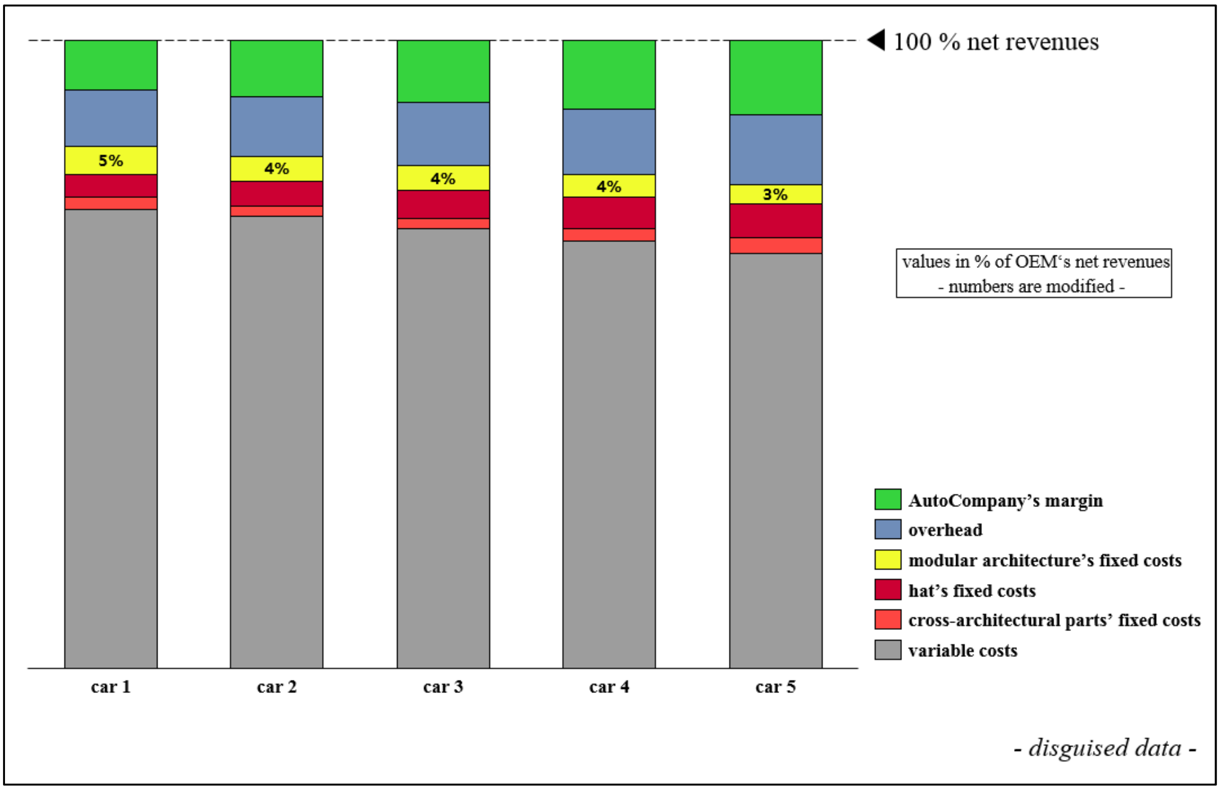

Figure 7. Illustration of car projects' cost structures

50% higher fixed costs for the next modular architecture. With the underlying analysis, the controllers could counteract on such ideas and argued the following way: if *AutoCompany* could not derive significantly more (or more expensive) units from the future modular architecture, increasing its fixed costs was financially not feasible. In addition, as long as *AutoCompany's* profitability objectives were not reduced by the management board, or increased fixed costs were compensated elsewhere (both scenarios were estimated to be unrealistic by all actors involved), the next modular architecture's fixed costs need to be significantly below the current one.

For the reasons mentioned above, the controllers set segment-specific cost ratios they found in the examined projects' target cost structure. For one current project, the controllers found an outstanding high cost ratio, as this project with comparably little sales units was standalone on one platform. Therefore, the controllers reduced the cost ratio for its successor ($\gamma < 0$).

CarEnterprise's controllers did not provide a detailed cost analysis. Therefore, the controllers provided their cost ratios as points of reference, and in cooperation with *CarEnterprise's* controllers, they were able to define cost ratios for *CarEnterprise's* planned car projects, too.

3.4.3.4 Processing the data to determine the fixed cost target

The controllers gathered required data, and were able to determine its fixed cost target for the future modular architecture (see equation (1)). For car projects that were defined to be based on the future modular architecture, the controllers multiplied each car project's expected sales units, its net revenue, and its cost ratio. Summing the individual results up yielded to the modular architecture's fixed cost target all car projects could afford. Table 6 illustrates this step.

With an illustration like Table 6, controllers were able to transparently disclose the applied logic. Moreover, they could compare these values with the current cost situation, and substantiate the need for a strategic change. For example, if particular market segments' or product families' sales units were expected to decrease significantly in the future, a stand-alone platform or variety on the current level was not affordable anymore. The controllers proposed solutions, such as aggregating more car projects on less platforms or reduce parts' complexity in order to shape a financially feasible portfolio for the future. A controlling manager emphasized this aspect:

> *"Here, we see that [car 5] can only afford [$ 430 Mio. - disguised number] in order to realize its target profitability. And if we agree that it is unrealistic to create an own platform for that amount of money, we need to aggregate [more] vehicles on one common platform. If [car 4] brings [this] amount of money, then it works."*

Table 6. Processing input data to determine modular architecture's fixed cost target

Product	*Sales units*	*Net revenue*	*Cost ratio*	*Affordable fixed costs*	*Fixed cost target*
Car 1	*550.000*	*$ 20.000*	*5 %*	*$ 550 Mio.*	
Car 2	*300.000*	*$ 40.000*	*4 %*	*$ 540 Mio.*	
Car 3	*200.000*	*$ 60.000*	*4 %*	*$ 440 Mio.*	*$ 2.44 bn.*
Car 4	*150.000*	*$ 80.000*	*4 %*	*$ 480 Mio.*	
Car 5	*143.250*	*$ 100.000*	*3 %*	*$ 430 Mio.*	

- disguised data -

3.4.3.5 Determining fixed cost targets for elements

As the future modular architecture's fixed cost target was defined, the controllers broke it down on its elements. In a first step, these elements were platforms and modules. After a discussion and work process that lasted for several months, the number of platforms as well as the projects that would be based on these were defined. According to equation (5), the sum of all elements' fixed cost targets were not allowed to exceed the modular architecture's fixed cost.

To determine an individual platform's fixed cost target, the controllers considered all projects' affordability that were defined to be based on it. While the cost ratios disclosed in Figure 7 respectively Table 6 comprised both a platform's and modules' fixed costs, the controllers dissolved the cost ratios' platform share. For example, project 1 was the follow-up project of project 0 ($z_{0,t-1} = 0.05$, see Figure 6), and the cost ratio of project 1 was defined to be 5% as well ($z_{1,t} = 0.05$, $\gamma_{1,t} = 0$, see equation (4)). Via further cost analyses of project 0, the controllers could define its platform share to 4.5% ($z_{1,\ platform} = 0.045$, see equation (6) respectively Figure 6). In order to comply with equation (7), $z_{1,\ modules}$ was equal to 0.005.

Applying equation (8) for all platforms resulted in fixed cost targets for individual platforms. For example, car project 1 and car project 2 were defined to be both based on platform 1, and summing up values each project could afford for platform 1 resulted in a fixed cost target of \$ 927 Mio. (=$a_{platform1,t}$, see Table 7 in the upcoming section). As car project 3, 4, and 5 were based on platform 2, the controllers did not consider them in the context of platform 1's fixed cost target. The fixed cost target of platform 2 was determined accordingly.

To determine the fixed cost targets for modules, the controllers slightly deviated from the method defined in Section 3.3. A straight implementation of the method seemed difficult, as there were ongoing discussions about which party was going to be responsible for this group of elements. Moreover, involved actors agreed to hold back a certain amount of the modules' budget. Therefore, the controllers determined a budget of \$ 440 Mio., which was the difference between the modular architecture's and the sum of the platforms' fixed cost target.

In a next step, actors from both *AutoCompany* and *CarEnterprise* decided not to install a platform-independent module management team. Instead, modules were going to be managed by the same managers that were responsible for managing platforms. An experienced controlling manager suggested to assign two thirds of the modules' budget to platform 1's responsible managers. This implied that one third would be available for additional modules and variants to fulfill requirements of car 3, 4, and 5. The controllers implemented this proposal, and aimed to force also the latter car projects to bring in their requests and pro-actively participate in modules' conceptualization right from the beginning.

3.4.3.6 Splitting elements' fixed cost targets on cost types

Next, the controllers broke the fixed cost targets of each element down to R&D costs, and investments related to production, purchasing, and quality. As a first approach, the controllers

Table 7. Break-down of AutoCompany's modular architecture's fixed cost target on elements & fixed cost types

Element	*Element's fixed cost target*	*R&D*	*Production investments*	*Purchasing investments*	*Quality investments*
Platform 1	$ 927 Mio.	$ 463 Mio.	$ 323 Mio.	$ 138 Mio.	$ 3 Mio.
Modules for platform 1	$ 293 Mio.	$ 205 Mio.	-	$ 88 Mio.	-
Platform 2	$ 1.073 Mio.	$ 642 Mio.	$ 149 Mio.	$ 277 Mio.	$ 5 Mio.
Modules for platform 2	$ 147 Mio.	$ 103 Mio.	-	$ 44 Mio.	-
Sum	$ 2.440 Mio.	$ 1.413 Mio.	$ 472 Mio. €	$ 547 Mio.	$ 8 Mio.

- disguised data

consulted managers by every department, and asked for ideas on how to conduct the split, but they refused to support the controllers in this task.

Therefore, the controllers analyzed cost data of existing modules and platforms, and defined element-specific cost shares for each fixed cost type. According to equation (9), they used these cost shares to split each element's fixed cost target to fixed cost types. As an illustrative example, the controllers found the cost shares of 0.5 (R&D costs), 0.35 (production investments), 0.15 (purchasing investments), and <0.01 (quality investments) for a current platform, which they applied to the fixed cost target of platform 1. The method's result, a table that split the modular architecture's fixed cost targets into elements & fixed cost types, is shown in Table 7.

3.4.4 Consequences of the method's implementation

Reactions to the implementation of the method were diverse. In the following subsection, we illustrate how different actors at *AutoCompany* responded as the controllers confronted them with the outcomes of the new method. We also show how the method impacted the ongoing decision process through several updates, when input data and the scope of the modular architecture (modules shifted to cross-architecturally used parts and vice versa) changed.

3.4.4.1 Implications of and reactions to fixed cost targets

The consequences respectively reactions to the proceeding and its result were diverse. As a first important step, the controllers succeeded to incorporate the fixed cost targets shown in Table 7 into *AutoCompany's* strategic cost planning system. This implied that the company respectively responsible managers had to consider the calculated values in order to anticipate future R&D respectively investment budgets years. The fixed cost targets became mandatory, at least until both *AutoCompany's* and *CarEnterprise's* management board would decide to adapt these.

The proceeding respectively the resulting targets caused several negative reactions. Particular elements' fixed costs were criticized to be not fair by those who were responsible for them. During a meeting about a particular car project, managers from development, production, and purchasing departments criticized the controllers that *'this makes absolutely no sense'*. For example, they reasoned that other elements' fixed cost targets were far too high, and doubted some input variables, for example estimated sales volumes for car projects besides their own. A controlling manager replied to these reproaches:

> *"We just cannot afford more for [this car project] – this is a fact."*

The controllers experienced that their fixed cost targets tended to receive more criticism from managers who were responsible for particular car projects or elements. They did not appreciate such a limitation of their decision freedom and budgets. Some managers criticized the top-down approach and emphasized that setting these cost targets could not be set before estimating fixed costs at the level of elements from a bottom-up perspective. One manager who was responsible for one of the first car projects planned to be based on the new modular architecture said:

> *"We just do not know yet how much money we will need for what!"*

Other actors appreciated the proceeding. An experienced manager in the field of coordinating *AutoCompany's* modular architectures replied to the comment above:

> *"But it is the question what we are doing here. Do we make target costing, or do we proceed according the principle 'let's see what the future brings'."*

And another manager, responsible for a particular group of modules, encouraged the controllers to go further and distribute the fixed cost targets to a more granular level:

> *"We absolutely need a cost break-down [...]. [CarEnterprise's car projects] always come with extra wishes and concepts with different solutions. And I cannot hold something against it that we cannot afford it. If we would have a concrete division of the targets then I could substantiate that it is not affordable."*

From the controllers' perspective, the fixed cost targets were welcomed by several experienced managers who were responsible for the coordination and management of the modular architecture. For them, the method provided a first instrument to efficiently manage a modular architecture's fixed costs.

During the following months, the fixed cost targets were used in many meetings and discussions as a restriction or at least orientation for concept discussions and strategic decisions. For example, production managers planned to produce future car projects that were based on the same platform in different plants. With the fixed cost targets, the controllers could substantiate that the implied duplication of required production investments would lead to a significant overrun of the fixed cost target, and, consequently, exceed the car projects' financial affordability. *AutoCompany's* controlling manager stated during a discussion:

> *"This [, achieving the fixed cost target], is the objective. For products in such an early stage, the target is realistic. The product is neither developed nor built, and it is important to set basic conditions in an early stage. But to say, this is it going to cost, because we did it like this in the past, is the wrong way."*

The modular architecture's fixed cost target was also critically examined by the group's management board. During that time, another brand of the group conceptualized a modular architecture as well (for other market segments) and its fixed costs were planned to be approximately 40 % lower than *AutoCompany's* modular architecture. Therefore, group's management board formulated the task to reduce *AutoCompany's* fixed cost target. By comparing the two modular architectures' portfolio, *AutoCompany's* managers argued that the additional fixed costs allow them to derive a more extensive product range for additional market segments, and therefore these car projects were able to generate more revenue in total. In addition, *AutoCompany's* controlling manager argued with the cars' profitability targets, and that the car projects' sales volume and net revenues justified the fixed cost target. Moreover, he pointed out that the fixed costs were planned to be reduced by 30% compared to the current generation. The group's management board understood and accepted that argumentation.

3.4.4.2 The method's implementation as a baseline to go further

The decision for the fixed cost targets was modified later, when the conceptualization of the new modular architecture got more concrete and changed. For example, some elements classified as modules were redefined to become cross-architecturally used parts, which enabled controllers to adjust the fixed cost target for modules from $ 440 Mio. to $ 400 Mio and, consequently, the fixed cost target for the entire modular architecture was reduced to $ 2.40 bn.

The usefulness of the fixed cost target became clear when an estimation of the fixed costs for the first platform of the new modular architecture significantly exceeded its target. During many discussions, the fixed cost target was an important weapon for the controllers. They repeatedly promoted efforts to realize synergies and requested a reduction of module variations and complexity to finally reduce fixed costs. For *AutoCompany's* controllers, this was a new approach during the NPD process. A controller, responsible for development costs, emphasized during a discussion:

> *"What we did until today is the following: when engineers come and say 'we make the defined technology from the technical product description, and this will cost 10 Mio. €'. Then, we calculate and say, 'alright, I think you can do it for 9 Mio. €', or we say 'the 10 Mio. € seem plausible'. What we never did before is, coming top-down from the products' [ROS] and say 'this is the target the products can afford'."*

Another important characteristic of the method was the fixed sum of all elements' targets. If some actors claimed for increasing an element's fixed cost target, the controllers demonstrated openness to redistribute cost targets within the boundaries of the modular architecture's target. This implied that another element's fixed cost target had to be reduced accordingly. These interrelations stimulated discussions about which elements and properties were worth it to invest which share of the architecture's fixed costs.

The modular architecture's fixed cost target was also a means to maintain cost pressure to the elements that were developed first. Due to its break-down, the controllers could transparently disclose the remaining amount of money for elements that were planned to be developed and realized at a later point in time. Responsibilities for the several elements were defined in a very early stage, and therefore, strong top managers prevented that too much money was spent for the "first" elements, and not enough resources remained for "their" elements.

Summarized, the fixed cost targets stimulated initiatives to base more car projects on less platforms, strengthened portfolio coordination, increased the application of common components, and reduced components' variance and complexity. Even they were facing frequent attempts to break through the cost targets, the controllers were able to maintain their target system.

3.5 Discussion and conclusion

Target costing takes a product's whole life cycle into account, but we have scarce insights how cost targets beyond variable manufacturing costs are determined and managed in target costing. Moreover, we know very little about how target costing can be combined with modular product strategies, which can also be vital cost management practices during product development. The study illustrates that managing R&D costs and investments in a modular context is a challenging, but crucial task for products' financial success.

We developed and implemented a method to determine fixed cost targets for a modular architecture. This method considers which level of fixed costs is affordable, based on data for the entire modular architecture, such as the expected sales volumes of all products, net revenues, and the shares of several kinds of costs. Furthermore, the fixed cost target is disaggregated to elements and to fixed cost types. These more detailed cost targets can be related to individual managers or project teams. The method adopts a top-down perspective and aims to help restricting unprofitable product variety and complexity.

We provide empirical evidence for the practicality of the method, based on a three-year case study at a car company. The company's current modular architecture was more project-by-project oriented (Ramdas et al., 2003) and fixed costs had increased and exceeded targets, which had eroded profitability. The objective of the method was to enforce a more coordinated approach and improve cost management activities for the next product generation.

Estimation of data was surrounded by significant uncertainty, caused by the novelty of the approach and the long time horizon of more than ten years for which data needed to be forecasted. The controllers demonstrated openness and transparency during presentations and discussions, and finally processed the method with best available data. Doing that, they did not argue for isolated budget cuts, as focusing on isolated cost minimization might not lead to optimal profitability (Fisher et al., 1999). Rather, they embedded the proceeding into a strategic context, anticipated future market and cost changes, and put focus on the firm's financial goals.

The controllers caused mixed reactions. On the one hand, they faced increasing resistance during the targets' break-down to elements and fixed cost types. At this level, affected actors could compare target fixed costs with the organization's past performance, and consequences for their area of responsibility became obvious. Therefore, some actors started bargaining and complaining about their cost targets, and others criticized assumptions and emphasized uncertainty as one of the method's weakness. On the other hand, actors besides controlling, for example portfolio managers, were aware of the task to reduce complexity and variety. For them, the proceeding was a powerful instrument to improve cost management activities, and they encouraged the controllers to go further.

The development and implementation of this method provides a number of contributions to the literature. First, we conceptually extend the methodological scope of target costing by applying the philosophy of a market-based target to R&D and investment costs for a modular architecture. Setting a fixed cost target for the sum of elements which are applied by a whole product portfolio will support cost efficient concepts, and therefore improve cost performance (Gopalakrishnan et al., 2015). The method helps to limit the emergence of unprofitable new and additional product variants, and stimulates the re-usage of existing parts. While Ramdas et al. (2003) present a method to determine the optimal variety of components to cover all applying products' requirements, we do not assume that there is complete information about all elements' costs in an early concept stage of complex NPD projects. We know that in complex development projects, i.e. when engineers have limited overview over the whole project, they tend to overestimate their components' importance for several reasons (Mihm, 2010). Therefore, we argue that a fixed cost target can serve as a centrally managed instrument to limit a high local variety. Instead of determining the optimal number of variants to minimize total costs, we set budget constraints to prevent too high variety.

Second, we illustrate the method's implementation in a case study to demonstrate its practicality. While the company's management struggled to impact complexity and variety, the new approach aimed to 'show the whole picture', and delegate decisions and efforts about reducing variety and complexity to engineers and component experts. The empirical evidence illustrates that it is not about data accuracy, but strengthen the philosophy of target costing. In an early development stage, consistent and comprehensible reasoning helped to point out that a cost-efficient development and planning of manufacturing investments are important levers for assuring the future products' profitability.

Third, the case study helps to better understand arising cost management challenges when a company both focusses on target costing and portfolio-oriented strategies such as modular design. In academic literature, we have plenty of studies that describe successful target costing application and best practices (see examples in Ansari et al., 2007; Woods et al., 2012), and also some studies that discuss or mention dysfunctional aspects of target costing (Davila & Wouters, 2004; Kee, 2010; Yazdifar & Askarany, 2012). But we have few empirical studies that discuss practical problems of target costing's implementation or illustrate a firm's poor cost performance despite target costing is applied. In order to realize a modular strategy's promised financial benefits, stimulating the portfolio-perspective seems necessary, as "[t]here has also been an overall trend in industrial practice toward more autonomous project teams. Such autonomy carries with it the difficulty of achieving the economies of component sharing" (Fisher et al., 1999, p. 311). In our case company, we could observe that such an autonomous project team philosophy led to insufficient management of R&D and investment costs. As the organization decided to follow a modular strategy, they missed to adapt their cost management and development processes in an adequate way. Many project teams participated and contributed to the modular architecture's implementation, also with a timely delayed impact, and this project-by-project approach led to a high level of complexity and variety. Ro et al. (2007, p. 188) commented on this aspect: "Automakers […] need to understand how mass customization and its use of modularity will affect their product development practices […]." With the current study, we aim to contribute to a better understanding of the organizational change processes an organization’s strategy shift towards more modularity entails, as proposed by Ro et al. (2007): “It is not clear in the academic literature what happens when an industry attempts to move nonmodular products to the modular context.[…] Very little is known about the organizational design implications, both within the firm and across the supply chain, when companies that produce nonmodular products begin to move toward a more modular product architecture.” (Ro et al., 2007, p. 174).

The limitations of the interventionist research study conducted in this study are quite comparable to other qualitative field research approaches. As Cooper & Slagmulder (2004b) state, researchers might have a selective perception, and this might result in biased observations and interpretations. As another characteristic of a longitudinal field study, researchers have low control over the empirical space (Ahrens & Chapman, 2006). In addition, the company’s specific circumstances of manufacturing complex products, operating in an investment-intensive industry, and executing cost-intensive and long-term development processes might limit the findings’ generalization to a certain extent. But on the other hand, these limitations come along with the approach’s strengths: first, we had access to information, processes, and details that otherwise would never have been available to “outside” academic researchers. Second, working on site allowed focusing on practical target costing challenges and provided inspiration for the presented method’s conceptualization. As Agndal & Nilsson (2009, p. 99) notice, “applying target costing can be more problematic than implied by the literature”.

There is additional potential for further research. The current study is, to the best of our knowledge, the first that illustrates empirical evidence about cost management challenges arising if a firm follows a modular strategy and simultaneously applies target costing. We would be very interested in additional empirical evidence how the method may work in other companies, as well as how other organizations face the challenges discussed above. Future research may also address several issues identified here that are unexplored in the literature. For example, the literature usually mentions “the” market price or “the” costs - but these numbers change over time, and represent an average of many different prices and costs a global operating firm is confronted with. How does a firm deal with this complexity, and to which granularity are such costs managed during NPD? Another interesting research opportunity may be how firms incorporate large time horizons in their target costing systems. For example, how do firms deal with these challenges of uncertainty, or to which extent do firms anticipate changes of manufacturing costs of a multi-years lasting manufacturing stage during the target costing process? How do firms take additional fixed costs for product updates take into account?

In addition, we would be interested in how considerations besides profitability affect the target costing approach. Cooper & Slagmulder (1999) talk about the cardinal rule of target costing to introduce a product only if estimated costs are equal or less target costs, and emphasize that this requires a well-disciplined target costing program. But they also mention that there are situations, for example legal requirements or strategic reasons, which require a relaxation of the cardinal rule. We would be very curious about empirical evidence considering this aspect. How do such situations impact a firm's target costing philosophy or target discipline? And which instruments may a project team apply to anticipate such situations? We are looking forward to future research studies that create deeper insights into further practical target costing challenges.

4 Persuasiveness of incomplete financial calculations and the role of additional details and explanations

Abstract

Management accounting information is inherently soft and incomplete: it is uncertain and leaves out facets organizational actors consider important as well. Calculations about future investments, cost and revenues are a compelling example. We can understand these as inscriptions, in the form of spreadsheets, presentations, memos, emails and other artefacts. These do not stand as representations of a future reality, but they recreate and make visible people's expectations, hopes, and fears about the uncertain future. How do soft and incomplete calculations become persuasive and influential? This study adds to prior literature by focusing on the role of providing additional details and explanations about a calculation (for example, information about the sources of particular input data or technical details of the calculation method). We analyze how providing these details and explanations may help to "harden" information and make more influential. This additional information can be used, firstly, for showing that the calculation has undergone scrutiny and, secondly, for enhancing the comparability of the calculation to other information or reference points that are important for organizational actors. We also investigate how accountants have their own agendas and deliberately disclose these details to increase the persuasiveness of their calculations for advancing their agendas. They can exploit these details and explanations to reverse and focus the burden of proof, and they can use it to open and close the window of opportunity for challenging a calculation. Details become something potentially influential, because the calculation has limitations that can be talked about. Incompleteness and softness turn the provision of these additional details into a lever accountants can use to increase the persuasiveness of the information they provide. We conducted a field study during three years at a management accounting department in product development at a car company. Through an interventionist case study, we could follow in great detail three episodes around decisions and calculations concerning the technical concepts of several new cars.

Keywords: *incompleteness, softness, persuasiveness, informational tactics, accounting calculations, product development decisions, accountants' work*

4.1 Introduction

The accounting literature has long recognized that accounting numbers are inherently incomplete (Jordan & Messner, 2012). Whether accounting numbers aim to measure performance from a previous period or want to show financial effects in the future, they are often uncertain and leave out important facets people will want to consider, too (Huikku & Lukka, 2016; Jørgensen & Messner, 2010; Lillis, 2002). These representational limits of accounting numbers have been described in terms of "incompleteness" or "softness," for example (Rowe et al., 2012). The accounting literature has started to provide an understanding of how incomplete accounting numbers are used and have effects. For example, accounting numbers are scrutinized, contested and reworked until people feel comfortable to act on them (Rowe et al., 2012; Wouters & Wilderom, 2008). They are combined with other information to provide a more comprehensive picture and to look at a situation from different perspectives (Bruns & McKinnon, 1993; Preston, 1986). And, the incompleteness can be productive if it engages people to consider and discuss different ideas, leaves room for various interpretations, and creates hope that things may change later (Qu & Cooper, 2011; Quattrone, 2017).

Some accounting numbers are calculations that, in a very fluid way, are intended to help understand what may happen in the future and make a decision (Andon et al., 2018; Rowe et al., 2012). Calculations are no forecasts, however. We can understand calculations as inscriptions, in the form of spreadsheets, presentations, memos, emails and other artefacts. These inscriptions do not stand as representations of a future reality, but they recreate and make visible people's expectations, hopes, and fears about that future (Busco & Quattrone, 2018b; Jordan, Mitterhofer, & Jørgensen, 2018; Themsen & Skærbæk, 2018). By showing prospects that may happen, the calculation may propel people and give energy to make promises come true or prevent threats to happen, but it may also make complacent, or paralyze and stifle. The calculation is not a forecast but emblematizes possibilities, promises, commitments, doubts, fears, and so on (Mouritsen & Kreiner, 2016). Calculations as "material representations can only partially re-present organizational worlds and discourses, since they are inherently incomplete and, therefore, cannot fully inform rational decision-making nor guarantee that certain consequences will ensue in the future" (Busco & Quattrone, 2018b, p. 16).

In the same spirit, decisions are no immutable dictates. A "decision" is not fully deterministic and not a definite end point, but it does have some concrete, tangible impact: for the time being, pathways for future courses of action are constrained; there's more funding, time, and other resources for doing some things but less for other things; there is time in formal meetings to talk about some issues but not about others. At the same time, people may still do things differently than what has been "officially decided" and use degrees of freedom that the decision leaves. And later, things happen that awaken old and raise new doubts that initiate tweaking earlier calculations and starting new ones, and that lead to revising earlier decisions. Calculations and decisions are never finished and final, but provide temporary understanding, agreement or truce, and direction for action (Busco & Quattrone, 2018a).

Incompleteness of calculations and the role calculations play in decision-making are socially constructed. People feel more or less comfortable to act on the calculation, because they have "different beliefs about the uncertain future" (Miller 1990, as cited by Quattrone, 2017, p. 592) and, more broadly, perceptions about how adequate the calculation is. Their perceptions and feelings are also shaped and potentially changed through discussions and negotiations (Rowe et al., 2012). Moreover, people often have preferences independent from the accounting information and will consider how the accounting information relates to these preferences and their interests (Briers & Chua, 2001). Hence, they will evaluate if they like what the accounting information suggests and, consequently, would like to act on it or would like others to act on it. And so, the calculation becomes part of a collective process with discussions, negotiations, further analyses, cross-checks, and so on. There is great variation in how much and in which ways calculations influence the process and outcome (Andon et al., 2018). But the key point is, calculations that some experts would argue are "technically" carefully constructed and are based on lots of "solid" data may end up not having much impact, while calculations that are based on questionable assumptions and leave out important elements may be playing an influential role in a particular decision-making process, because most actors consider them good enough or simply like what these calculations suggest.

Recent studies in the accounting literature have started to look how incompleteness of accounting may be overcome (Groen, Wouters, & Wilderom, 2017; Lillis, 2002) or how incompleteness may even engage, mediate, and innovate, asking if accounting can "be articulated in a way that fosters enablement and pragmatic solutions without putting aside a critical concern?" (Busco & Quattrone, 2018b, p. 17). Accounting inscriptions, although inherently incomplete, may support action by providing "something" to hold on to that creates some order and simplifies things, but that also helps to reflect on and talk about the "unavoidable conflicts, ambiguities and tensions originating in different attitudes, objectives and beliefs" (Quattrone, 2017, p. 592).

Against this background, this paper investigates the role of disclosure of additional detailed information and explanations on how a particular calculation has been conducted.

Thus, we study a feature of the inscription itself (Busco & Quattrone, 2018b). Which details are shown, for example, about the sources of particular input data, the scope of the analyses, or the calculation method? What is the effect of providing such additional details and explanations? It may influence how people consider the adequacy of the calculation and their comfort to act on it, and it may also influence how the calculation is discussed, attacked, revised, respected, or discarded. However, the literature provides only scarce insights in how that may work through the provision of additional details. For example, it has been found that if a proposal is supported by a calculation, which also includes some details about how this has been conducted, this proposal may become more persuasive (because of the objectivity and competence the calculation suggests) but also less persuasive (because the information reveals the incompleteness of the calculation that may be used to discredit it) (Kadous, Koonce, Towry, & Wright, 2005; Loraas, 2009).

The focus of our study is to explore the role of disclosure of additional details and explanations for hardening soft, incomplete information (Rowe et al., 2012). We propose that disclosure may help to harden soft information and, thereby, to enhance the influence of calculations. We also dig deeper by looking at the motives for disclosure, because disclosure is deliberately done. We look at accountants as the people who construct calculations and do disclosure (Goretzki, Lukka, & Messner, 2017). We show that they have agendas, too, and how they use disclosure as a means to increase their influence of the information they provide.

In the remainder of this paper, we first present studies that deal with the topic of incomplete management accounting information and its impact. Next, we develop our theoretical framework before describing the research method and presenting the findings from the case study. Of course, the research process has been one of going back and forth between the field and theory. The chosen structure is not to suggest a deductive process of theory testing, but we simply feel this helps to better put forward the theoretical ideas developed in this study and to better analyze the case through this theoretical lens (Ahrens & Chapman, 2006).

4.2 The influence of incomplete management accounting information

In the following section, we first review literature that deals with the incompleteness of management accounting information. These studies examine in particular to which extent calculations capture aspects in a valid way that actors really care about. Next, we present studies that show how this information can be influential either way, or even that incompleteness of management accounting is not a problem, but fruitful for going on during discussion and decision processes.

4.2.1 *Incompleteness of management accounting information*

A key reason for the incompleteness of management accounting information is that people believe that particular numbers are not validly representing what they really care about. The numbers do not capture particular facets that people also want to consider—they provide an incomplete picture (Wouters & Wilderom, 2008). For example, performance indicators may not capture all the dimensions of performance that people consider important (Jordan & Messner, 2012). And while attempts can be made to create performance measures that are considered more valid and more complete (Wouters & Roijmans, 2011), accounting may, realistically, never develop towards a valid and stable state. For example, Andon, Baxter & Chua (2007) describe attempts to create performance measures in a field study of a business unit of a telecommunication organization, which tried various performance measurement approaches "in an effort to obtain a stable suite of metrics. However, in spite of management's desire to improve performance through measurement, the considerable amount of time and resources committed to this project, as well as the intermittent assistance of 'experts', such desires remained unfulfilled. Instead, the performance agenda retained an unsettled quality" (Andon et al., 2007, p. 273). The paper tells a story of how creating measures was a struggle that happened through iterative trials, improvisation and making do.

Jordan and Messner (2012) investigate incomplete performance measures and the effects these had on managers. For example, one performance indicator was "cycle efficiency" defined as the "percentage of value-adding standard time relative to total lead time" (Jordan & Messner, 2012, p. 550). Managers realized that the indicator did not account for the monetary values of inventory, which they considered important if this indicator was supposed to express something about adequately managing inventory and shareholder value. Although not initially, incompleteness became problematic when superior managers started to take the measures more literally and to give more weight to targets and actuals for the incomplete performance indicators (incompleteness as a problem for performance evaluation). Moreover, when some measures became more difficult to improve further, the performance indicators did not help managers enough to understand what was going on and to find ways for improving things (incompleteness as a problem for coordination and action).

Another reason for incompleteness of accounting information is that people have doubts about the reliability of the data that are used for producing the information.[13] The term

[13] Jordan and Messner (2012) talk about forms of incompleteness ranging from broad to narrow concerns with the representational qualities of the indicators. They suggest that narrow concerns can be solved with minor repair work, such as changes to the definition of an indicator. Broad concerns reflect that what the indicator

“softness” is also used for this, referring to “subjective information from interviews and surveys without sufficient verification” (Rowe et al., 2012, p. 260), and so it is soft or subjective because “the estimates, predictions, and assumptions may not be readily verifiable” (Kadous et al., 2005, p. 652). This reason for incompleteness is particularly important if the accounting calculation concerns an unknown future (Goretzki & Messner, 2016), which makes the input data uncertain and also raises anxiety about unknown unknowns (Andon et al., 2018). The study by Andon et al. (2018) looked at a large investment project in a proposed Public Private Partnership (PPP) scheme for a housing project. People acknowledged, for example, that they did not know whether maintenance for the next 30 years would be actually be going to cost as much as they now estimated it to be. A central calculation was the present value of projected net cash flows for the life of the PPP. Examples of important estimates going into these calculations were the average value per developable unit, the number of such units, construction costs, and the cost of services (such as tenancy management, maintenance, relocation and rehousing). There were considerable doubts about many of these estimates, people in the organization “had concerns about numerous numbers. They knew their records of past expenditure did not predict well future expenditure. They had no information on the cost of multiple services since they were not familiar with discretely costing these activities. They had little knowledge of future land prices of transformed public housing estates. In short, they knew their numbers were soft” (Andon et al., 2018, p. 31). Moreover, people felt that bigger things could be unsure than the numbers themselves. “For example, what if market conditions changed such that predicted land prices were wildly wrong? What if conditions changed such that the cost estimates were wildly wrong? What if the risk contingencies were too low? After all, this was a thirty-year project and there were bound to be unknown unknowns” (Andon et al., 2018, p. 32).

Thus, incompleteness in this literature is socially constructed. It concerns people’s ideas about the representational quality of accounting information, about which there can be more less agreement.

4.2.2 The impact of incomplete accounting information

If incompleteness is such an inherent characteristic of accounting information, how does accounting information have influence? We focus on how accounting information becomes

shows is so different from what is really considered important that incorporating it into the indicator is not possible. All this we would see as doubts about the validity of the accounting information, so incompleteness because people believe that particular numbers are not representing in valid way what they really care about. Doubts about the reliability of the input data is not something Jordan and Messner talk about, which is understandable as they study ex-post measurement numbers.

something that enables people in organizations to find pragmatic solutions, to act, to move forward. Incompleteness does not have to stand in the way of such a productive role of accounting information (Busco & Quattrone, 2018b). It may be helpful to think of two kinds of ideas in research on how incomplete accounting information has effects: some studies have focused on how people try to make the information "better" and become comfortable to act on it. A second idea is that incompleteness may not be a problem and can actually be productive and accounting information has impact not despite of, but because of incompleteness.

Incompleteness or softness of accounting information can stimulate activities to construct more complete or harder information, as the basis for making the information more persuasive and influential. For example, firms may implement more advanced performance measurement systems, such as designing efficiency performance measures that account for more demanding, other performance targets (e.g., regarding quality) or implementing weighted performance indices (Lillis, 2002). Another technical solution is reported by Davila & Wouters (2005). The organization in their case study had designed a budgeting system that reduced emphasis on cost targets and provided budgetary slack when performance attributes other than costs required attention. Incomplete performance measures may also stimulate more detailed design activities and participation of employees for developing performance measures that are seen as more valid and enabling (Wouters & Roijmans, 2011; Wouters & Wilderom, 2008).

Two studies are particularly relevant for the present paper, because they investigated incomplete, soft numbers that concerned a very uncertain future. These studies showed how people needed to become comfortable to act on these numbers, whereby being emotionally comfortable played a role (Andon et al., 2018) as well as more cognitive and "political" aspects of being comfortable (Rowe et al., 2012). The earlier mentioned case study by Andon et al. (2018) helps to understand how people try to build *emotional comfort with soft accounting numbers*, so that these enable action. People involved in the PPP scheme were anxious that numbers and calculations were not too precise or complete. Andon et al. (2018) investigated how action could occur when a degree of comfort was achieved with the deployment of these soft numbers. "Comfort is an emotion associated with a sense of ease or safety/security. Discomfort then is associated with anxiety, a sense of unease, concern, or worry" (Andon et al., 2018, p. 15). The emotions of comfort or discomfort involved relationships with other people and objects. Actors could become more comfortable to use these numbers for further actions and decisions in the course of time, and three relations supported that process: relations of supplementation, relations of commensuration, and relations of providence. Relations of supplementation add information and thereby extend the meaning of existing accounting estimates. “For example, instead of using two years of past data to arrive at an average, it could be decided to use five years of data in the belief that this would provide more information as to cost patterns. Or attempts might be made to use mathematical techniques (for example, Monte Carlo simulations, sensitivity analyses) to construct knowledge of how outcomes vary given a variety of scenarios” (Andon et al., 2018, p. 17). Relations of commensuration draw associations and/or make comparisons with other legitimated calculative processes, knowledge, or expertise. Cross-checking is central for building such relations of commensuration: actors “relied heavily on what Housing Interviewee 2 described as “due diligence” – the constant checking of numbers calculated in different ways and cross-referencing between different datasets” (Andon et al., 2018, p. 29). Relations of providence engage with imagined threats. They “protect the foreshadowed and calculated future; that help ensure that the expected resistance of foes/critics and/or foreshadowed risks have been mitigated” (Andon et al., 2018, p. 18). Building such relationships was an ongoing process, and “soft numbers did not incapacitate. Indeed, it was because the numbers were soft and perceived as lacking that they were always deemed to be work-in-progress; always to be worked upon” (Andon et al., 2018, p. 46).

Furthermore, being comfortable to act on numbers may have to do with perceptions of the quality of the numbers. Rowe et al. (2012) investigated social processes for hardening soft information, involving activities such challenging, verifying and reworking the information, until people are willing to use it. Hardening meant that “group members who have different individual interpretations of the information come to agree on an interpretation that the quality of the information exceeds a minimally acceptable level” (Rowe et al., 2012, p. 261). Based on game theory and social psychology, Rowe et al. (2012) theorize four games to harden soft accounting information and call these faith, power and politics, practical arguments, and statistics games. These games differ regarding the players, comparability of soft accounting information, and rules of the game. When there is little comparability and standardization, accountants and/or consultants are the players, faith games reflect a belief in capacity of accounting techniques to harden accounting numbers when they are properly implemented. When there is little comparability and standardization, but powerful central managers are the players, they use their authority to harden soft numbers in power and politics games. This may involve intentional distortion of information. When comparability and standardization are medium and the players are committees and/or cross-functional teams, decision-making becomes broader. In practical arguments games, the information is hardened through inclusive debates and majority rule. Practical arguments become increasingly persuasive when they survive public challenges during debates, meet required burdens of proof, and beat rival interpretations. Finally, when comparability and standardization are high, accountants and/or consultants can use statistical analysis to harden the numbers. Rowe et al. (2012) suggest that the practical-arguments game is effective for hardening numbers and making them more persuasive, because actors perceive a democratic, legitimate, transparent and understandable process.

Another perspective in research on incompleteness of accounting information is that this does not have to be a problem, but it can be productive for the persuasiveness and influence of accounting information. For example, incompleteness does not have to be much of a problem if mangers use the information not too strictly but more *to indicate a vision and to stimulate discussion*. In the earlier mentioned case study by Jordan & Messner (2012), the incompleteness (even in combination with ambitious targets) was not seen as very problematic by the managers whose performance was being measured, as long as they believed their superior managers used the performance indicators in a flexible way. The indicators and their target values were communicated as visions. The project was building on the past, and managers understood the idea behind the project, and why they were working on particular topics and what they wanted to achieve. The numbers didn't tell the whole story, and they didn't have to. Managers often had other and complementary kinds of understandings they could also draw on for their own work, and so they could overcome the limitations of incomplete accounting information, as several studies have also shown (Bruns & McKinnon, 1993; Jørgensen & Messner, 2009; Preston, 1986; van der Veeken & Wouters, 2002).

In the second chapter of this thesis, we already described the studies by Jørgensen & Messner (2009, 2010), and they are worthwhile to be mentioned in this section, too. The authors found how measurement of modularity in product development was a strategic goal that could only be measured incompletely, but calculations helped in discussing and working towards that goal. The case company wanted to achieve various strategic objectives through a modular product strategy, but the very diverse benefits (and costs) of modularity could not be fully quantified with the company's existing calculation tools. Understandably, "the existing spreadsheet model was designed to handle only one product at a time, while in the case of modularity, there would be several products or product variants that had to be evaluated in tandem because they would share one or more modules." (Jørgensen & Messner, 2010, p. 193). "When modularity was introduced, the representational limits of the earlier mentioned calculation model became apparent" (Jørgensen & Messner, 2009, p. 118). The CEO made the decision to go modular, because intuitively it seemed a good idea, and many people also expected they would learn much from the new project and then better understand the consequences.

Although engineers and project managers had the opportunity to introduce add-on spreadsheets and could, to some extent, repair the calculation model with such technical solutions, severe limitations remained. Managers in the case study mentioned that the implications of reuse, project lead time, and economies of scale were still not reflected in the calculation model. This was not too problematic, however. The management board focused on high-level targets and on coordination. Strategic objectives were not completely quantified with numbers, but they were discussed together with financial arguments. Although strategic objectives, such as quality, lead time, or production efficiency could not be fully quantified, the calculation model provided a starting point to talk about how design choices and tradeoffs affected these strategic objectives. "The management board drew from their own practical expertise in order to 'see through' numbers that featured in the project reports" (Jørgensen & Messner, 2010, p. 202). "Strategic concerns were regarded as means to profitability that had to be balanced in a reasonable way" (Jørgensen & Messner, 2010, p. 201). The management board focused its inquiry to emphasize that the integration of different concerns of different parties was important at any stage during product development. Anticipation of the discussions with the board made project managers think about how they could explain how their actions might impact overall profitability - even if such arguments could often not be quantified as hard calculations. It made them consider how they could argue their decisions supported strategic objectives, and it let them engage in horizontal information sharing so they would be able to show a wider perspective. "The enforcement of financial accountability at the gates can be seen as a means to remind managers of the importance of accounting numbers - even if these are only imperfect representations of the decisions and practices in [new product development]" (Jørgensen & Messner, 2010, p. 202).

The papers by Mouritsen et al. (2001, 2009) we already discussed in earlier parts of this thesis, also help us to understand the impact of management accounting information despite its "imperfection". The authors present several case studies on management accounting and product development in technology companies. Accounting information was influential, because it made ideas about innovation visible and credible, and it challenged managers to relate their ideas and concerns about innovation to other important considerations, such as strategic objectives, profitability of products, and operational constraints in their own organization or elsewhere in the value chain. Even the costing information disregarded several aspects (such as increased inventory costs per unit, increased waiting time for critical components, or higher R&D and complexity costs), this was not the essential aspect. "Sales performance, contribution margin and ABC margin are powerful because they can motivate actions to be performed by innovators. This translation, rather than represent the innovation choices, creates a context for innovation activities to occur" (Mouritsen et al., 2009, p. 751).

Incompleteness of accounting numbers also enables people to use different pieces of incomplete information in a flexible way to suit their needs when they are trying to persuade others. Goretzki, Mack, Messner, & Weber (2016) show how people used the completeness of accounting-based performance measures to switch between different numbers and increase the persuasiveness of these. They discuss that persuasiveness of accounting numbers is a "situated achievement" that depended if interactive alignments between different actors can be achieved. They look at accounting-based performance numbers and examine how these accounting numbers are applied as a kind of "framing devices", and they follow the question why one number is prioritized over another one by a particular actor in a particular situation, and what makes accounting numbers persuasive. They illustrate discussions between subordinates and superiors during performance review meetings and try to make sense of why actors use different accounting numbers in order to persuade each other. They theorize that it is a question of how legitimate an indicator is to the involved actors, as well as if the provided signal is perceived to be salient (so noticeable, meaningful, and memorable) so, hence, strong when compared to the actual outcomes on alternative indicators.

Denis, Langley, & Rouleau (2006) examine the role of numbers in a strategic setting about the question which public hospitals need to be closed down because of budget cuts in health care. They find that "seeking complete information is more likely to confuse, enhance uncertainty and promote conflict than generate the commitment needed to produce concrete action" (Denis et al., 2006, p. 351) in pluralistic contexts. They state that previous studies suggest that mobilizing numbers for decision making in pluralistic settings (ambiguous goals, diffuse authority) are unlikely, and they make several propositions with their detailed empirical illustration about the decision process. They "show how a particular set of contestable numbers came to acquire power and legitimacy in a controversial situation where the outcome could have been quite different" (Denis et al., 2006, p. 361 f.), and talk about the "highly constructed nature of objectivity" in the context of their numbers. They discuss three dimensions of micro-practices associated with the usage of numbers: construction of objectivity, persuading the audience of rationality behind numbers (show consistency, transparency, competency), and disempowering adversaries. Finally, the authors summarize that it did not really matter if the numbers were objective, but the board mobilized them in order to enable them to achieve their major objective, which was "closing sufficient hospitals to meet the demand for resource reductions" (Denis et al., 2006, p. 367).

The incompleteness of accounting information also helps to make that information acceptable and influential by giving people room for multiple interpretations (Briers & Chua, 2001; Busco & Quattrone, 2015; Emsley, 2008; Qu & Cooper, 2011). Accounting information such as balanced scorecards, customer profitability, and quality costs have the potential to be many things to different people. People can discuss and agree what the information means at a more general level. At the same time, the incompleteness allows telling different stories and motivating diverse conclusions. People can live with and mobilize accounting, just because it does *not* plan and measure everything unambiguously and completely. For example, Briers and Chua (2001) describe a striking contrast between the way particular management accounting information was developed and how it was later presented. The development of information on cost and profitability in the steel company they studied took many years, failed several times, included the creation and shutting down of various costing models, and involved many compromises regarding scope and data. However, the final costing system was presented to outsiders (such as in practitioners' publications) as a straightforward, rational and unproblematic account of developing a better costing system: an exemplar case presented as leading practice. Accounting was not "better" in the sense of providing more accurate information, but accounting was successful when it could be used to hold together different interests, to accommodate different interpretations about facts, and to suggest different ideas about information needed. Accounting information could temporally settle down on something that worked for the different actors involved. They adopted particular accounting information as long as it represented also their interests, interpretations, and ideas.

Incompleteness creates elusiveness that is also productive in different ways. It creates methodological opacity about how performance measures are precisely calculated, thereby preventing too many opportunities for questioning the method for calculating performance measures. Furthermore, incompleteness allows ambivalence of professional identities to exist (Dambrin & Robson, 2011). Dambrin and Robson (2011) examine the construction of performance measures in the pharmaceutical industry. The performance evaluation systems of pharmaceutical companies could not directly trace the sales agents' performance, and this study investigates the question "why fragile networks of imperfect numbers can still perform" (Dambrin & Robson, 2011, p. 429). The problem with the performance measures was that pharmaceutical companies could not measure the sales generated by their sales representatives. Government regulation prohibited them having access to doctors' prescriptions that ultimately generated the sales. These companies had created several technical solutions to be able to approximate the performance information of sales representative they sought, which they also used for determining bonus payments. However, this performance measurement system was approximate and complex. As a result, many sales representatives did not understand the calculation of sales bonuses, but they also did not perceive it as a problem. It is shown that imperfect performance measures' functionality is ensured by opacity and ambivalence. "Transparency would offer opportunities to question the interruptions of traces between drug reps' activities and the performance measures shaping their rewards. Transparency and visibility of bonus' calculations would probably reinforce the selling side of drug rep activity, a facet of their professional identity that is tacitly acknowledged but cannot take front stage" (Dambrin & Robson, 2011, p. 441).

The incompleteness of accounting information can also propel action and have productive effects, because it leaves room for doubts and debate, which stimulates questioning but also continuing to collaborate (Busco & Quattrone, 2018a). In a case study of an Italian fashion company, Busco and Quattrone (2018a) analyze how cost calculations and nonfinancial performance indicators stimulated cross-disciplinary collaboration in the creation of a new collection. The provisional budget brought together information such as the number and types of units to be produced and sold, the variable material costs and the (internal and external) production costs of the items, sales revenues and contribution margins. More detailed cost information was available on the cost cards. Furthermore, a balanced scorecard provided additional information (such as delivery time and customer satisfaction). Different preferences and difficult tradeoffs came through in this information set, but of course, the information was incomplete and fragmented, and people needed to be discussing the issues and making decisions. "In this context, the Provisional Budget acquires a central role as it engages professionals with different backgrounds in a dialogue, and offers a space in which the different interests and concerns materialize and get translated into financial terms. Together with other accounting and performance measurement practices, such as Cost Cards and the Balanced Score-card, the Provisional Budget sustains Gioconda's decision-making process, which underpins the creation of the collection" (Busco & Quattrone, 2018a, p. 10). It does not mean that there will be consensus, but the incomplete accounting information is productive because it stimulates people to ask questions, discuss, have different opinions, but at the same time sustain collaboration and move on, such as the develop a new collection - even searching for a perfect one.

In some settings, organizational members have differing values, so fundamentally dissimilar ideas about what matters (Chenhall, Hall, & Smith, 2013). This is different from what we have considered so far. We focus on settings in which organizational actors can have very different ideas about what they prefer to have happen, because they have different interests and different expectations about an uncertain future, and they may weigh various objectives differently. Incompleteness relates to the gap between what matters to (most) people and what is captured in the calculation, or it is about the uncertainty of the data used for a calculation. Yet, in settings that predominantly characterized by fundamental disparity among organizational members about which goals matter, incompleteness concerns the fundamental significance of particular accounting information. So perhaps beyond the scope of this study, but it is interesting to see that in such settings, incompleteness can also be productive (Chenhall et al., 2013). The development and operation of accounting performance measures can make existing values more visible and concrete, "because it is in discussions over the different metrics, images and words that can be used to represent performance that the actual worth of things is frequently debated and contested " (Chenhall et al., 2013, p. 269). Such discussions may stimulate debate and potentially help finding more or less acceptable compromises and reaching temporary agreement on what matters and is measured. Problems with performance measures "helped to provide a fertile arena for productive dialogue and discussion between individuals and groups with differing values" (Chenhall et al., 2013, p. 269). Furthermore, involving people in the development of performance measures may also lead to performance measures that are able express their differing values (Chenhall, Hall, & Smith, 2017). The expression of values through performance measures can be beneficial for the organization by mobilizing the energy, motivation and commitment of various organizational members. Specifically, they found that it led to more positive attitudes to the performance measurement system, better quality of data captured by the system, and more learning and exploration of alternatives (Chenhall et al., 2017)

To conclude, incompleteness stimulates various ways in which accounting has influence in organizations. Incompleteness does not need to limit but can actually enhance the influence of accounting information. Research trying to better understand that influence has focused on the psychological, social and political context of accounting.

4.3 Providing details and explanations by accountants for increasing their persuasiveness

In the following section, we first explain which actor is in the focus of our study: accountants in the role of information providers with an own agenda. Next, we present two studies that show how disclosure of quantified information might hurt the information's persuasiveness. Doing this, we aim to sharpen our own ideas of how disclosure of additional details and explanations may increase calculations' persuasiveness. Finally, we present our theoretical framework: we conceptualize the aspect of providing additional details and explanations, we introduce the two main effects providing details and explanations have to harden accounting information, and last, we connect the accountants' own agenda to the way they provide these details and explanations.

4.3.1 Accountants as the focal actors in this study

One actor is remarkably silent in the literature on the influence of incomplete accounting information: the accountants who prepare that information. With some notable exceptions (Goretzki et al., 2017), these people seem to be unimportant for what happens around incomplete calculations, as if they are neutral providers of accounting information.[14] That is a surprising perspective because at the same time, prior research on incomplete accounting information considers that the information accountants have prepared becomes part of a complex social setting in which interactions, interests, and all kinds of other psychological and social factors play a role. Why would accountants not be part of that? In this study, we explicitly focus on the information preparer as part of the social setting. We investigate that they may also have an agenda that matters for the information they provide and for the effect the provision of this information has.

Specifically, we focus on the details and explanations the information preparers provide about how the accounting numbers have been created. We refer to additional details and explanations as data and aspects information preparers provide in order to reason and explain the main information in order to increase its persuasiveness, for example, about the sources of particular input data or details of the calculation method. We investigate how the information

[14] There are studies on accountants as organizational actors of flesh and blood, however, these consider mainly how accountants behave because of the agendas of others that implicate accountants. For example, accountants have shown to engage in quite elaborate forms of data misreporting (Fauré & Rouleau, 2011; Maas & Matejka, 2009) or budgetary slack building (Davis, DeZoort, & Kopp, 2006) to address the expectations of particular actors towards them. However, we approach the accountant as an organizational actor with an own agenda that goes beyond dealing with what others want from them.

preparers may use disclosure of these data to influence what happens towards their agenda. The provision of details may influence how people consider the adequacy of the calculation and their comfort to act on it, and it may also influence social processes for hardening the information, such as mobilizing, discussing, challenging, checking, or revising the information. The context is important: incomplete calculations about the future which need to be crafted for a particular situation, so there is no clearly defined and enforced format or information flow (Goretzki et al., 2017). There is considerable flexibility for the controller, both for conducting the calculation as well for providing details and explanations.

This study shares with Goretzki et al. (2017) the focus on detailed informational tactics used by accountants. They describe how accountants skillfully use informational tactics such as choosing when to inform headquarters, framing information, and even withholding information.[15] They investigate how such tactics help accountants to deal with the competing responsibilities as corporate watchdog on behalf of the central finance function and as a business partner for local management. They find, for example, that accountants consider very carefully when, how and what to report to which other organizational actors. They "act differently to different directions in order to enact their accountabilities and meet the expectations of their different stakeholders" (Goretzki et al., 2017, p. 23). But however tactically they behave, they want to create an image of a trustworthy informer and the information they provide should appear truthful to those confronted with it. "If controllers go too far with their tactical behavior and tell 'barefaced lies', they risk harming their image and identity as 'producers of truthful knowledge'. Hence, the tactics that controllers employ must remain somewhat 'hidden' to others" (Goretzki et al., 2017, p. 3). Compared to Goretzki et al. (2017) and other prior research, our study introduces a specific issue not investigated before, namely the provision of details and explanations as an informational tactic. Moreover, our study considers that controllers have their own agenda and investigates how they skillfully provide information to advance that.

In this context, providing details and explanations becomes something potentially influential, *because* the calculation has limitations. The additional, detailed information can be insightful for making sense of incomplete accounting information, but it would be trivial if the accounting information would be "perfect" - there would be no nuances to elucidate through additional details. Incompleteness makes the provision of additional details and explanations into a lever that the information preparer can use to deliberately influence decision-making and

[15] They use term "controllers" to include job titles such as management accountants, management controllers or financial managers.

increase the persuasiveness of the accounting information they provide. Thus, we look at incompleteness as something that matters for making accounting information more persuasive. Incompleteness is not something that needs to be overcome, but that is skillfully made use of.

Before exploring how the provision of additional details can help making an incomplete calculation more persuasive, we will address a counter argument that helps to sharpen our ideas of how disclosing additional details and explanations may “work.”

4.3.2 A counter argument: disclosure makes the information more vulnerable

The few studies that provide some insights into possible effects of disclosure of detailed information seem to suggest that disclosure would *not* enhance the persuasiveness of incomplete accounting information, because it may lay bare more limitations of the information and reveal how it can be discredited. Kadous et al. (2005) investigated a setting in which proposals for a particular course of action could be quantified or nonquantified, whereby quantified specifically referred to a numerical calculation of the expected net dollar benefit or costs associated with a proposed course of action, which also included information about how the calculation had been conducted. A nonquantified proposal only included qualitative information and no calculations or numbers about costs or revenues. They investigated the persuasiveness of both kinds of proposals. Persuasiveness in this study was measured (an explicit definition of the theoretical construct as such was not provided) by asking research participants to indicate the likelihood that they would support the proposal (which concerned a change in operating procedures, namely to postpone routine, but expensive, maintenance on machinery).[16]

A quantified proposal could be more persuasive because it reflects more positively both on the competence of the manager who prepared it and on the plausibility that a favorable outcome could result from the proposed action. On the other hand, a quantified proposal might be perceived as a persuasion tactic, which might trigger the receivers of the information to critically review and analyze the calculation’s details. Compared to nonquantified information, details of quantified information are more readily available and therefore enable critical investigation. Moreover, persuasiveness may depend on whether the input is objective or

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[16] In the experiment, “the quantified and nonquantified proposals were identical in terms of the qualitative content (that is, both listed the same categories of costs and benefits of postponing the maintenance, and both recommended postponement). The quantified proposal, however, provided a dollar estimate for each line item and showed the details of all calculations” (Kadous et al., 2005, p. 655). In the subjective inputs condition, participants were told that “[m]ost aspects of turnaround analyses are inherently subjective. In fact, much of the analysis typically done for this type of decision is based on soft data, such as opinions and assumptions. Accordingly, there is a lot of room for judgement in this type of analysis.” (Kadous et al., 2005, p. 655).

subjective and whether information is provided by a particular actor or interest group with own agendas that have an incentive to mislead. They found that the strength of quantification on persuasion depended on whether the data is subjective or objective, and if the proposal's preparer's incentives go along or against with the firm's incentives. Moreover, while quantification enhanced the perceived competence of the preparer as well as the plausibility of a favorable outcome, under specific circumstances, it invited greater critical analysis than nonquantified proposals which can harm persuasion. They concluded that "individuals do not exhibit blind trust in numbers and are unlikely to be inappropriately persuaded by quantified proposals" (Kadous et al., 2005, p. 648).

Loraas (2009) investigated quantification as a persuasive tactic, and examined scenarios in which quantified analysis were more persuasive than qualitative ones. The basic idea was that quantified analysis is not necessarily more persuasive, because quantified information enables decision-makers to carefully evaluate input data and processing, even if they are not familiar with the topic. This can harm numbers persuasiveness, because "when cues are put under scrutiny, they tend to lose persuasive power" (Loraas, 2009, p. 49). Based on experiments, she found out that executives are more persuaded by the quantitative analysis if they were familiar or experienced with the context. But she found no statistical significance of persuasion between qualitative and quantitative proposals if the participants of her experiment were unfamiliar with the context. Moreover, she was also interested in framing effects, and therefore varied her experiment by framing the qualitative proposals' consequences in a positive (i.e. emphasizing chances and potential gains) respectively negative way (i.e., emphasizing avoidance of potential negative consequences). As an additional result, she found out that if decision-makers are unfamiliar with the context, a qualitative proposal is more persuasive if it is negatively framed.

4.3.3 Providing details and explanations for hardening accounting information

While these studies provide one way to think about the effect of disclosure, we argue that the role of disclosure can also be more intricate. We build on the theoretical framework of a practical arguments game (Rowe et al., 2012). As in that study, we focus on a context in which there is a need for action, and accounting information is supposed to inform about it. There is considerable ambiguity and the accounting information is based on estimates and other information that may include unintentional or intentional mistakes. This makes people skeptical to act based on the accounting information they receive. Hardening the information can happen in several ways, such as the proper implementation of accounting practices or the use of statistical analyses by accountants and other specialists, the use of authority by powerful managers, or in-depth scrutiny of the information by accountants together with representatives from various other functions. Rowe et al. (2012) call the people who harden the information "players". The hardness of the information is socially constructed and defined as the level of agreement among group members (called "users") that they are willing to let the accounting information inform their actions. The willingness to act on the information depends on the perception "that the quality of the information exceeds a minimally acceptable level" (Rowe et al., 2012, p. 261). When the information is of sufficient quality to, for example, plan organizational change, Rowe et al. (2012) call it "hard" or "persuasive", and they demonstrate how a practical arguments game was effective in their case study. Users became more willing to act on the information, because they realized the information had undergone scrutiny by people from various functions by "analyzing, evaluating, and potentially changing the information" (Rowe et al., 2012, p. 261). This scrutiny was public (within the company), documented, and communicated in a language that was understandable for non-specialists. Moreover, the scrutiny was based on many comparisons between various kinds of information.

In such a context, we investigate the role of providing data and explanations that disclose details about how the accounting information has been created. We argue that the provision of these detailed information can be used for hardening the accounting information, i.e., make it more persuasive for users to act on it. Furthermore, we zoom-in on the accountants as players who significantly determine the provision of these details. We posit that they also have an agenda, that they also have a preference for particular actions (or at least develop them in the course of examining a task) and would like the information to be persuasive for users to act accordingly. We argue that the provision of details and explanations by the accountants can be used for hardening the accounting information in a way that fits their agenda. To begin with, we will develop a more detailed conceptualization of detailed information and explanations.

4.3.3.1 Provision of details and explanations

Providing details and explanations about how the calculation has been conducted can be thought of in several levels: a *description* of particular aspects of the calculation, a *motivation* for why particular aspects of a calculation have been done in certain ways, and a *qualification* of the appropriateness and limitations of the way in which particular aspects of the calculation have been done. This latter level may also lead to providing information on the consequences of such limitations, for example by showing a range of potential outcomes or probabilities of achieving particular outcomes. Aspects of the calculation that can be disclosed at these levels are, for example, the sources of input data, assumptions made for input data and other parameters, the calculation method as such (which method is used) as well as other additional technical details.

The communication of these details and explanations can happen in several ways. It may be shown *in writing*, such as on presentation slides or on other documents that are made available to other players or to users. The information can be more or less salient, for example because some slides are presented and other slides are available in the slide deck but not shown during a meeting, or because some information is in the management summary of a report and other information is on the footnote of an appendix. Information may also be provided *orally* when a calculation is discussed with other players or users, and therefore might add certain aspects to information that is available in writing and pointed out. The provision of additional information may be triggered by the discussion or explicit questions, or the information provider may have intended to provide the information, but only orally. We also can imagine that details and explanations are provided at different moments around *meetings* when the calculation is discussed: *before* meetings, when some elements of the calculation that are very technical or sensitive are discussed with individual players or users, or with a subset of players or users; and *after* a meeting, when this has triggered following-up elements with individual or a subset of players or users.

4.3.3.2 Hardening through the provision of details and explanations

We propose there are two main effects for how the provision of details and explanations helps hardening accounting information, namely by communicating that this information has been scrutinized and by creating comparisons. Both effects are likely to harden the information, i.e., make it more persuasive (Rowe et al., 2012).

First, details and explanations can be used to **explicitly** show the **scrutiny** that has taken place. This additional information provides a space that enables, for example, explaining checks that have been conducted, indicating names or positions of experts who have provided estimates or have sanctioned particular assumptions or the calculation method, or referring to earlier meetings in which the information has already been shown and discussed. This detailed information communicates explicitly to what extent the accounting information has been analyzed, evaluated, and potentially changed.

Information providers can also disclose details and explanations to **implicitly** express that the accounting information has been **scrutinized**. The fact that accountants are able to show detailed information about numbers, experts, sources, etc. suggest that they must have been in contact with experts, consulted several data sources, and conducted specific analyses. The provided details and explanations imply that these kinds of hardening activities were needed to be able to come up with that information.

Furthermore, details and explanations can be used to **enable users** to **scrutinize** the information. These additional information can include explanations without using too much technical language, for example, with the intention of making the accounting information more transparent and understandable for users who may have limited accounting knowledge. This could enable users not only to verify whether the overall implications are making sense to them and are consistent with their broader experience and "gut feeling", but it also helps them to evaluate if particular parts of the accounting information they have received is credible in relation to specific non-accounting knowledge they have.

Second, providing details and explanations enables creating more comparisons, which is another characteristic of accounting information that helps to harden it (Rowe et al., 2012) by making the information more plausible (Goretzki & Messner, 2016). These additional information provides a space for mentioning how the accounting information is related to other information or reference points that are important for users. We propose several types of such comparisons.

Details and explanations can show **comparisons between various parts of the calculation** and demonstrate internal consistency. For example, information may come in the form of detailed breakdowns of numbers to show where the aggregate information that is important for users comes from. This enhances comparability because users can see how numbers are aggregated and disaggregated, so how numbers add up. Details may also explain how input data and several calculation steps lead to the aggregate information. Such relationships between detailed numbers and the aggregate information provide users with comparisons and consistency checks, helping to harden the information and make it more persuasive.

Disclosing details and providing explanations can show **comparisons to numbers and sources** that are already hard. For example, details can explain how the calculation starts out with actual (ex-post) numbers that people would not question and how the calculation is derived from that starting point. Or, these details can highlight that particular people whose opinions matter to users, for example, because of their expertise or hierarchical position, have provided particular inputs.

Furthermore, providing insights into the calculative proceeding can detail how the current calculation **compares to calculation methods** that are important to users. For example, there may be calculations for similar issues, and transparently disclose how they were conducted could explain that all calculations follow the same method for analyzing a comparable issue. These details could be used for explaining how the calculation compares to legislation, technical standards, or accounting standards. Additional, detailed information provides an opportunity to argue the consistency with such anchors in terms of method and logic.

Finally, details and explanations can describe **comparisons to a broader context** of the calculation. For example, particular assumptions may become more persuasive by comparing these to business practices in other parts of the same organization or in similar other organizations, by connecting these to the strategy of the organization, or by showing how these are consistent with broader societal trends.

4.3.3.3 The accountants' agenda and the provision of details and explanations

So far, we have discussed that the provision of details and explanations may help to harden the accounting information, so to create more agreement among users that the information is good enough to act upon. We now zoom-in on the accountants as a key group of people involved in preparing and hardening the information, and also as a group that has a significant influence on which and how details and explanations are provided. What could be behind choices the accountants make for disclosing detailed data? Rather than seeing them as neutral providers, we posit that they also have preferences for what they would like to have happen as a result of providing accounting information. And so, if they have an agenda, too, and disclosure is not "neutral" but something that influences the impact of accounting information, we consider that the accountants would use the provision of details and explanations first to persuade other players to accept the information they provide and then to have more influence on what users may do based on the information the players provide to them.

It starts during discussions within the group of people with whom accountants are preparing and hardening the information (the other players). Accountants can start to make the information they provide more persuasive to that group by carefully including detailed information, using the whole arsenal discussed above. The key point here is that we expect accountants to be persuasive in particular directions that fit their agenda. The agenda could influence how favorably they consider particular numbers, just as other players do. For example, they could be inclined to favor higher cost estimates and lower revenue estimates for decisions they do not prefer. There is some room for such interpretations, because of the context of much ambiguity, but within boundaries (Goretzki et al., 2017)—"a truth cannot be stretched too far" (Quattrone, 2017, p. 590). Even in a context of much uncertainty, some extreme assumptions will be considered as being unrealistic by almost everyone. But, there is likely a grey zone of reasonable assumptions—in between the extremes—that many people would consider believable. In this grey zone, if some people have doubts and disagree with assumptions the accountants propose, they might have difficulties convincing other players of alternative inputs and assumptions. In the grey zone, nobody really knows and nobody can muster convincing reasons why some uncertain assumptions would be more convincing than other uncertain assumptions. Thus, accountants, just as other players, could propose inputs and assumptions that are in the grey zone, but fit their agenda (more than other inputs or assumptions within that grey zone). Hardening then takes place among the players, whereby the accountants, too, have an agenda and try to persuade others. The players continue debating, challenging, checking, and changing the calculation until they agree it is good enough to provide the calculation to the users. Hardening continues with the users, until they agree it is good enough to act on it. Such phases of hardening will likely happen iteratively, so it goes back-and-forth between the users, players, and accountants.

In this context, accountants will try to gain influence in the group of players. Information is often discussed in pre-meetings in which accountants inform key actors about critical issues, before the information is discussed in official meetings (Goretzki et al., 2017). We propose two further ways in which the provision of details and explanations can strengthen the accountants' persuasiveness, and thereby influence. First, providing explicit information on their assumptions that are in the grey zone may have the effect of **reversing the burden of proof**. Rather than the accountants having to defend an assumption that is both "reasonable" as well as arbitrary, other players who question that assumption are expected to provide good grounds for an alternative assumption. Disclosing an assumption is like staking your claim. For example, suppose the accountants provide detailed information disclosing that particular supporting calculations were based on the assumption of a 3% cost increase, and this seems reasonable but also uncertain to most players. If somebody else would like to change it to 5% which is equally reasonable and uncertain, that may easily be seen by the other players as not enough of a reason for having to change it. Why would that be any better?

Second, providing details and explanations on inputs and method may also shift the discussion for the conclusion of the calculation to the inputs and the method and thereby have the effect of **focusing the burden of proof**. The provided details draw attention to particular aspects of the calculation and suggest that these are the aspects to talk about. It makes those aspects more salient and puts those up for discussion and challenge. Thereby, it also becomes harder for a player or user to challenge another aspect of the calculation that is not disclosed by the information preparer, because first they need to understand that aspect, and second they need to be able to explain the issues they want to address to the other players. And so, the accountant can cleverly choose which aspects they would prefer to be "on the stand" and which aspects they would like to keep silent.

Third, providing details **opens** respectively **closes the window of opportunity for challenging the calculation**. If accountants provide a calculation and explain in detail how it has been conducted, this suggests openness, neutrality, and seems to invite other players to challenge the calculation and bring in their own expertise. The accountants can still use the provision of details in clever ways, as discussed above, to make their calculation more persuasive. However, the fact that details and explanations have been provided limits future possibilities for other players to disagree if the group of players presents and defends the information during interactions with users. Issues the other players did not raise during earlier discussions with other players are difficult to bring up later with users. Disagreeing positions players took during earlier discussions with other players, but which they could not successfully defend, are difficult to propose later with users. Accountants can make it clear to users that a lot of details about how they have produced their calculation have been shown before within the group of players, thereby suggesting that everybody has had their chances, and so what's now presented must be the hardest information possible about an uncertain future. That message is not only directed at users to indicate that hardening activities have taken place (something we already mentioned in an earlier section), but the message is also intended to silence other players when they interact with users - they have had their chances. Therefore, the provision of details and explanations enforces a closed front and a common agreement among the players.

4.4 Research method

We conducted a field study at a car manufacturer. The initial topic of the research project was cost management in product development, in particular through methods such as product modularity that go beyond target costing (Davila & Wouters, 2004). We wanted to know what kinds of methods were being used, how technical approaches such as modularity and platforms were applied for cost management purposes, how these approaches were implemented, and how accounting departments and accountants were implicated. The researcher' supervisor had already conducted quite a lot of research in this area and realized that there were many open questions about how and why modularity, product platforms and such approaches were used. We chose this particular research approach because in-depth field studies are appropriate to understand such how and why questions (Ahrens & Chapman, 2006).

We aimed to conduct the study at a car company because of the importance of cost management during product development in that industry (Anderson, 1995; Ansari et al., 2007; Ibusuki & Kaminski, 2007; Mahmoud-Jouini & Lenfle, 2010). The particular company we approached was known for at least one key project in the area of modularity and platform design. We aimed to conduct an interventionist study, because this could provide access to the organization at an unparalleled level (Jönsson & Lukka, 2006), which we considered important because the topic requires an in-depth understanding of complex product development processes and cost management methods that are used in car companies, which we expected to be very difficult to obtain by "only" visiting the company.

The company, which we will call *AutoCompany* in this paper, provided the opportunity to do the intended kind of interventionist study for the researcher and his supervisor. The supervisor visited the company approximately twice a year, but was basically offsite and coached the research process. The researcher was mostly onsite, working in the controlling department of *AutoCompany*. The university received funding from *AutoCompany* to be able to employ that researcher, but neither of the researchers received personal financial compensation from the company. The research project lasted for three years, which we will refer to as 20xx, 20xy, and 20xz in the following.

At *AutoCompany*, the researcher was working as a colleague; he joined the daily business of the controlling department and was actively involved in several strategic episodes in the context of modular architectures. Besides taking intensive notes, conducting interviews, and collecting various kinds of data, for example company documents, presentations, and emails, the researcher was involved in creating new controlling technologies and information to facilitate strategic decisions. During the research project, there were regular meetings between the researcher and his university supervisor. In addition, a top manager of *AutoCompany's* controlling department, the supervisor, and the researcher met roughly every six months to discuss progress and further direction of the research project.

Over time, the research topic became more focused and also shifted. Parallel to the early work in the company, we continued developing our understanding of the literature, and realized that the topic of influence of the accounting department in product development was providing very interesting research openings, and this could also potentially provide interesting contributions to the literature. This guided the further practical work in the company.

In the second half of the research project, the researcher was actively involved in producing several calculations around decisions about *AutoCompany's* future modular architecture's strategy. Several themes resonated with us, such as that these calculations where surrounded with enormous uncertainty, and it was anyway impossible to model and quantify all relevant considerations. We also noticed the very different preferences people had, not based on the financial numbers, and how the accountants fought to get attention for their viewpoints and calculations. This triggered further reading of prior research on quantification, persuasiveness, rhetoric, and softness and incompleteness of accounting information, more thinking, discussing ideas with colleagues, and collecting data. We gradually realized that one element that seemed important in the company and that intuitively seemed to matter theoretically had not received much attention, namely how uncertainty is communicated, and more broadly, how the provision of details and explanations about calculations matters for their persuasiveness.

We selected three episodes at *AutoCompany* as fruitful and valuable empirical sources. In all of these three episodes, the researcher played an active role as a controlling representative of *AutoCompany*. He determined numbers, calculations, and additional controlling information that was influential for the final decision. Figure 8 gives an impression in which stages of the research project the empirical findings were made.

Analyzing the information and guiding the research happened in layers. From the beginning, both the researcher and his supervisor kept their own separate research diaries. This was a way to reflect on what was going on in the organization, the research process, interesting topics and angles for the potential theoretical contribution of the study, and emerging theoretical ideas. For the researcher on site, the research diary was also a medium for collecting data by making notes on events, conversations, meetings, and so on. Next to the research diary as a Word file, he made handwritten notes during the day in hardcover notebooks. The research diary and these notebooks turned out to be an important and helpful asset, which provided much information that enabled the researcher to write the empirical part of this paper.

When the focus of the research had reached the stage described above, the researcher started to write extensive summaries of each of the three episodes, including hundreds of references to internal documents, such as presentations, protocols, and emails, and to his notes

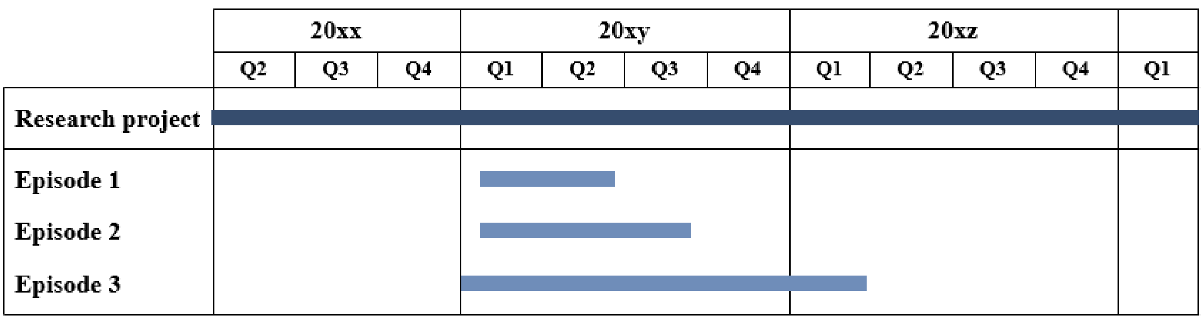

Figure 8. Timeline of the whole research project, as well as the several empirical stories

in the research diary and handwritten notebooks (for example, quotes of things people had said during discussions or meetings). These summaries grew to around fifty pages in total and were mainly structured according to the chronology of the events. The researcher used these summaries for discussing the findings with his supervisor, and estimate how these could be relevant for potential scientific contributions. This was the basis for writing next versions of these extensive summaries, which also entailed no more references due to reasons of confidentiality (which was an important aspect for *AutoCompany's* controlling top manager). These next versions were more structured around the interesting aspects the researcher had identified in cooperation with his supervisor, such as: how did the company deal with uncertainty, how were rough assumptions derived and included in the calculations, how and why were such assumptions (not) presented, discussed, and accepted or rejected during decision-making processes? In other words: how did the way of communicating the calculations impact their persuasiveness, therefore the whole decision processes as well as the decisions?

Thus, the initial focus of the study and the research method were motivated by our understanding of unanswered questions in the literature, the research focus became more specific by finding topics that were current for the company and could potentially lead to theoretical contributions. The process of finding the specific ideas for the current study was characterized by intense iterations between the literature, the data and our own evolving ideas and texts.

4.5 Case analysis

In this section, we present three empirical episodes, all dealing with calculations that contributed to strategic decision making, and processed and provided by the researcher in cooperation with an *AutoCompany* controlling manager and other colleagues. In these settings, the decision processes were supported by the financial calculations and entailed large consequences for the company's future portfolio and product strategy. The provided calculations expressed the decision alternatives' estimated financial implications. Besides these calculations, other departments, such as engineers, production, procurement, or marketing and sales provided arguments, too. Therefore, the financial calculation was an important, but not the only argument in each episode.

In all three episodes, past data and estimates were combined with assumptions as means to prospect the future. The calculations, in combination with all other arguments, were produced and discussed in *project teams* and presented to a management committee that could formally take decisions (the project team could only give recommendations). Almost all project team members were also part of this management committee, but not all members of this management committee were in the project team. Still we consider the members of the project team and the management committee as the "players" in the sense that they were producing a calculation. Their results were presented to a top management committee and, finally, to *AutoCompany's* executive board, sometimes more than once. These actors decided if they wanted to act on the calculation - the "users." We describe these separate episodes, realizing that the formal decisions were not end points, but triggered subsequent analyses, discussions and probably refined decisions.

The three episodes were all taking place in the context of the company's modular strategy. *AutoCompany* sold many different car models globally, and followed a modular strategy for decades. Their modular strategy implied that several car models were based on a common architecture. Intended benefits were, for example, fixed cost savings and economies of scale. *AutoCompany* was part of a larger group, and shared modular architectures with two other brands: *VehicleFirm* and *CarEnterprise*. The three firms' current product generation was based on three modular architectures which differed with respect to technical concepts. The reason for these deviating concepts were the different market segments products were manufactured for. Each of the brands was responsible for one architecture's development, and all of them were, at least partly, involved in the episodes we present in this section. For a more detailed description of the group's modular architectures, see Chapter 3 of this thesis.

Episode 1 and *episode 2* are about a similar decision. For the current product generation, similar car models (in the sense of cars' size) of two brands were based on two different platforms from two modular architectures, and the tasks were to examine if aggregating these similar car models on a common platform (as part of one modular architecture) for the next product generation would make sense. In other words, the group wanted to know if one platform per segment could be saved in the future. Affected segments, initial situations, working processes, involved actors' interests, calculation's result, and also the final decision differed significantly for the two market segments, and therefore, we present them separately in two episodes.

Episode 3 is about another task. *AutoCompany* was facing the challenge to offer both combustion and electric vehicles in the future, and episode 3 illustrates the decision process about the future modular architecture's concept.

4.5.1 Episode 1: Future platform(s) in segment 3

This first episode deals with the task if and how the number of platforms in market segment 3 (see Figure 9**)** could be reduced to one for the whole group. The task was formulated at the beginning of 20xy, and during that time, both *AutoCompany* and *VehicleFirm* sold cars in that segment, and also planned to do so for the subsequent product generation. Each brand developed its own platform for the current models (as part of two different modular architectures), and the group assigned the task to examine if the two brands could cooperate and base their future products' generation on one common platform.

This empirical part is structured as follows. In Section 4.5.1.1, we explain the motivation for the task and provide additional background information. The following Section 4.5.1.2 introduces the involved actors. In Section 4.5.1.3, we give a chronological summary of the whole episode. Then, we give detailed insights into a few key processes and situations that are important in the context of this study: first, we explain in detail how *AutoCompany's* respectively *VehicleFirm's* controllers gathered and created data. We describe how the gathered information was communicated, which discussions emerged from the provided calculations, and how these issues impacted the decision process. We also illustrate other actors' argumentation. Finally, we describe which decision was made.

We link our empirical data to the theoretical framework we presented in Section 4.3, and discuss the provided examples through that lens. For each episode, we number the provided examples. At the end of Section 4.5.3.6, we provide an overview of all empirical examples we provide during the three episodes in Table 11.

4.5.1.1 Initial situation and motivation for episode 1

At the time the task was formulated, both *AutoCompany* and *VehicleFirm* offered products in segment 3, and based their products on their own modular architectures. The consequence was a duplication of platforms in segment 3. In other words, there existed two platforms for the same market segment in the group. At first glance, this seemed contrary to the basic modular idea the group was striving for. This situation is illustrated in Figure 9. As mentioned above, we illustrate and discuss episode 1, the decision process of the platform overlap in segment 3, in this section. Section 4.5.2 will do so for episode 2 (the overlap in segment 5)**.**

The trigger for the task was *AutoCompany's* start of conceptualizing the subsequent generation of its modular architecture. A major question was which market segments the future modular architecture should cover, in other words: what are the upcoming architecture's

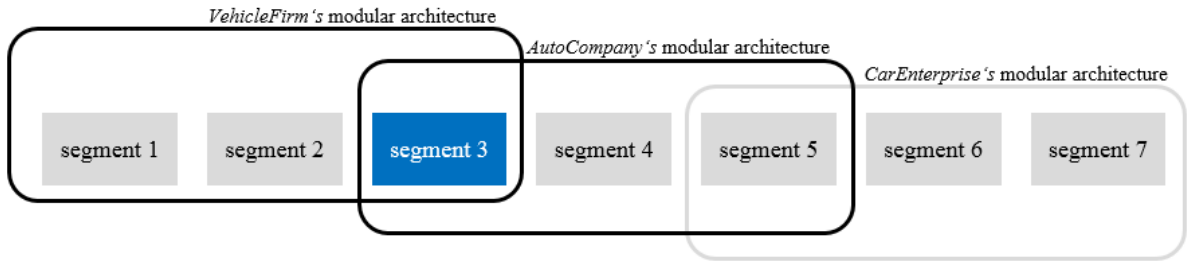

Figure 9. Existing modular architectures & segments covered – focus on segment 3

boundaries (in the sense of market segments)? According to current strategic planning, the first car based on it was going to be sold five years after 20xz.

In order to achieve intended cost savings for the future modular architectures, the group's CEO set the task of a

> *"group-optimal mapping of the modular architectures of the portfolio in the [relevant] segments."*

Moreover, before *AutoCompany* started with the actual development of its subsequent modular architecture, group's management set the task to reduce the modular architectures':

> *"It is about the question how many modular architectures are needed in the group to cover [a] segment [...], and how a cost-optimal conceptualization of the modular architectures is made [...]."*

More concretely, the group formulated to evaluate if *AutoCompany* could base their next product generation in segment 3 on *VehicleFirm's* modular architecture.

4.5.1.2 Which actors were involved?

The task of episode 1 was addressed to a *project team* led by a representative of *AutoCompany's* general management, subsequently referred to as the chairperson of the *project team*. The team comprised managers of several functional divisions, both by *AutoCompany* and *VehicleFirm*. General management was a department that directly reported to *AutoCompany's* CEO, and additional departments involved were controlling, development, production, marketing & sales, purchasing, and quality management.

Two members from *AutoCompany's* controlling department were part of the project team, a controlling manager (who was the formal project team member) and the researcher (who was conducting most of the analyses and also participating in most of the meetings). In this section, we will refer to them as "the controllers". They cooperated with *VehicleFirm's* responsible controlling managers in the sense of asking for information, as well as preparing and discussing results. But overall, the controllers conceptualized and led the evaluation process, and *VehicleFirm's* controlling manager's role remained quite passive.

The *project team's* results were presented and discussed in inter-brand and inter-disciplinary committees that existed on several hierarchical levels: a management committee and a top management committee. In most cases, department representatives of the *project team* were the same managers who represented their departments in the management committee.

4.5.1.3 Chronological summary

After the group's CEO had formulated the task (to estimate the advantages and disadvantages if *AutoCompany* would base its next product generation in segment 3 on the follow-up architecture provided by *VehicleFirm)*, it was adapted by the management committee right at the beginning of the working process. *AutoCompany's* engineers criticized the CEO's initial task, and claimed for what they considered to be a more balanced evaluation: they argued not to discuss only the potential cancellation of *their* platform, but also to consider the possibility to cancel *VehicleFirm's* platform. *AutoCompany's* management board confirmed to expand the task in that way.

In order to operationalize the task, the *project team* formulated two basic scenarios for segment 3, shown in Table 8.

Scenario 3.1 implied that all segment-3-vehicles (by both brands) would be based on *VehicleFirm's* future modular architecture. Consequently, *AutoCompany* would cancel its own platform for this segment, and its future modular architecture would start at segment 4 (see Figure 9). In contrast to that, *scenario 3.2* suggested to base all brands' segment-3-vehicles on *AutoCompany's* future modular architecture, implying that *VehicleFirm* would adopt the platform provided by *AutoCompany* and not develop its own platform anymore.

The *project team* defined technical, financial, and production aspects to be the most important evaluation criteria. Marketing, purchase, and quality arguments were defined to be of less relevance for the task, but these departments formulated criteria they considered to be important, too. Examples for criteria evaluated by other departments besides controlling were driving dynamics, comfort, production capacities, or customer requirements.

Table 8. Scenarios to be evaluated in episode 1

Base of future product generation of all car models in segment 3	
VehicleFirm's modular architecture	*AutoCompany's* modular architecture
scenario 3.1	**scenario 3.2**

In cooperation with *VehicleFirm's* controlling manager, the controllers evaluated the group-wide financial consequences of the defined scenarios for roughly two months. In consultation with the *project team*, the controllers incorporated consequences for material costs, scale effects, fixed costs, and profits in their financial evaluation, and presented working statuses and discussed their results a few times to the management committee – and other departments did so, too. As already mentioned, we will describe the way they processed the task in detail in the follow-up section.

AutoCompany's controlling manager was aware of the limited attributes *VehicleFirm's* existing platform offered compared to *AutoCompany's* own one. Still in the first phase of the evaluation process, he expressed some skepticism about aggregating these vehicles on one common platform:

> *"Here [in segment 3], I am really not sure if it would be clever to go on VehicleFirm's platform".*

At the end of the working process, every department separately presented their findings to the management committee. Only few days before presenting the results to *AutoCompany's* top management committee, the chairperson of the *project team* adapted the way of disclosing the task's results, and involved actors were asked to disclose their arguments from a single brand's and department's perspective. Until that point, the controllers evaluated the task from the group's perspective. The controllers doubted the usefulness of this proceeding right away, but finally had to accept it. *AutoCompany's* controlling manager criticized that

> *„[n]ow, everybody fills in their check marks and lightning flashes without knowing or considering the other brands' estimations. And [then], everybody will put their evaluations on the table. That is going to be fun. […] The different scenarios are expected to be evaluated by all brands separately, in order to get a collective recommendation. In my opinion, this will lead to isolated optimums: For example, one brand recommends scenario [xy] and ignores potential negative effects for another brand."*

The chairperson of the *project team* aggregated information and arguments by all departments in one presentation. This was first presented to and discussed with the management committee, followed by the top management committee. In the middle of 20xy, approximately half a year after the initial task was formulated, the group's top management committee decided to not aggregate all vehicles for that particular segment on one platform, but to go on with two separate platforms (from two different modular architectures) for the future product generation. This decision was supported by the group's financial top manager, conditional that financial impacts were evaluated sufficiently. After the meeting, he contacted the controllers who had to send and explain in detail their financial evaluation and all supporting calculations via email.

After explaining some additional questions on the phone, the financial evaluation was finally accepted.

4.5.1.4 Zooming-in: Preparing the calculation

In this section, we present the detailed working process and additional issues that show how disclosing the controllers' calculation and providing additional details and explanations impacted the decision process. First, in order to give the reader a deeper understanding of the calculation's softness, we explain how the controllers quantified the several financial impacts. Next, we describe how the calculation was presented to and discussed with the actors involved in order to come to a conclusion and recommendation. And last, we present the final decision, and how the controllers could defend it by explaining and disclosing details to a top financial manager of the group.

As the concept stage of the planned modular architecture just started and was going to be developed in the upcoming five years, the controllers had no hard financial information for it. Moreover, required product characteristics were not clear at this point. While *AutoCompany's* current product portfolio was dominated by combustion cars, *AutoCompany's* strategy suggested that a significant number of electric cars will be part of its future product portfolio. But the strategy how to handle the change towards electric cars was not matured, and at this point, *VehicleFirm's* and *CarEnterprise's* ideas for it differed significantly. These questions had significant impact on the task, and *AutoCompany's* concept engineers criticized that

> *"with respect to the future modular architecture, a fundamental discussion about the implementation of the electrification strategies [...] is necessary."*

Because of the high level of uncertainty, engineers chose the approach to

> *"compare the current vehicles [...] with an outlook to the next generation."*

The controllers followed this approach, and based their financial evaluation on current cost data of today's modular architectures. In a first step, they aimed to examine financial consequences if the current product generation would have been based on only one instead of two platforms, and second, they estimated and prospected these impacts' relevance for the future product generation. Instead of making too many assumptions about a modular architecture's concept that was nonexistent at this point of time, they believed to simplify the task and gain greater acceptance for their numbers if the calculation was based on comparably hard data of the current product generation. As *AutoCompany's* responsible controlling manager states it:

> *"Who am I that I can answer all these questions today? As controllers, we cannot tell."*

In coordination with the *project team*, the controllers defined to evaluate platforms' variable costs, fixed costs, scale effects, and profit effects. With **variable costs**, they referred to costs that depended directly on a car model's sales units – in this context, they focused on material costs. **Fixed costs** were independent on a car model's sales units within a specific range – in this case development expenses, as well as production, supplier, and quality investments. Evaluating **scale effects**, the controllers aimed to quantify financial impact of purchasing risks or chances due to a modular architecture's total output (sum of all cars' sales that are based on it). And finally, **profit effects** were contribution margins that could have been additionally realized (or not been realized anymore) if a car could be offered with additional (or less) properties. From past experiences, the controllers were aware of significant cost increases if the time range of new product launches from one common platform was large. They verified that the planned SOPs of the relevant car projects were within a time range of a year, and therefore decided to ignore this aspect.

In the following, we describe the controllers' procedure of gathering data and creating detailed information.

4.5.1.4.1 Evaluating variable cost effects

One major aspect of the financial evaluation was to quantify variable cost differences between *VehicleFirm's* and *AutoCompany's* platform. The result of the variable cost difference analysis is shown in Figure 10. This illustration was also used as a backup slide to present and explain the estimated variable cost difference the controllers included in their calculation to the management committee.

The controllers started the evaluation of the **variable cost** differences with an existing, two-year-old comparison of *AutoCompany's* and *VehicleFirm's* segment 3 vehicle's material costs. Such comparisons among products were a common procedure in the group. The existing analysis compared two specific car configurations (not an average of all model variants and available configurations), and indicated that *VehicleFirm's* platform was $600 cheaper than *AutoCompany's*.

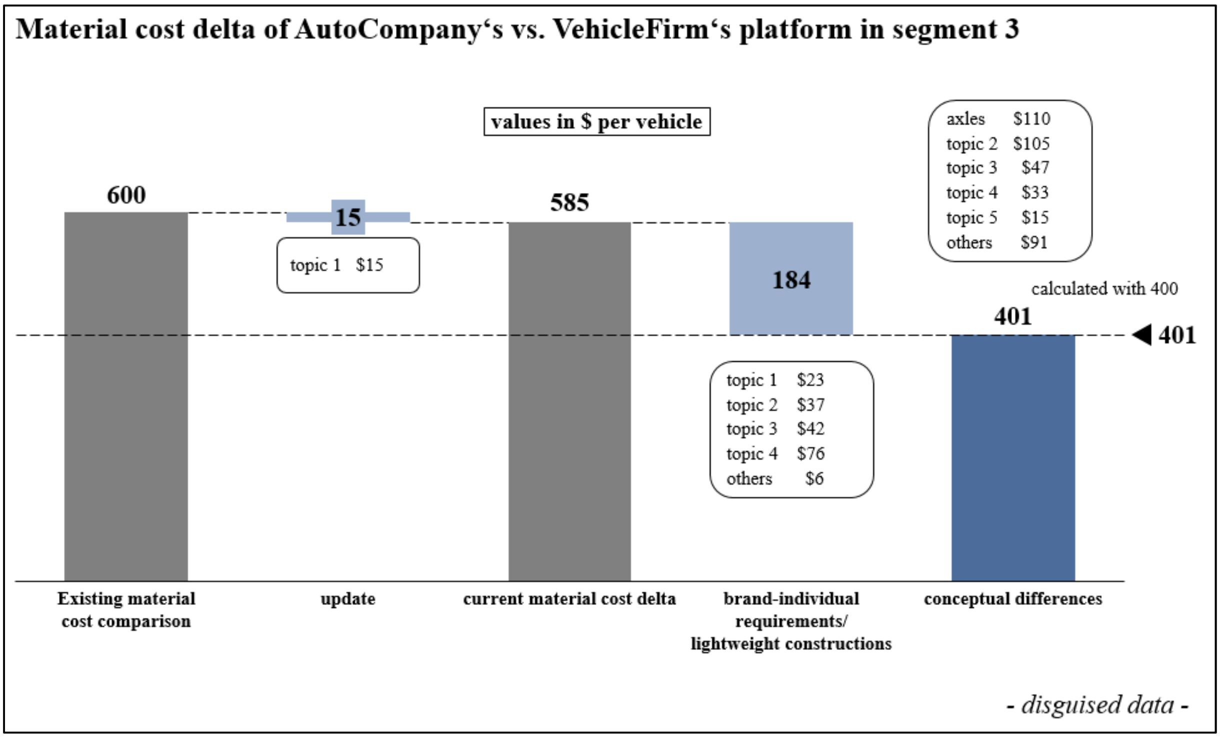

Figure 10. Material cost delta analysis for segment 3

In the first step, the controllers validated and updated the existing cost comparison in order to understand the cost differences, and included decisions within the past two years. During the first meeting with some cost experts at *AutoCompany*, one controller said:

> *"Okay, so we are doing it again. This discussion is coming back every few years."*

Discussions with cost experts during several meetings resulted in a reduction of the platforms' variable cost difference by 3%. In other words, the two-year old material cost comparison was still quite up to date.

In the next step, the controllers tried to consider future impacts, and tried to evaluate which cost differences would still remain if all vehicles in this segment would be based on one common platform. They discussed this aspect with cost experts at *AutoCompany*, and finally distinguished two different kinds of cost differences. First, they set the premise that some cost differences, for example caused by different technical solutions for the same attribute or brand-specific lightweight construction issues, were not relevant for the current purpose. The controllers argued that cost differences caused by interchangeable and brand-individual components would not play a role for the scenario to base both vehicles on a common platform. They also decided to deduct cost differences that are caused by a sub-optimal technical implementation (in retrospect), and argued that these could be avoided on one common platform.

Second, cost differences that are caused by platform-specific concepts remained. The discussions about the hypothetical distinction of these two aspects were sometimes difficult, and a clear separation was not always possible. The controllers often ended up in very detailed technical discussions with cost experts, trying to estimate if brand-specific requirements were important, and how these had influenced other conceptual settings. For example, one main variable cost difference resulted from *AutoCompany's* axles which were more expensive than *VehicleFirm's*. As *AutoCompany's* engineers argued with the superior performance of *their* axles, *AutoCompany's* controlling manager classified this cost difference to be of conceptual relevance, and therefore relevant for the task.

In addition, individual cost experts were used to precisely calculate material costs, for example by considering different degrees of vertical integration. Sometimes, it was laborious for the controllers to emphasize the task's strategic purpose, as *AutoCompany's* controlling manager said:

> *"We need to know if we talk about $ 200 or $ 600 - it does not matter if it is $ 250 or $ 270."*

This second step – distinguishing the variable cost differences in *not relevant* and *relevant* for the task - resulted in an additional reduction of the material cost difference of approximately 30%. Finally, a variable cost difference of $ 400 remained. In order to disclose individual parts and detailed costs, the controllers added boxes on the slide to show which aspects were incorporated in the bars.

The controllers calculated a total variable cost impact by multiplying the assessed variable cost difference per car with the planned sales units of current car projects. As the sales units *AutoCompany* and *VehicleFirm* sold in segment 3 were approximately on the same level, the total variable cost effect had the same size, but indicated a cost saving for the group in scenario 3.1, and a cost burden in scenario 3.2 (see Figure 12 respectively Figure 13).

Discussion of example 1: We believe this example provides support for our theoretical framework in several ways. Disclosing the individual topics in boxes beneath or above each bar *implicitly expressed* that the information was *scrutinized*. The process of gathering detailed cost data was a complex one, and the controllers invested a lot of time and effort. Transparently disclosing numerous aspects that add up to a single bar was a means for the controllers to illustrate the considered details, and also to show how much effort they had invested into the task. Both for the *project team* and the management committee, it was obvious that such detailed data required much effort and consultation of several experts. Therefore, disclosed details were a means to demonstrate competency.

Second, disclosed details *enabled comparisons between various parts of the calculation*. By taking care that the individual values of all aspects in one box sum up to the value represented by the bar, actors could zoom-into the evaluation, and the controllers could demonstrate consistency.

And third, disclosed details *enabled comparisons to numbers and sources.* The controllers based their evaluation on existing data from the past which was overall accepted to be hard. Disclosing how the existing data set was updated added even more hardness: by incorporating recent decisions, the controllers prevented doubts about the numbers' hardness. Otherwise, enemies of the calculation could have reasoned that the information was obsolete and not appropriate for the task. The controllers also relied on current hard data by multiplying the calculation's result with the expected sales units of today's product generation. Even as this number was an estimation for the current product generation, it was accepted to be the hardest information available.

4.5.1.4.2 Evaluating scale effects

The controllers had a serious issue quantifying **scale effects** for the scenarios in segment 3. They consulted *AutoCompany's* purchasing experts who told them that a detailed analysis would be far too work intensive, and also estimated that such an analysis would not lead to a very reliable result. Moreover, they argued that sales units of *AutoCompany's* car models in segment 3 were that high that additional sales would lead to negligible scale effect. This train of thought was supported by a seven-year-old cost analysis, provided by a *CarEnterprise* controlling manager, which related material cost savings to total sales units. It showed decreasing scale effects with increasing sales units, and implied insignificant scale effects in the magnitude of sales units in segment 3.

For these reasons, the controllers decided to provide only qualitative statements, and referred to the total sales units by both affected modular architectures. They analyzed that, in total, far more sales units were based on *VehicleFirm's* modular architecture than on *AutoCompany's*. They argued that, if *AutoCompany's* platform would be cancelled, negative scale effects for the remaining products on *AutoCompany's* modular architecture would overcompensate positive scale effects the products based on *VehicleFirm's* modular architecture could realize, and vice versa. This qualitative reasoning was confirmed by *AutoCompany's* purchasing experts. Therefore, the controllers disclosed a tendency how they expected a scale effect would be part of the financial evaluation, but expressed the missing quantification with a question mark (see Figure 12 respectively Figure 13)

Discussion of example 2: We argue this example also provides support for one aspect of our theoretical framework: providing qualitative reasoning *explicitly expressed scrutiny*. As the controllers were not able to quantify a scale effect in this case, they still decided to disclose a tendency, and gave more details about this aspect of the calculation. The detailed information expressed the qualitative reasoning for the disclosed tendency, and emphasized that the controllers did not just forget or were not motivated to evaluate this aspect. It has passed a process of scrutiny, and at the end of this process, experts concluded that a quantification was not possible, at least not with acceptable effort. Disclosing that information enabled the controllers to explain the process and add further information orally, for example that even purchasing experts could not provide a better input.

4.5.1.4.3 Evaluating fixed cost effects

In this section, we describe how the controllers evaluated the **fixed cost impact** of saving one platform in segment 3. They based the fixed cost analysis on actual accrued cost data of *AutoCompany's* current modular architecture. Even as they estimated these accrued fixed costs as unsatisfyingly high (for example, inefficiencies and late changes during the development stage led to a significant overrun of development budgets), they expected to get higher acceptance for their calculation if it was based on these "true" costs. They considered all product-related fixed costs, namely initial development, launching, and update costs, as well as investments in machines, tools, and production facilities. During several discussions with experienced controlling managers, the controllers developed arguments and derived assumptions for scenario 3.1. Applying these assumptions to the fixed cost data of the current platform resulted in the numbers shown in Figure 11.

As first assumption, the controllers argued that fixed costs for the **modules** *AutoCompany's* car models in segment 3 applied exclusively could be saved. This was only a small share of all modules' fixed costs, as most of the modules were used by other vehicles that are based on the same modular architecture. Next, an experienced controlling manager (who was responsible for the vehicles in segment 3) estimated that 30% respectively one third would be reasonable numbers to take **launching cost** savings respectively **supplier investment** savings into account. The controllers did not consider any savings from **production or quality investments**, as all controlling managers involved argued that these costs would accrue no matter on which platform cars were based on.

As the segment 3 platform was the first platform of *AutoCompany's* modular architecture cars were based on, its **development costs** were quite high, and the subsequent

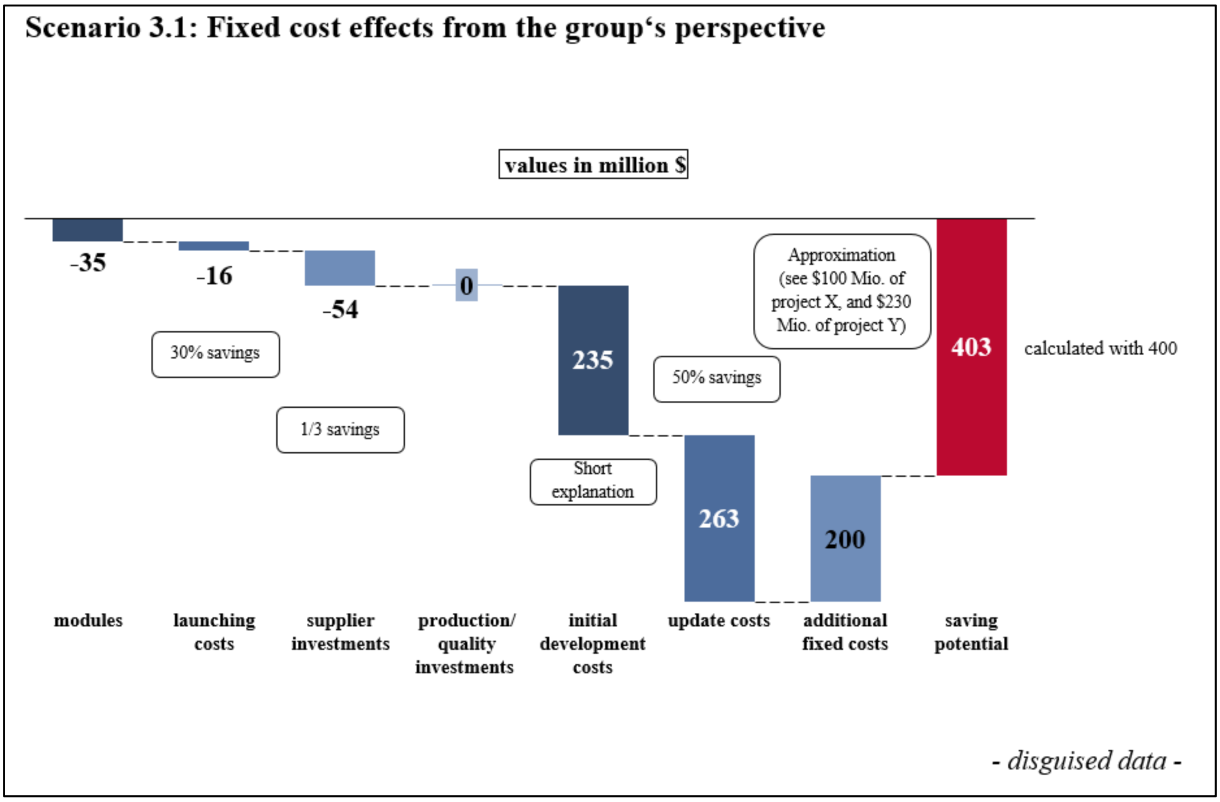

Figure 11. Fixed cost effect analysis for scenario 3.1

platform’s (for an adjacent market segment) development costs were significantly lower. The experienced controlling manager argued that this second platform benefited significantly from the first one. Consequently, the controllers reasoned that this second platform would have been much more expensive if the segment 3 platform would have not existed. Therefore, they considered the second platform’s accrued development costs as a cost saving in the calculation. The saving potential of 50% **update costs** was a rough estimation by the experienced controlling managers. And finally, the controllers integrated $ 200 Mio. **additional fixed costs** to enable *VehicleFirm’s* platform to fulfill many of *AutoCompany’s* (additional) requirements. They were able to substantiate this number with two past platform projects of the group. In these cases, $ 120 Mio. respectively $ 230 Mio. were invested for new, additional platform users that broadened the scope of the initial platform’s attributes.

These assumptions were rough estimates the controllers received during discussions with experienced controlling managers, and they integrated them in their calculation. Besides the last assumption, there was no analysis or data these values could be substantiated with. In general, *AutoCompany’s* responsible controlling manager had no problem using these rough estimations for the calculation:

> *“If anybody knows something better, he can tell.”*

The controllers contacted *VehicleFirm's* controllers and presented the premises they aimed to use for scenario 3.1. As internal cost information was needed to apply these assumptions, they asked their *VehicleFirm* colleagues to apply an analogue proceeding on scenario 3.2, and also invited them to improve the quality of these assumptions with additional information. But *VehicleFirm's* controlling manager could not be convinced to do so. He assessed the numbers to be not reliable, so there was no quantification of the fixed cost effect in scenario 3.2.

Discussion of example 3: We think this example supports our theoretical framework in several ways. First, it illustrates how disclosed details *enabled comparisons to numbers and sources*. Using today's accrued fixed costs as a basis for this part of the calculation was the hardest source the controllers could gather in that situation. Moreover, they cooperated with experienced controlling managers and developed reasonable assumptions they could process the data with. Disclosing both the input data and the assumptions developed by experienced experts, the controllers created an opportunity for the other actors to compare the provided information. If actors would doubt their assumptions, the controllers were able to refer to well-known and highly accepted experts. This hardened the calculation (see also Section 4.5.1.5).

Second, by transparently disclosing and explaining their assumptions, the controllers *reversed the burden of proof* to critical actors. The controllers were not able to "proof" their assumptions about the several fixed cost types, and they did not even try to. But the controlling manager was able to provide reasonable arguments, in one case with two benchmark values, and in the other cases both with general reasoning and expertise gathered through discussion with highly accepted controlling managers. Their assumptions made sufficiently sense. By transparently disclosing them, the controllers suggested openness and neutrality, and if actors aimed to challenge the calculation, they needed to proof that the controllers' assumptions were inappropriate. Even more, they had to provide alternative input data as well as evidence why their numbers' quality might exceed the other ones.

And last, we argue that disclosing both the numbers as well as the assumptions *implicitly expressed scrutiny*. Disclosing and explaining the proceeding made it obvious to actors that the controllers invested effort both by collecting hard data as well as by discussing and working with experienced experts. If actors compared the fixed cost input for scenario 3.1 to the fact that *VehicleFirm's* controlling manager rejected to deliver an evaluation for scenario 3.2 made it obvious that the controllers did their best to evaluate an uncertain task.

4.5.1.4.4 Evaluating profit effects

The car models both brands offered in segment 3 differed in a myriad of aspects, but one of the most obvious ones was the different range of powertrains that could be installed into the platforms. Simply speaking, *AutoCompany* was able to offer stronger engines in their car models than *VehicleFirm*. The reason why these stronger powertrains did not fit into *VehicleFirm's* platform were geometrical limitations caused by the whole modular architecture. Even as it was unclear at this point to which extent powertrain variance would be an important attribute for the future product generation, the controllers based their evaluation on the current product generation.

They gathered data for prices, costs, and installation rate about *AutoCompany's* platforms' powertrains. This enabled the controllers to compare the **profits** of powertrains that could not be offered anymore in scenario 3.1 with the profits of the strongest powertrain that would still fit into *VehicleFirm'*s platform. They set the premise to ignore potential sales unit losses. In other words, they assumed a 100% substitution rate, what implied that all customers who bought a car model with the strong powertrain would still buy one (with a much weaker powertrain then). The controllers were aware of the fact that this assumption might be far too optimistic. Nonetheless, with the introduced assumptions, they estimated this profit loss to be one billion $ (see Figure 12).

The controllers discussed potential profit effects with *VehicleFirm's* controlling manager, too. Again, he neglected to quantify an impact for scenario 3.2, so the controllers just indicated a qualitative positive impact. During a discussion in the management committee, the controllers asked representatives from other departments for more input that could impact the scenarios' profits, but nobody had additional ideas for a perceptible and quantifiable impact.

Discussion of example 4: We believe this example provides support for one aspect of our theoretical framework. By disclosing detailed information about the main assumptions (see Figure 12), the controllers *enabled* actors *to scrutinize.* The controllers were aware of the fact that a 100% substitution rate might be unrealistic, but they were not able to quantify a more reliable number. By transparently disclosing the assumptions the calculation was based on, they invited other actors to scrutinize and add information that might improve the calculation's quality. As the resulting negative profit effect was salient enough and in line with the other actors' interests, this did not happen.

4.5.1.4.5 Aggregating financial evaluation

In this section, we explain the diagrams the controllers created as a means to aggregate their financial evaluation in a comprehensible way. These figures were also presented to the management committee. For scenario 3.1., the financial evaluation is aggregated in Figure 12**.**

The controllers disclosed each result of the four individual financial impacts with one bar. While a green and upward directed bar indicated a positive financial impact for the group, a red and downward directed bar represented additional costs or negative profit effects for the group. The sum of these four bars was finally aggregated in the fifth bar which indicated the overall estimated financial group impact.

It was important for *AutoCompany's* controlling manager to disclose the main assumptions for every financial effect in small boxes. This enabled him to create a connection from more granular and detailed calculations he explained with other (back-up) slides (such as the figures shown in previous sections) to this aggregated diagram. Above the bar about the variable cost impact, the controllers disclosed both the estimated $ 400 per car and the estimated sales units. Multiplying these numbers resulted, transparent for everybody, in a total variable cost impact of $ 900 Mio. With respect to the unquantified scale effect, the controllers disclosed a question mark and a short qualitative explanation. The box that explained the total fixed cost impact entailed the main quantities the total sum consists of. And finally, the controllers disclosed the main assumptions about the profit effect calculation, too.

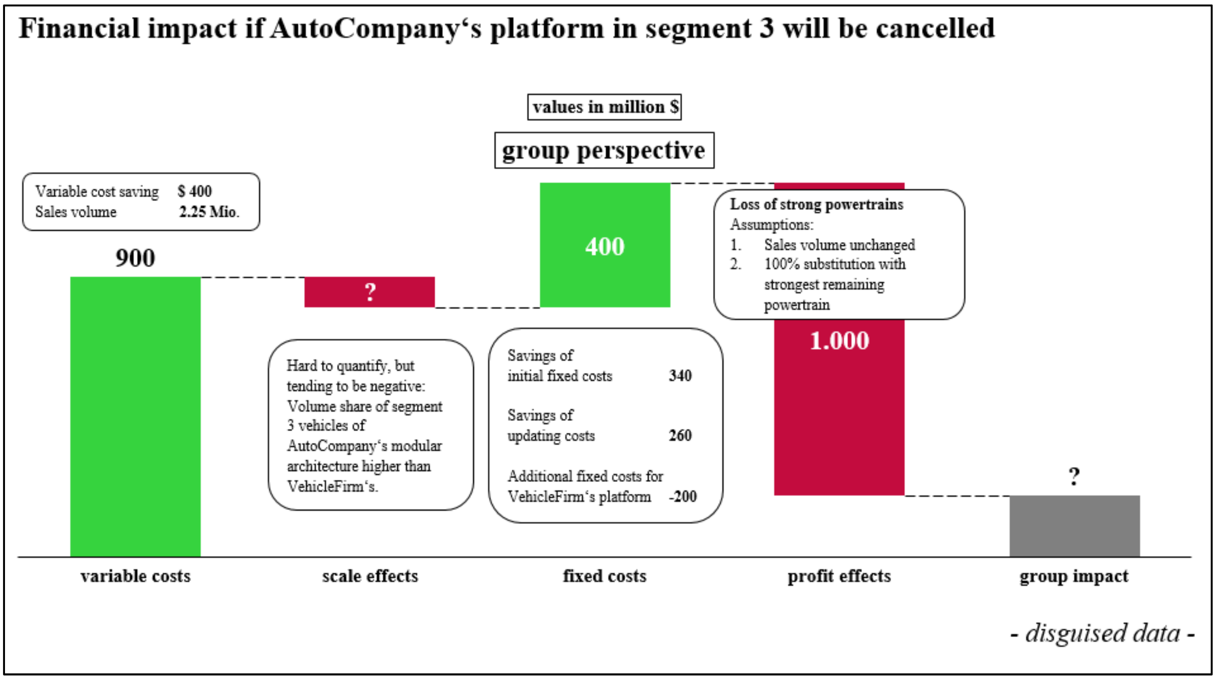

Figure 12. Aggregated financial evaluation of scenario 3.1

Summarized, if *AutoCompany* would base its future product generation in segment 3 on *VehicleFirm's* future platform, the controllers estimated significant variable and fixed cost saving potentials. On the other hand, they qualitatively argued for a negative scale effect, and quantified a large negative profit effect. In total, the controllers were not able to quantify one aggregated number for the group's impact, but disclosed a slightly positive financial impact. Figure 13 shows the aggregated financial evaluation of scenario 3.2.

As already mentioned, estimated sales units in segment 3 were quite similar for both involved brands. Therefore, the variable cost impact had the same size as in scenario 3.1, but was directed downwards. As *VehicleFirm's* controlling manager did not provide any financial estimates, *AutoCompany's* controllers could not quantify the other three financial impacts, but indicated them in a qualitative way.

As a conclusion, *AutoCompany's* controlling manager remained unsure if canceling one platform in this segment would be economically reasonable, and also formulated into the final written document that

> *"from a financial perspective, there is no clear preference derived to cancel one of the two future platforms [in segment 3]."*

Discussion of example 5: We believe this example provides additional support for our theoretical framework. First, the illustration and the provision of details *enabled comparisons between various parts of the calculation*. As every bar represented the result of one individually evaluated financial aspect, the controllers could link these several levels, zoom-into each of the

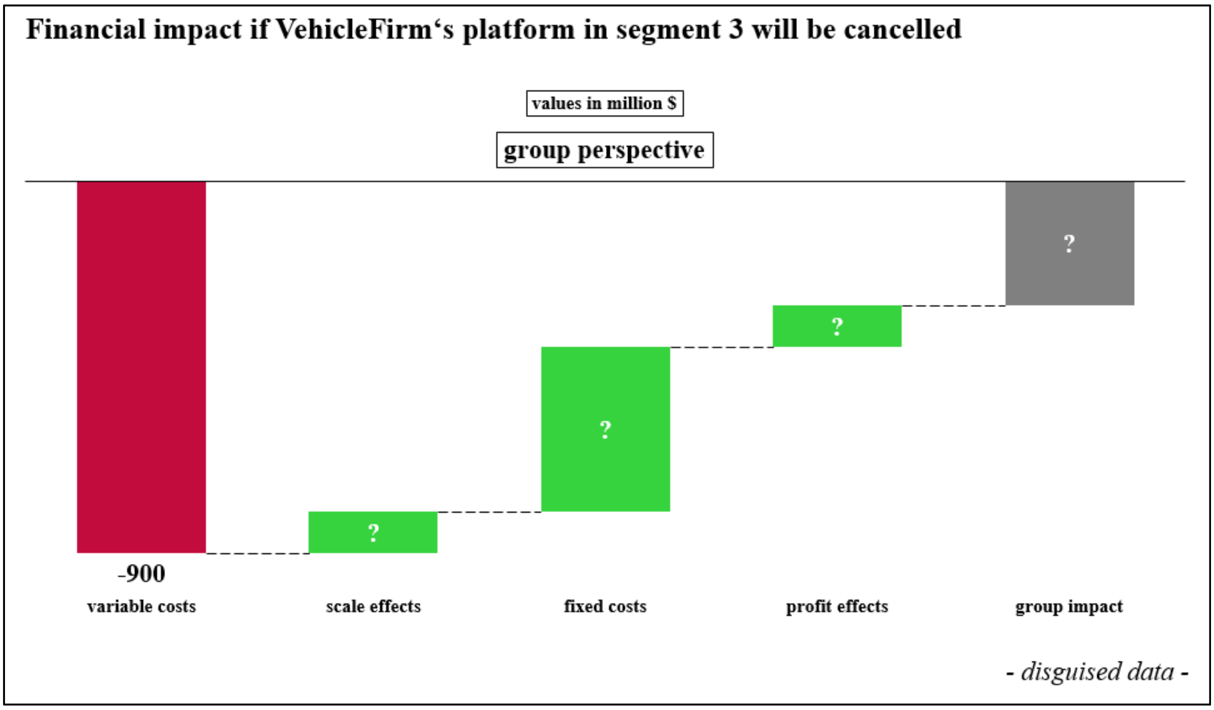

Figure 13. Aggregated financial evaluation of scenario 3.2

individual aspects, and demonstrate their calculation's consistency. Moreover, actors were able to link the calculations of both scenario 3.1 and scenario 3.2, as similar inputs, such as the variable cost difference, were disclosed on both slides.

Second, disclosing details in boxes and explaining the main assumptions and input data for every single aspect *enabled* actors *to scrutinize*. The controllers transparently disclosed their assumptions, proceeding, and input data. So, all actors should be able to understand and check the provided information, and, if necessary, criticize or correct it.

Third, the disclosed details and explanations *opened and closed the window of opportunity for challenging the calculation*. The controller aimed to transparently disclose all information they used for their evaluation in plain language. Disclosing the calculation in a meeting was the chance for critical actors to challenge it. After it was presented, explained, discussed, and finally accepted, critical actors might hardly argue that they did not know or understand how the calculation was executed. This might also lower the probability that these actors would attack the calculation later, for example during the presentation to the top management committee.

Fourth, disclosing that the calculation was based on quite hard data (such as the current projects estimated sales units) *enabled comparisons to sources and numbers.* On the one hand, this enabled other actors to check the underlying data for consistency. And on the other hand, they were able to simply reproduce the total financial impacts by processing the disclosed numbers by their own.

4.5.1.5 Zooming-in: Presenting and discussing the evaluation

Several times during the evaluation process, all involved department representatives presented working statuses to the management committee. These presentations were meant to give the committee and the *project team* an impression how things were going and developing, and what difficulties the individual actors were confronted with.

Finally, towards the end of the process, *AutoCompany's* production manager's conclusion was not to change the status quo, as

> *"[t]here is no possibility to identify explicit potentials, as vehicles are strategically anchored. An [AutoCompany segment 3 vehicle] on [VehicleFirm's platform] might probably create chances […], but these will be compensated by general facility occupancy topics."*

In the following, also other department representatives mentioned their arguments. Both *AutoCompany's* marketing and development department rejected scenario 3.1 because of reasons such as "technical disadvantages" or "not adequate for the brand".

AutoCompany's controlling manager presented the controllers' final result to the management committee at the end, too. He started the presentation by transparently disclosing and explaining the controllers' assumptions on the first two slides. He emphasized that the whole evaluation was based on the existing platforms, and went on to roughly describe and explain the method for the calculated variable cost difference. For example, he mentioned that they considered brand-individual requirements and other topics to be not relevant for the task, and therefore, subtracted variable costs of these aspects from today's variable cost differences. Subsequently, he disclosed the main assumptions for the fixed costs', scale effects', and profit effects' evaluation.

During the presentation, *AutoCompany's* controlling manager also added some comments how they derived these assumptions. For example, he mentioned that the fixed cost estimations were the result of several meetings and discussions with a few very experienced and well-known controlling managers. He also mentioned the name of one well-known, highly accepted and competent controlling manager. But he did also not insist on their assumptions' accuracy:

> *"If somebody has better input or data for us, we are totally open to it."*

He structured his presentation around the aggregated financial evaluation of scenario 3.1 (see Figure 12), and disclosed and explained every single aspect step by step. Starting with the variable cost impact, he disclosed the two-year old material cost comparison which entailed many numbers and details. By showing the same number on the first bar of our variable cost analysis (see Figure 10), he connected the controllers' analysis to this hard data. Following to that, he also explained one or two examples of each category, and reasoned why these aspects were estimated (not) to be relevant for the underlying task.

In a next step, he orally explained why they did not quantify a scale effect. Nonetheless, he argued that they expect a positive scale effect, explained how they got to that qualitative assumption, and emphasized that purchasing experts support that result. He went on and explained how the total fixed cost effect emerged. With another back-up slide (see Figure 11), he explained step by step which numbers were calculated by applying the already explained assumptions to today's fixed costs. Last, he explained that the calculated profit loss entailed a 100% substitution rate, and added his estimation that this might be too optimistic. This was immediately confirmed by the responsible marketing manager, but he did not insist to incorporate this aspect and change the calculation.

As a next step, *AutoCompany's* controlling manager presented Figure 13 not too extensively. While the variable cost effect was the same than for scenario 3.1, there were no additional quantifications left to explain. *AutoCompany's* controlling manager told the committee that *VehicleFirm* did not provide any data or quantification. Surprisingly to the controllers, this was not further criticized, but accepted by the committee.

While all involved departments of *VehicleFirm* rejected scenario 3.2, the controllers' impression was that people were relieved that their financial evaluation did not suggest to change the status quo. Therefore, maintain the current state, also for the future product generation, was the *project team's* recommendation. The group's general manager was present during the final discussion in the management committee. He seemed convinced and commented that

> *"finally, there is a reason why we do the things how we do them."*

Discussion of example 6: We argue that this example provides additional support for our theoretical framework. First, transparently disclosing and explaining the assumptions of the whole calculation supports several aspects of our theoretical framework. On the one hand, by emphasizing that the whole evaluation was based on current product generation's data, the controllers *enabled comparisons to numbers and sources*. In addition, the controlling manager referred to an experienced controlling colleague's name to substantiate his assumptions. He used the fact that the assumptions evolved in cooperation with this well-known expert to increase actors' perceived quality of the calculation.

Moreover, disclosing anticipated future changes was a means to *implicitly express scrutiny*. This aspect showed that the controllers did not just collect and apply current data (a proceeding some actors could estimate to be rather simple and inappropriate). To the contrary, it expressed that the controllers put effort into the numbers, hardened them, and made them appropriate to include in the calculation. The fact that *VehicleFirm's* controlling manager did not provide any evaluation at all implicitly supported that impression. While his counterpart was not able (or motivated) to provide any kind of evaluation, *AutoCompany's* controlling manager provided a quite sophisticated calculation, and was able to disclose, explain and substantiate many elements of it.

In addition, by transparently disclosing the assumptions and inviting other actors to contribute, the controlling manager *reversed the burden of proof.* He suggested neutrality and openness, what could also be seen as a means to increase the calculation's acceptance by dispersing the suspicion of a biased evaluation. As long as anticipated changes and assumptions were within a reasonable grey zone, critical actors might have difficulties to challenge the calculation.

Disclosing and explaining their calculation method and logic *enabled comparisons to calculation methods.* The applied method was not a standard or a highly accepted routine procedure. Therefore, the controllers aimed to first create an understanding and acceptance for the applied method, and afterwards disclose the results. If actors had understood and accepted the applied method, it might be harder for critical actors to challenge the resulting numbers by arguing that the method is inappropriate.

Second, zooming-into each financial aspect with one or even two levels of back-up slides that disclosed more details *enabled comparisons between various parts of the calculation*. The controlling manager used the aggregated slide to summarize all relevant aspects. The most important aspects of each impact were disclosed on it. Actors could find those numbers in much more detail on provided back-up slides. This enabled them to bring the several aspects together. Furthermore, it was a means for the controllers to demonstrate consistency.

Third, the fact that all actors of the *project team* presented their working statuses during the process *opened*, but also *closed the window of opportunity to challenge* it. During the working process, individual aspects of the evaluation were already presented and discussed with the management committee. But at these stages, no final result existed, and the whole evaluation was still not finished. Later, when the whole evaluation was presented, critical actors might have difficulties to challenge aspects that were already presented and accepted in previous sessions.

4.5.1.6 Zooming-in: Final decision and justifying the calculation

Before the group's top management committee took place, the group's responsible top financial manager requested via mail that details about the financial evaluation have to be present at the meeting. The official document he was briefed with included only the aggregated evaluation shown in Figure 12 respectively Figure 13. Therefore, the chairperson of the *project team* (who was meant to present the topic to the group's top management committee) asked the controllers for further details of the evaluation:

> *"Is there another back-up to explain the [$400] variable cost difference in more detail? I could imagine that the [group's top management committee] wants to see some more about it."*

He expected that the financial evaluation would be examined in a critical way by group's top management. Therefore, it was important for him that he was able to defend it with further details and background information. The controllers sent him several back up slides that explained in detail how the financial effects were calculated.

Unfortunately, the controllers did not know if and how he finally used these back-up information during the top management committee, but as a result, top managers by all involved brands confirmed to maintain the status quo in segment 3, in other words, not to realize scenario 3.1 or 3.2. This decision was also supported by the group's top financial manager (how we could see in the official protocol of the committee)

> *"under the assumption that the parallel covering of segment 3 was considered extensively from a financial point of view."*

The group's responsible financial top manager contacted the controllers after this decision, and requested more detailed information about the financial evaluation. Obviously, he wanted to check the numbers. The controllers delivered information, data, and explanations developed during the process via mail. *AutoCompany's* controlling manager also pointed out that they made quite a few assumptions, and emphasized that *VehicleFirm*'s controlling representatives did not provide any data at all. In the following, the controllers also had to explain several issues on the phone to a subordinate of the financial top manager. Finally, their evaluation was understood and accepted.

Concluding discussion of episode 1: We believe that it helped the controllers that they were able to provide rich details and information about their calculation after the decision was made. This expressed both their effort as well as the extent the calculation has been scrutinized. Especially compared to the almost non-existing calculation of scenario 3.2., attacking the calculation would have been quite hard for the group's top financial manager.

Even as the controllers were not able to quantify all aspects, we argue that they increased users' acceptance by not overestimating the magnitude of the negative and not-quantified financial impacts. Disclosing both a too high negative scale effect for scenario 3.1, as well as a (soft) premise about a lower substitution rate for the profit impact might have caused users' resistance. The negative impacts could be sufficiently explained, and were also big enough to reduce the net result to only a slightly positive impact of scenario 3.1. This was also in line with the controlling manager's agenda. The total impact suggested by the calculation seemed far not big enough to outweigh the high level of uncertainty, and therefore it seemed not appropriate to trigger a change of the status quo.

We argue that the calculation was reasonable like this, but we would expect that, if the evaluation would have suggested a change of the status quo, some actors' resistance and requirements to the calculation's quality would have been significantly higher. But in this setting, the calculation was strong enough to prevent change. With the disclosed assumptions, the controllers were within the boundaries of an acceptable "grey zone" – without letting the

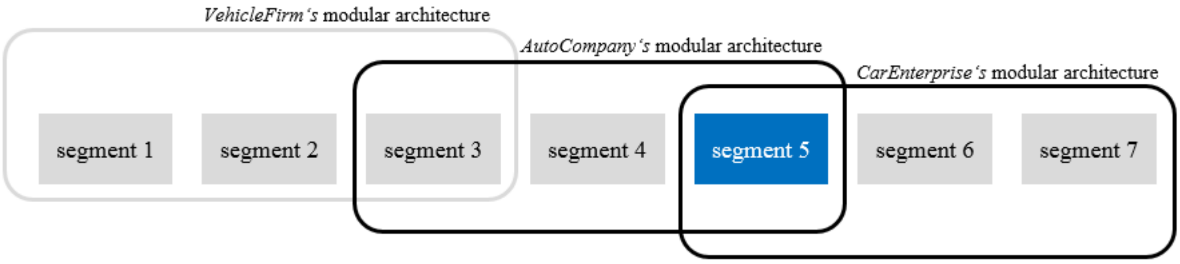

Figure 14. Existing modular architectures & segments covered – focus on segment 5

calculation appear to be biased or promote individual agendas. Being able to transparently disclose the evaluation's details was important to maintain its credibility.

4.5.2 Episode 2: Future platform(s) in segment 5

In this section, we present episode 2. The task was comparable to the one in episode 1, but the segment, circumstances, interests, decision process, affected brands (*AutoCompany* and *CarEnterprise* in this case) as well as the result were different. In this case, the *project team* was asked to evaluate if the number of platforms could be reduced from two to one for the future car generation in segment 5 (see Figure 14). The task was formulated at the beginning of 20xy, too. In order to avoid too many repetitive elements, our explanations will be partly less extensive compared to episode 1.

The structure is similar to the previous section. First, we introduce the initial situation, and explain the trigger of the task. Next, we present the key actors involved during the evaluation process. In the following, we give a short summary of the whole process, and zoom-into a few key steps and situations. Finally, we describe how the final decision was made. Analogue to the previous section, we will look on our empirical data through the lens of our theoretical framework.

4.5.2.1 Initial situation and motivation for episode 2

The task of this second episode was to examine if the current situation in segment 5, namely that both *AutoCompany* and *CarEnterprise* based their products on separate platforms (of different modular architectures), could be improved in the sense of one common platform for the future generation. Similar to episode 1, the task was formulated before *AutoCompany* started to work on its future modular architecture's concept. The current situation and the field of interest is shown in Figure 14.

More precisely, the initial task was to evaluate the consequences if *AutoCompany* would base its future product generation in segment 5 on *CarEnterprise's* future platform. Like this, the group's top management aimed to realize synergies.

4.5.2.2 Which actors were involved?

The organizational structure and work processes were comparable to episode 1. Responsible managers and actors of *AutoCompany* were nearly the same, and they cooperated with *CarEnterprise's* managers to solve the task. The evaluation process was coordinated by the chairperson of the *project team*, and working statuses respectively results were presented to the management committee respectively top management committee.

The controllers, namely *AutoCompany's* controlling manager and the researcher, led the financial evaluation process, but *CarEnterprise's* controlling manager was intensively involved. He contributed several aspects to the analysis, provided data, and executed own evaluations.

4.5.2.3 Chronological summary

Analogue to episode 1, the management committee agreed at the beginning of the process to widen the evaluation's scope, and examine to base the relevant cars on *AutoCompany's* future modular architecture. Therefore, two analogue scenarios were formulated, see Table 9. Both the *project team* and *AutoCompany's* controlling manager defined the same evaluation criteria than for the task of episode 1. Therefore, the controllers collected data and evaluated effects about variable costs, fixed costs, scale effects, and profit effects for a couple of months (we will present this process in detail in the following section).

It was very important to *AutoCompany's* controlling manager to apply similar procedures and assumptions on this second task. Doing that, he expected to raise evaluations' acceptance and credibility, and the controllers only deviated from that if good reasons were apparent. The controlling manager was far less skeptical about this second task. During the first phase of the evaluation process, he said to the other controller:

> *"We have to make it to base all the[se] [...] vehicles on one platform - no matter if it is developed by us or CarEnterprise. It makes absolutely no sense to develop two platforms for this segment. There is just too much saving potential we cannot ignore anymore."*

The result of the financial evaluation of scenario 5.1 were significant cost savings. For scenario 5.2, the aggregated financial impact, evaluated in cooperation with *CarEnterprise's* controlling manger, was insignificant. Similar to episode 1, the chairperson of the *project team*

Table 9. Scenarios to be evaluated in episode 2

Base of future product generation of all car models in segment 5	
AutoCompany's modular architecture	*CarEnterprise's* modular architecture
scenario 5.1	**scenario 5.2**

slightly adapted the way the results were presented, and asked every brands' department to disclose their individual findings separately. Moreover, towards the end of the evaluation process, several additional scenario variants were brought up, and the task's complexity increased. In the remaining period of time, the controllers were not able to fully evaluate each of these additional scenario variants, so they provided individual aspects of their financial evaluation where appropriate. As general guideline, *AutoCompany's* controlling manager recommended every scenario variant that resulted in only one platform for the segment. Therefore, the controllers maintained their recommendation to base all car models on one common platform.

The controllers' recommendation was opposed to the interests and arguments by marketing, development, and production managers, so the *project team* did not come not to a collective conclusion. Presenting the individual scenario variants to the committees, neither the management committee nor the top management committee made a decision. Instead, the committees postponed the decision for several months, and the new modular architecture's conceptualization was started anyway. This implied that, in the first step, segment 5 car models' requirements were not taken into account. *AutoCompany's* controlling manager commented on that:

> *"If you ask me, not having the courage to decide that now means that we only bought some time."*

In the second half of the year, both *AutoCompany's* and the group's CEO determined that the future segment 5 vehicles by both brands had to be based on one common platform.

Discussion of example 1: We believe this example illustrates one aspect of our theoretical framework. The controllers forced to provide a similar calculation for both the first and the second task to *enable comparisons to calculation methods*. If their proceeding during episode 1 was accepted, critical actors might have difficulties to reason why an analogue method might be inappropriate for this similar task. Therefore, disclosing consistency between both evaluations was a means to protect the calculation against actors that did not favor just one of the two evaluations' outcome. Moreover, the controlling manager's agenda came to light already at the beginning of the evaluation process. He seemed to be convinced that one common platform in this segment would be the best alternative for the group, regardless which brand would provide the corresponding modular architecture.

4.5.2.4 Zooming-in: Preparing the calculation

In this section, we zoom-into several key processes and situations during the evaluation process, and give detailed insights how the several financial effects emerged. We also describe how the task's complexity was raised towards the end of the evaluation process, and why the final decision was postponed.

4.5.2.4.1 Evaluating variable cost effects

Similar to episode 1, the controllers started the **variable cost effect** analysis with an existing and two year old material cost comparison of two car models. The existing comparison suggested that *AutoCompany's* platform in segment 5 seemed approximately \$4.500 cheaper than *CarEnterprise's*.

This initial cost difference was significantly high, and the following updating and evaluation process was much more laborious. During this process, the controllers struggled with several challenges and complexities. *AutoCompany's* respectively *CarEnterprise's* definition which parts belong to the platform differed. In addition, the two platforms significantly varied with respect to degrees of vertical integration, number of wheelbases, transmission technologies, engine performances, lightweight philosophies, and models (for example, one brand based a cabriolet on its platform. This implied a much more complex concept). All these aspects might influence a platform's material costs, but the controllers were not able to fully extract their individual cost shares.

As already explained above, the existing evaluation compared two car models (with a particular set of properties, such as powertrain technology, suspension system, etc.). The controllers found out that *AutoCompany's* car model's particular configuration represented less than 10% of its total sales units. In other words, the underlying analysis was not too representative. As time was scarce, the controllers decided to work with what they had, and started to evaluate the variable cost impact similarly to episode 1. Figure 15 shows their first result.

The initial variable cost difference of over \$4.500 decreased to approximately \$3.000 by updating the data and including recent decisions. In other words, *AutoCompany's* decisions during the past two years increased their platform's variable costs by approximately \$1.500. Following the same logic than in episode 1, the controllers deducted \$990 because of brand-individual requirements. For example, *AutoCompany's* controlling manager estimated that there was no comprehensible argument why the two involved brands should apply two different axles in that segment. Consequently, the controllers classified the axles' cost difference as not relevant for the underlying purpose. A comparably high cost difference of nearly $2.000 remained.

Until that point, the controllers evaluated the variable cost difference in cooperation with *AutoCompany's* cost experts. As they planned to present a working status to the management committee, the controllers sent the analysis (basically the chart shown in Figure 15 with a few explanations) to *CarEnterprise's* controlling manager to inform him beforehand. He contacted the controllers immediately and expressed his dissatisfaction:

> *"I disagree with the diagram of the material cost delta. I cannot confirm the material cost delta like this. […] [CarEnterprise] is not more expensive here […]."*

Both the controllers and *CarEnterprise's* controlling manager agreed to present the current status to the management committee, and *AutoCompany's* controlling manager promised to emphasize the working status characteristic of the analysis. Both him and *CarEnterprise's* controlling manager announced to further examine the remaining $2.000 cost difference, mainly caused by the different powertrain concepts. Consequently, the management committee instructed the controllers to compare the different powertrain concepts in more detail.

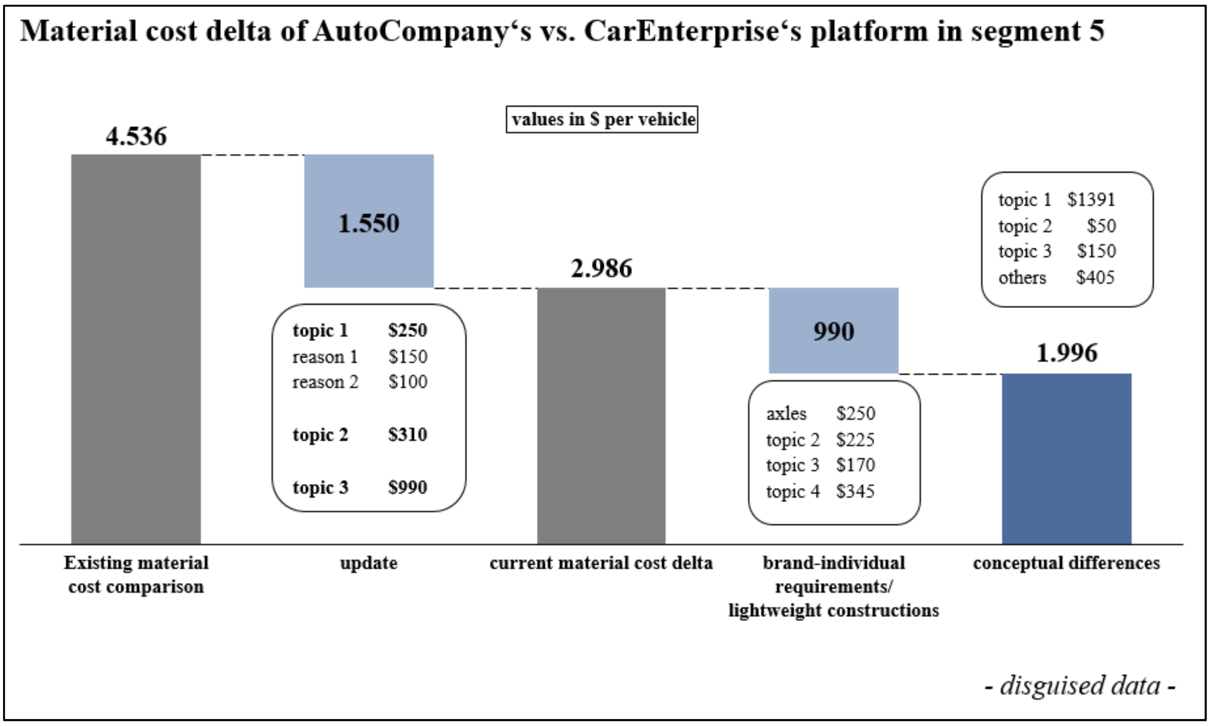

Figure 15. Material cost delta analysis for segment 5 (version 1)

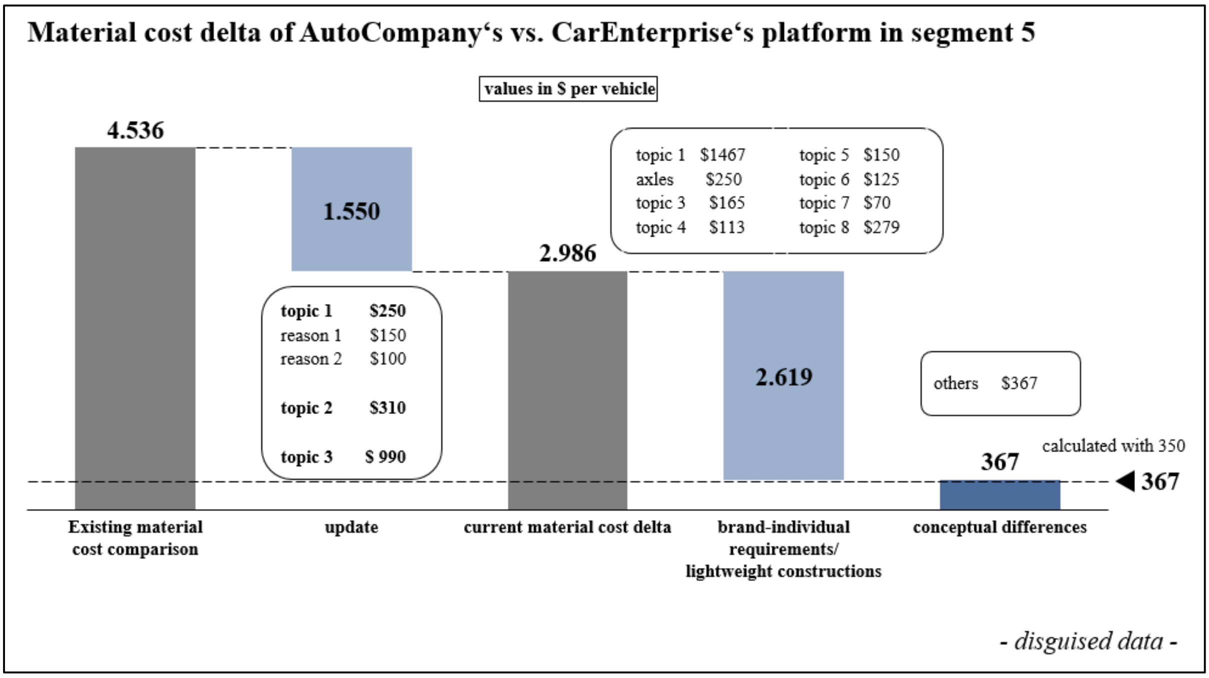

Figure 16. Material cost delta analysis for segment 5 (version 2)

The controllers conducted additional analysis for several weeks. They found out that the remaining material cost difference was mainly caused by different gearbox concepts. They decomposed the gearboxes' cost difference and disclosed more details, and finally set the assumption that both kind of gearboxes could be integrated into a common platform. The controllers were able to justify that assumption, as another existing platform within the group already offered both kinds of gearboxes. The controlling manager orally referred to that existing platform during his presentation to the management committee. After all, the controllers were able to reduce the remaining variable cost difference to $367. This second, updated analysis of the cars' material cost differences is shown in Figure 16.

The controllers were not able to verify the remaining $367. As the result was in a similar range than in episode 1, they defined the residual variable cost difference to be caused by deviating concepts, and included it in their calculation.

Discussion of example 2: We argue that this example provides additional support for our theoretical framework. Analogue to the example 1 in episode 1, the calculation *implicitly expressed scrutiny*, and enabled *comparisons between various parts of the calculation* and *to numbers and sources*. While actors could compare the calculation to hard data, such as the existing cost comparison, they were also able to compare the result to the analogue calculation of episode 1. Also due to that similar result, the calculation seemed plausible to actors.

Going beyond these already discussed aspects, the calculation enabled *comparisons to calculation methods*. The controllers chose an analogue proceeding, and disclosed the calculation's details in an analogue way. This made it more difficult for critical users to attack the calculation.

Nonetheless, the variable cost difference analysis deviated significantly from the one in episode 1. Updating the initial material cost comparison resulted in a far higher reduction of the cost differences. As a first result, the cars' variable cost difference remained remarkably high. This led to a further cost evaluation, and we argue that two aspects led to the additional task: first, it was not in line with *CarEnterprise's* controlling manager's interests to disclose that the platform his company was responsible for was much more expensive, as this would have implied two things: on the one hand, actors could conclude that *CarEnterprise's* future product generation should be based on *AutoCompany's* platform to realize significant cost savings. And second, the way the controllers disclosed detailed information that explained the remaining cost difference *enabled actors to scrutinize.* They showed that one particular component caused a large part of the remaining variable cost difference. This disclosed information enabled actors to connect the calculation's result to their own expertise and gut feel, and discussions were started to which extent cost differences of deviating gearboxes impacted a platform's concept.

Several weeks later, the controllers presented an updated version of the variable cost evaluation. This *explicitly expressed scrutiny*. Actors were aware of the evaluation's first version, and the controllers could refer to the task they were instructed with. By disclosing and explaining much more details, actors could clearly see that the controllers processed the task in an adequate way.

The additional and much more detailed evaluation also enabled the controllers to set and justify the assumption that the gearboxes' cost difference was not relevant for the task. Doing that, the controllers *reversed the burden of proof*. In order to attack the calculation, critical actors should be able to provide evidence why the controllers' assumption was not correct. In this particular context, the controllers could refer to an already existing platform that offered both kind of gearboxes. This enabled *comparisons to a broader context.* If critical actors would try to attack this crucial assumption, the controllers could protect it by referring to information we would argue to be very hard.

4.5.2.4.2 Evaluating scale effects

In contrast to episode 1, the controllers assumed that significant **scale effects** could be realized in segment 5. They reasoned this deviating assumption with the same low total sales units of both car models. Experienced *AutoCompany's* controlling managers neglected a significant impact on *AutoCompany's* modular architecture if their car model would be based on

CarEnterprise's platform in the future. They assessed that their current segment 5 platform applied only few carry over parts from other platforms of the same architecture, and reasoned that the current car models realized only few synergies of the modular architecture.

The controllers based their scale effect evaluation on an existing scale effect quantification. About a year ago, the group's management board was confronted with the decision to realize or cancel an additional car model in segment 5, and *AutoCompany's* controlling and purchasing experts conducted an analysis to estimate scale impacts for the other car models. Their evaluation resulted in scale effect rates between 3% and 12% of cars' material costs, and these values were accepted and considered during the decision. The controllers applied the same figures on the platforms' current material costs. Finally, this led to a positive scale effect of 400 Mio. $, both in scenario 5.1 and 5.2 (see Figure 18 respectively Figure 19).

Discussion of example 3: We believe this example provides support for our theoretical framework in two ways. On the one hand, the controllers referred to an existing evaluation what *enabled comparisons to numbers and sources*. The applied percentages were accepted and considered during a decision by the group's management board in the past. Therefore, actors accepted them, because the numbers seemed to be quite hard, and the controllers did not provide much details about the way or method these numbers emerged.

On the other hand, disclosing the assumed percentage figures also *reversed the burden of proof*. For the existing evaluation, different percentages were used, and the controllers chose to apply an average value (4%). There was no final proof that this was the right number to calculate with, but critical actors were not able to argue for different numbers that would have fit their interests in a better way.

4.5.2.4.3 Evaluating fixed cost effects

During several discussions with experienced controlling managers, the controllers developed arguments and assumptions to evaluate the **fixed cost impacts**. These arguments deviated in two ways from episode 1: on the one hand, the controllers assumed that 100% of the platform's development costs could be saved in scenario 5.1, as its impact on the remaining modular architecture was assessed to be insignificant. And on the other hand, they set a (lower) amount of $150 Mio. to enable *CarEnterprise's* platform for *AutoCompany's* additional requirements. The controlling manager argued that, from his perspective, the car models in segment 5 differed less than the ones in segment 3. Figure 17 shows the fixed cost quantification for scenario 5.1.

Overall, the controllers' evaluation resulted in fixed cost savings for scenario 5.1 of over $600 Mio. As an additional means to prevent attacks on the calculation, *AutoCompany's* controlling manager suggested to include a 20% deviation corridor. He was expecting attacks on the calculation, for example that critical actors would try to question single elements of the assumption set, and therefore also the calculation as such. By disclosing a 20% range of the calculation's result, he aimed to prevent such detailed discussions.

For a fixed cost evaluation of scenario 5.2, internal cost information was needed, so the controllers informed *CarEnterprise's* controlling manager about their assumptions and explained their evaluation to him. During this meeting, it became obvious that *CarEnterprise's* controlling manager shared *AutoCompany's* controlling manager's opinion that one platform in this segment would be beneficial for both brands. And, as *AutoCompany's* controlling manager requested an analogue evaluation for scenario 5.2, *CarEnterprise's* controlling manager confirmed to do so. Several days later, he informed the controllers that an analogue logic for scenario 5.2 would lead to a favorable fixed cost impact of approximately $500 Mio. This result seemed plausible to *AutoCompany's* controlling manager, and he accepted to include it in the evaluation without asking for further details.

Discussion of example 4: We think this example provides additional support for our theoretical framework. As already discussed in Section 4.5.1.4.3, basing the calculation on current cost data *enabled comparisons to numbers and sources*, and disclosing and explaining

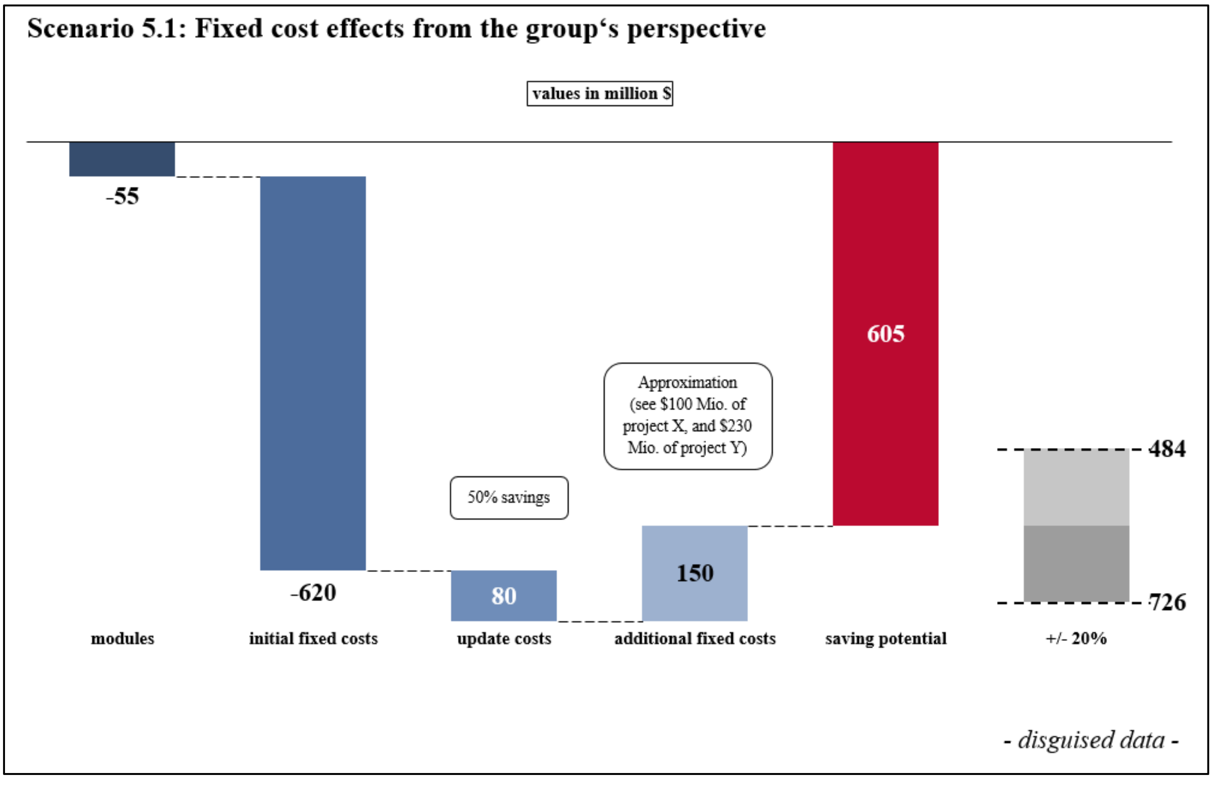

Figure 17. Fixed cost effect analysis for scenario 5.1

the controllers' assumptions *reversed the burden of proof.* Besides these already discussed aspects, the calculation *enabled comparisons to calculation methods*. The applied method was, at least to a large extent, similar to episode 1. In this second episode, *CarEnterprise's* controlling manager was also willing to calculate a fixed cost effect, and actors were able to compare results of these two calculations. The two results were not too different, and this helped the controllers to demonstrate consistency. Moreover, *CarEnterprise's* controlling manager applied an analogue proceeding (with the same assumptions) to calculate the fixed cost impact for scenario 5.2. This additionally supported the controllers' assumptions' credibility.

Compared to episode 1, the controllers disclosed and explained partly deviating assumptions. This *implicitly expressed scrutiny*. Instead of calculating in an identical way, the controllers could argue why it seemed more adequate to adapt some aspects of the proceeding. We argue that these scenario-specific assumptions, as long as the controllers could provide logic and reasonable arguments for it, expressed the controllers' competence. This might have increased the persuasiveness of the calculation, too.

Finally, the controllers disclosed the sensitivity of the calculation's result as a means to protect their evaluation. Their assumptions were, at least in parts, not too strong, and the controllers also did not want to act like if they would be. They transparently disclosed them, and *opened the window of opportunity to challenge the calculation*. By showing that a 20% deviation of the final result would not change the evaluation's message, the controllers implicitly approved their assumptions' softness, and aimed to shift the focus away from these details. If the calculation was then presented, discussed and accepted, the *window of opportunity to challenge* it was closed.

In addition, the controllers had won an ally. *AutoCompany's* controlling manager was strongly interested in reducing the number of platforms in this segment, and *CarEnterprise's* controlling manager aimed to change the status quo, too. We argue that, because of this agenda, he provided a fixed cost estimation, and *AutoCompany's* controlling manager demonstrated confidence in these numbers by not asking for further details or explanations.

4.5.2.4.4 Evaluating profit effects

For the **profit effects**' evaluation of scenario 5.1, *AutoCompany's* controlling manager was aware of one particular property *AutoCompany* included already in its base model in segment 5, while other competitors offered this property as special equipment. *AutoCompany* cancelled to offer this property as special equipment years ago to reduce complexity. *AutoCompany's* controlling manager estimated this strategy quite critical, and argued that, while other brands realize additional profits with it,

> *"we give [the particular property] away for free".*

CarEnterprise also offered that particular property as special equipment, and the controllers asked *CarEnterprise's* controlling manager to deliver data about installation rate, price, and costs of the property. He did so, and the controllers slightly adapted these figures and calculated a business case. This business case suggested that *AutoCompany* could realize additional profits of $ 100 Mio. if they would apply an analogue strategy (see Figure 18). The controllers assumed a 100% substitution rate – in other words, analogue to scenario 3.1, they set the premise that total sales would remain unchanged. The other controller also discussed the topic with an *AutoCompany* marketing manager who criticized the approach:

> *"You might be right, but the pricing methodology works like this since umpteen years. This is all not that easy."*

AutoCompany's controlling manager was not convinced (or even a bit annoyed) by this attitude, and included this aspect in the evaluation anyway.

For scenario 5.2, profit effect estimations were evaluated by *CarEnterprise's* controlling manager. First, he estimated a profit loss if *CarEnterprise* would not be able to offer the particular property as special equipment anymore. But in contrast to the controllers' business case, he also assumed a significant sales loss. This deviating logic resulted in a significant higher profit loss of $250 Mio. Second, he announced an additional profit risk for scenario 5.2 of $ 750 Mio., and referred to a working premise by *AutoCompany's* development department not to offer the strongest powertrains for the future product generation anymore:

> *"After consulting [AutoCompany's] R&D department, the next platform generation will not provide the possibility of [the strongest] powertrains. Not offering them, we expect a significant loss of sales."*

Again, he deviated from the profit effect logic the controllers had applied in scenario 3.1, and also considered a significant loss of sales (i.e. substitution rate <100%). The other controller told *AutoCompany's* controlling manager about this inconsistency, but *AutoCompany's* controlling manager had no problem with that. He immediately accepted the fact that scenario 5.2's profit loss compensated the other cost savings (see Figure 19), and announced to briefly mention the methodological inconsistency during his presentation to the management committee.

The other controller estimated the profit loss to be not valid for another reason. From existing projects, the controllers were aware that integrating a powertrain into a platform implied investments of a fraction of the profit loss *CarEnterprise's* controlling manager had evaluated for scenario 5.2. Therefore, it would be economically not advisable not to enable the platform for the strong powertrains, and considering this aspect with an additional amount of fixed costs in scenario 5.2. would have made more sense from the other controller's perspective. But, as already mentioned, *AutoCompany's* controlling manager refused to challenge these inputs, and decided to include them in the calculation.

> *"If somebody criticizes these aspects, he [CarEnterprise's controlling manager] has to defend them by himself."*

Discussion of example 5: We believe this example provides additional support for our theoretical framework. The controllers disclosed the data the business case was based on, and this *enabled comparisons to a broader context.* The controllers could argue that the data and information was based on *CarEnterprise's* business model. Consequently, it might be hard for critical users, such as the marketing manager, to argue that this aspect was too soft to integrate into the calculation.

Moreover, disclosing the business case's details *opened the window of opportunity for challenge*. Even as the marketing manager did not agree to the proceeding beforehand, he did not attack the final calculation. We assume he did not because of another reason besides the one mentioned above. It became obvious that the calculated profit effect in scenario 5.1 was not too salient, and the disclosed sensitivity corridor might have prevented further critics.

The disclosed calculation also *enabled comparison*s *to calculation methods*. Even as the controllers did not hide the deviating approaches for the profit impacts (see the deviating designations of the profit effect bars in Figure 18 respectively Figure 19), they also did not transparently disclose it. We would argue that they pretended consistency. *CarEnterprise's* controlling manager did not provide any details about his profit estimation, and we argue he did not in order to prevent a critical discussion about it. On the other hand, it helped him that actors were able to make comparisons to the profit effect in episode 1. In scenario 3.1, the profit evaluation's result was, even for different reasons, even larger.

From our perspective, this example also implicitly expresses the agenda of *CarEnterprise's* controlling manager. He announced a large profit loss for scenario 5.2, without providing any details. This procedure could indicate that he shared the objective of saving one platform, but aimed to prevent that *CarEnterprise's* next car generation was based on *AutoCompany's* platform. We assume that *AutoCompany's* controlling manager, who had no intense interest to keep the platform's responsibility, did accept that proceeding in order to not lose his ally.

4.5.2.4.5 Aggregating financial evaluation

Analogue to episode 1, the controllers created illustrations that aggregated the four financial impacts. Finally, these individual impacts added up to a total financial impact for the group. Figure 18 summarizes the financial implications of scenario 5.1.

Compared to episode 1, the total variable cost effect was low, foremost because of the low sales units in this segment. On the other hand, scale effects, fixed cost savings, and a positive profit impact added up to a significant positive financial impact for the group. Besides the details the controllers also disclosed in episode 1, they also showed the main assumptions the profit effect was based on in the relevant box. During his presentation to the management committee, *AutoCompany's* controlling manager emphasized orally that the input data was based on *CarEnterprise's* current strategy.

The controllers included a 20%-variation bar also in this diagram. This should demonstrate that they did not claim for perfect accuracy. *AutoCompany's* controlling manager introduced this idea to prevent that the whole calculation was doubted because one or two assumptions seemed too imprecise:

> *"If somebody is going to grumble about one small element of our evaluation, we can prevent distraction from the whole thing by saying: We know our assumptions are rough, but even if we are 20% wrong, there is still so much money to be saved."*

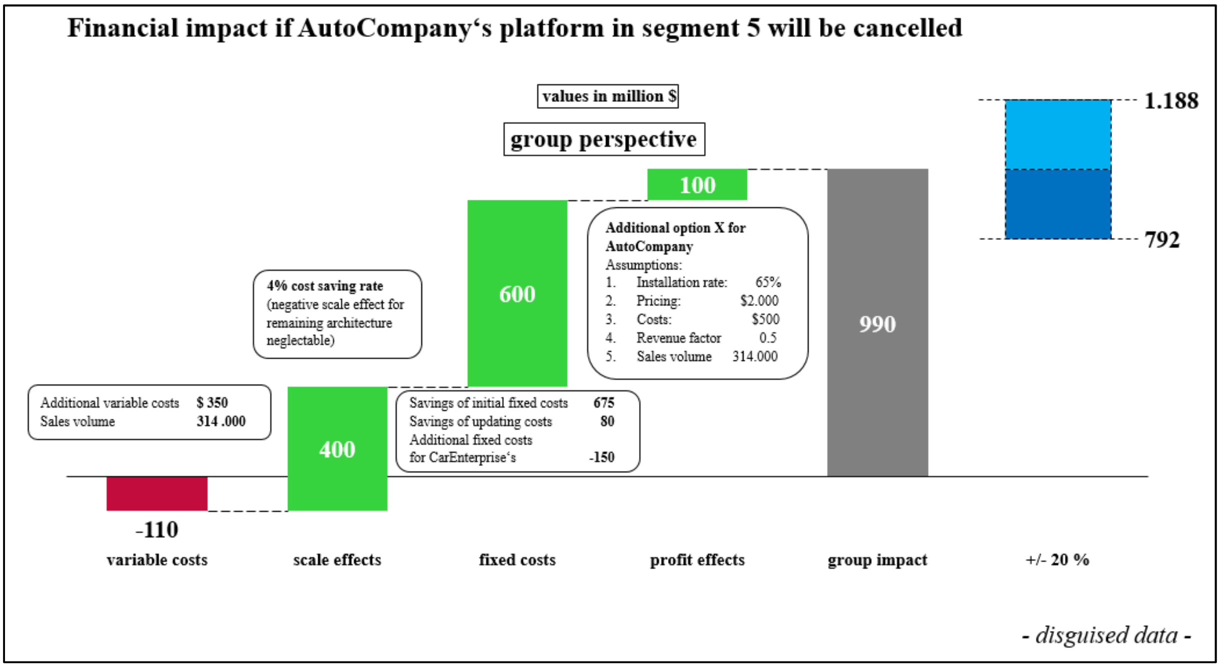

Figure 18. Aggregated financial evaluation of scenario 5.1

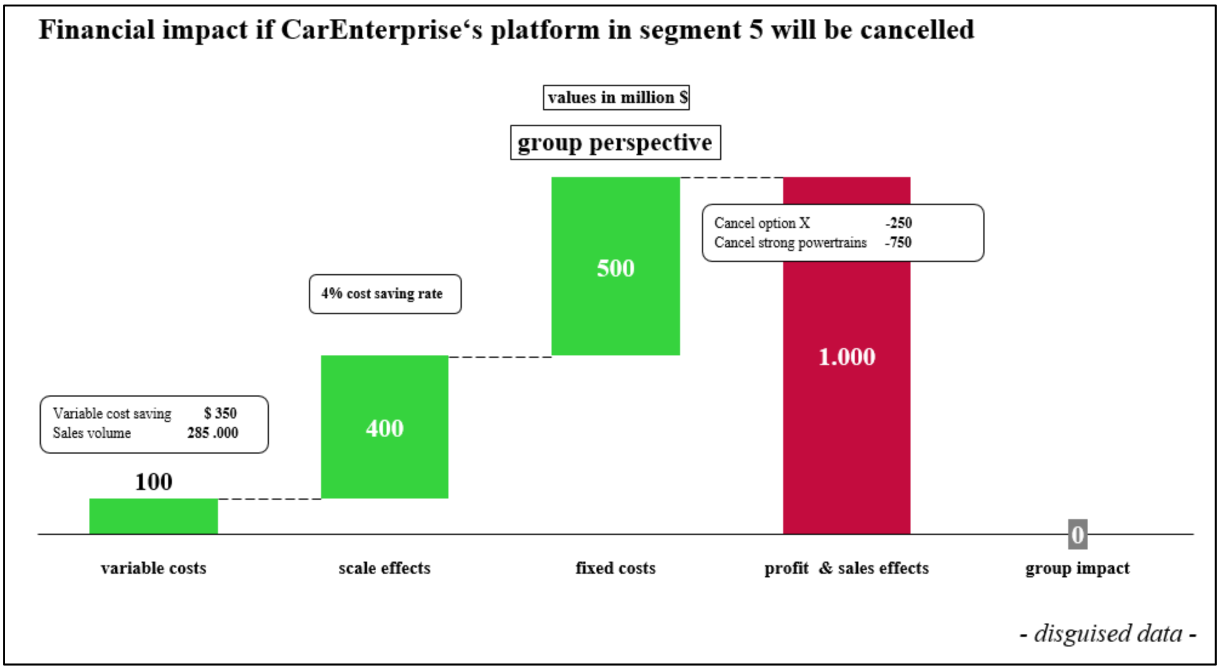

Figure 19. Aggregation of financial effects of scenario 5.2

The controllers summarized the financial evaluation for scenario 5.2 in Figure 19. The favorable impacts of variable costs, scale effects, and fixed costs were compensated by the large negative profit impact. The other controller adapted the label of the bar to 'profit & sales effects'.

Compared to episode 1, one main difference was that the controllers intensively tried to quantify all financial aspects in episode 2. From their perspective, the financial evaluation implied a clear recommendation to reduce the number of platforms.

Discussion of example 6: Besides the already discussed aspects, we believe this example provides additional support for our theoretical framework. The way the controllers disclosed the calculation *enabled comparisons to calculation methods.* The calculation was disclosed in an analogue way than in episode 1, so the controllers could demonstrate consistency. They disclosed similar details, and if a critical actor aimed to challenge some aspects of this particular calculation, this might imply a challenge of the other calculation, too. As the first episode's result was in line with almost every actors' interests, it was an additional means to prevent criticism about their calculations in episode 2.

4.5.2.5 Zooming-in: Presenting and discussing the evaluation

AutoCompany's controlling manager presented the final evaluation to the management committee. As already mentioned in episode 1, he first transparently disclosed the assumptions and explained them to the audience. He emphasized that both evaluations (for episode 1 respectively episode 2) were conducted in a similar way, and reasoned and explained in a few sentences why they partly deviated in episode 2.

Next, he explained the calculation step by step, and presented several back-up slides, too. First, he explained the updated variable cost comparison (see Figure 16). He referred to the additional task the management committee instructed after a first work status was presented, and explained how they had investigated the remaining cost difference in more detail. He mentioned a detailed analysis in cooperation with experienced powertrain experts, and described some technical details that were also disclosed on the slide. As he was done with explaining the technical reasons for the initial high variable cost difference, he justified the assumption that a common platform in the future could offer both gearbox concepts by referring to an existing platform that already did so. Finally, he concluded that the result seemed plausible by comparing the remaining variable cost difference with the result of the evaluation in episode 1.

Subsequently, he presented Figure 17**,** and explained why the fixed cost effect was higher than in episode 1. This was partly a repetition of the things he already mentioned at the beginning. He did not disclose a back up slide to explain the estimated scale effect. The main assumption (the 4% rate) was disclosed in the box above the relevant bar in the aggregated figure, and orally, he connected the assumption to the existing analysis. He emphasized that they had used similar numbers of an already accepted evaluation.

As a next step, he explained the business case which was the base for the calculated profit effect. He emphasized that the disclosed input information was based on data provided by *CarEnterprise*'s comparable current model. Finally, he closed the presentation of scenario 5.1's with the conclusion that there was a significant cost saving potential for the next product generation. He reasoned that uncertainty or rough assumptions were inappropriate arguments, as, even if a deviation of 20% was assumed, the evaluation would still recommend to change the status quo.

He went on and presented scenario 5.1's financial implications (Figure 19) less extensively. Orally, he explained that the variable cost effect, the scale effect, as well as the fixed cost effect were calculated consistently. He also briefly mentioned that the profit effect was calculated in a slightly different logic, and explained that *CarEnterprise* also expected significant sales losses in scenario 5.2. This was confirmed by *CarEnterprise's* controlling manager. Finally, he ended his presentation with the conclusion of an insignificant total financial impact. To the controllers' surprise, there were no critical comments or attacks during or after the presentation.

During discussions within the management committee, and also during the whole working process, the controllers' impression was that the involved actors' majority aimed to conserve the status quo. The controllers observed that general-, production-, development-, and sales managers from nearly all brands involved seemed to focus on arguments that contradict a common platform. In addition, they observed limited willingness of sharing information between the brands' departments. *AutoCompany's* controlling manager summarized that

> *"we can see few real willingness to find an optimum for the group."*

As an illustration, *AutoCompany's* engineers and the chairperson of the *project team* emphasized technical superiorities of "their" platform. They listed today's technical deviations, for example small differences in seating positions or divergent dimensions of one or two centimeters. As another example, *AutoCompany's* marketing managers and engineers argued with 'loosing brand-specific genes' or an 'inadequate positioning' of the product.

AutoCompany's production managers based their evaluation on current production plans, and emphasized employment protection in 'strategic anchored locations'. As another means to prevent the implementation of scenario 5.1., they announced to intensify synergies within their own modular architecture. An *AutoCompany* production manager concluded that he wanted to

> *"maintain the current modular architecture portfolio and intensify synergies with the [AutoCompany intern segment 4 production]. Due to employment protection, the production site [X] is set."*

In preparation for the upcoming top management committee, the chairperson of the *project team* defined additional scenarios for segment 5. Among other things, these additional scenarios were combinations of updating existing platforms, combining *AutoCompany's* future car generation of segment 4 and 5 on a common platform, and also combining electric and combustion powertrains in one platform. These additional scenarios made the evaluation far more complex, and the controllers' impression was that they were brought up in order to prevent a decision. During discussions about the departments' recommendations, the chairperson of the *project team* tried to convince the controllers to change, or at least moderate their formulations:

> *"Isn't there a way we can formulate it somehow different or in a softer way?"*

But the controlling manager refused to do so, and formulated that

> *"from an [AutoCompany] perspective [...], maintaining the status quo is financially not feasible."*

This was also supported by *CarEnterprise's* controlling manager during the management committee who said

> *"from my perspective, this [maintaining the status quo] is a clear miss of the task."*

Discussion of example 7: This example brings many elements together we already discussed above, but it also provides support for one additional aspect of our theoretical framework. The controllers *enabled comparisons between various parts of the calculation* by using Figure 18 respectively Figure 19 as means to guide actors through their evaluation. They disclosed the most important details on the slide that summarized their evaluation, and were able to go deeper and explain every single aspect with one or two additional back up slides. When appropriate, the controllers disclosed the same detailed information for both scenarios, and demonstrated that they had used consistent data.

4.5.2.6 Final decision

Besides the significant uncertainty about the brands' future strategy in segment 5, mainly actors' deviating interests were the reason why the *project team* did not come to a collective conclusion. Consequently, the group's top management committee received a summary of the different scenarios, including the main pros and cons, individually evaluated by each brand respectively department. The controllers could not participate in that meeting. As a result, the top management committee decided to start the conceptualization of *AutoCompany's* new modular architecture without considering requirements of segment 5. The decision for the car models in segment 5 was postponed for several months.

In the second half of 20xy, the other controller noticed that both *AutoCompany's* CEO, as well as the group's CEO, formulated that the *AutoCompany's* future segment 5 car models would be based on a common platform in cooperation with *CarEnterprise*. The chairperson of the management committee reported that the group's CEO formulated during a meeting that

> *"to have only one platform [...] across all brands is not the objective – it is the order."*

The controllers could not really trace back how the group's CEO finally came to this conclusion. As the significant cost saving potentials they had evaluated was also known in the group's top management, it seemed reasonable to them that he was aware of their financial evaluation.

4.5.3 Episode 3: Future modular architecture's concept

We present episode 3 in this section. This episode deals with the decision process about the future (technical) concept for the new modular architecture. While *AutoCompany's* current modular architecture was designed for combustion cars, its future strategy implied that also a significant number of electric car models needed to be sold. Therefore, the question how both drive technologies would be implemented for the future product portfolio came up at the beginning of the new modular architecture's concept stage. The architecture aimed to cover several market segments of sedan vehicles (also different body variants such as station wagons or coupés), and two SUV segments: compact and full-size SUVs.

It took *AutoCompany's* management board more than a year to make that decision. During the first nine months, most arguments involved actors brought up strongly recommended to follow a flexible modular concept that combines both combustion and electric drive technologies. But towards the end of the process, additional, also financial aspects, changed this view. The final decision was to strictly split the future product portfolio into pure combustion and pure electric car models, and consequently, develop two separate modular architectures.

The structure we present this third episode partly deviates from the previous two. First, we explain the reasons for the task in more detail. We clarify which actors were involved, and give a chronological overview of the work process. Next, we zoom-into main steps and situations, namely the processes of data creation, as well as presenting and discussing results. We present the empirical evidence in quite a chronological structure, because controlling's participation was quite rare during the first months, and became more intense and important towards the end of the process. We end this section with explaining the final decision. Similar to the two episodes before, we also discuss the data and link it to our theoretical framework.

4.5.3.1 Initial situation and motivation for episode 3

AutoCompany was aware that several legal restrictions forced them to significantly reduce CO_2 emissions of their future products. For example, the European Union forced car manufacturers to not exceed an average of 95 gram CO_2 per km from 2021.[17] In the United States, a bonus-penalty-system would reward or punish car manufacturers if they range below or above a pre-

[17] 95 gram CO2 per km refers to a car weight of roughly 1.4 tons. The value is linearly adjusted in dependence of a car's weight, so according to a firm's product portfolio, the target value can deviate. Source: https://www.vda.de/de/themen/umwelt-und-klima/co2-regulierung-bei-pkw-und-leichten-nfz/co2-regulierung-bei-pkw-und-leichten-nutzfahrzeugen.html (access: 10/2017)

defined and yearly-declining target value of average CO_2 emissions per vehicle.[18] And in China, at least 10 per cent of car manufacturer's sales had to be electric from 2019.[19] If firms failed these legislation, penalties ranged from fines to sales bans.

At the time *AutoCompany's* decision-makers initialized the future modular architecture's conceptualization, they knew that further developments of combustion cars' technology would not lead to sufficient CO_2 savings to meet the legal requirements. Consequently, they decided to complement the portfolio with battery electric vehicles (BEVs).[20] This plan was supported by public policy with several incentives: for example, German government promoted the purchase of a full electric car with 4.000 € since 2016, and in Norway, sales and import taxes for zero emission cars were eliminated.[21,22] Analogue to *AutoCompany,* many other global car manufacturers announced to intensify their activities in this field: General Motors planned to introduce 20 new electric car models until 2023, the VW group announced to invest 34 billion euros in electric mobility until 2022, Daimler AG aimed to spend 10 billion euros in the same period for their electrified products, and BMW group expected that the share of sales of electric cars in 2025 was going to be 25%.[23,24,25,26]

AutoCompany started to conceptualize the next generation of its modular architecture in 20xy, and sales managers estimated a required electric car ratio of 35-50% to achieve emission compliance in the future:

> *"In order to realize the required and increasing BEV-mixes from [three years after 20xz], all new projects of the high sales unit series need to be electric. Focusing on individual niches or segments is not enough."*

At this stage, *AutoCompany* did not aim to sell more electric cars than required. On the one hand, the company was successful in selling profitable combustion cars, and on the other hand, estimates indicated that electric cars' contribution margin would be far beneath

[18] Source: Internal documents at *AutoCompany*
[19] Source: http://www.manager-magazin.de/politik/weltwirtschaft/china-fuehrt-elektroauto-quote-erst-ab-2019-ein-dafuer-aber-10-prozent-a-1170325.html (access: 10/2017)
[20] BEVs emit no CO_2. Therefore, they were a means to reduce the average emission value of all products sold.
[21] Source: http://www.zeit.de/mobilitaet/2016-12/elektroautos-kaufpraemie-elektromobilitaet-bilanz (access: 10/2017)
[22] Source: http://www.manager-magazin.de/unternehmen/autoindustrie/norwegen-elektroauto-anteil-steigt-auf-53-prozent-a-1157126.html (access: 10/2017)
[23] Source: https://www.emobilitaetonline.de/news/wirtschaft/3640-ford-und-gm-wollen-mehr-geld-in-die-elektromobilit%C3%A4t-investieren (access: 10/2017)
[24] Source: http://www.faz.net/aktuell/wirtschaft/vw-investiert-34-milliarden-euro-in-elektromobilitaet-15297179.html (access: 10/2017)
[25] Source: http://www.focus.de/auto/news/elektromobilitaet-bei-vw-und-daimler-viele-milliarden-fuer-viele-neue-e-autos_id_7581499.html (access: 10/2017)
[26] Source: https://www.press.bmwgroup.com/deutschland/article/detail/T0270203DE/bmw-group-setzt-beim-ausbau-der-elektromobilitaet-auf-innovationskraft-der-deutschen-produktionsstandorte?language=de (access: 10/2017)

combustion cars'. In this context, the question arose how to develop, manufacture, and sell significant units of both combustion and electric cars. The concrete task was to enable a decision which modular strategy to follow in order to get an emission-compliant product portfolio for the upcoming decade.

4.5.3.2 Which actors were involved?

An interdisciplinary *project team* was responsible to elaborate the task. It was guided by a representative of *AutoCompany's* general management, subsequently referred to as the *project team leader*. The team consisted of managers and employees from development, marketing, production, controlling, and purchasing departments, and the team met for two hours once a week respectively twice a week in work-intensive phases. From the second half of 20xy, the controllers were intensively involved in the working process. In this third episode, "the controllers" refers to a controlling manager, the researcher, and two other controlling colleagues.

The *strategic management committee* consisted *AutoCompany's* management board and several top managers. It met approximately once a month to discuss and decide strategy-relevant topics. It was the most powerful strategic committee at *AutoCompany*, and it intensively discussed the future modular architecture's concept six times in 20xy and 20xz. Before topics were going to be decided by the *strategic management committee*, they were discussed a hierarchical level beneath in the *top management committee*. This committee was staffed with top managers of all departments, too.

As *AutoCompany* planned to share its modular architecture with other brands of the group in the future, discussions about its conceptual design were also impacted by the other brands' positions and interests.

4.5.3.3 Chronological summary

The third episode's issue was discussed by the *strategic management committee* six times during 20xy and 20xz. The points in time are shown in Figure 20.

	20xx		**20xy**												**20xz**		
	11	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
Strategic management committee				◆ 1.				◆ 2.			◆ 3.	◆ 4.	◆ 5.			◆ 6.	

Figure 20. Points in time the topic was discussed in the strategic management committees

In advance of each *strategic management committee*, the *project team* intensively worked on the task. In the following sections, we describe the main working steps and a few important meetings (such as the third *strategic management committee* the controllers could participate) in much more detail. The controllers started to contribute extensively to the task after the second *strategic management committee*. Until that point, the focus was mainly on arguments and inputs from engineers, production managers, and marketing experts.

In the first *strategic management committee*, a concept engineer presented three options how both combustion and electric powertrain technologies could be implemented for the future product portfolio. **Option 1** was the idea to reintegrate electric components to the current modular architecture, and therefore also base BEVs on the current architecture. Involved technical experts estimated that those kind of BEVs' would not possess enough attractive attributes to be competitive. *AutoCompany's* management board rejected this option immediately.

Option 2 meant the strict split of *AutoCompany's* future product portfolio into combustion and electric cars. This option implied to go on and update the existing modular architecture for combustion cars. In parallel, engineers would develop a new, independent modular architecture for BEVs. For several technical reasons, these drive-specific modular architectures would also impact components that belong to cars' hats (see Chapter 3 of this thesis for a detailed explanation of *AutoCompany's* different kinds of car components). Simply said, a consequence of *option 2* was that combustion cars' and BEVs' outward appearance would also differ to a large extent.

And **option 3** referred to the idea of one common, new modular architecture on which both combustion and electric cars could be based, a so-called multi-traction modular architecture. One major aspect of this option was that other parts of the car, for example a car's hat, would be the same for all kind of drive technologies. Basically, the electric powertrain would be an additional type of drive, just like gasoline or diesel were for the current product generation.

As the controllers became more involved, they experienced that the *project team leader*, the engineers, marketing, and production managers seemed to strongly prefer *option 3*. As first estimates, engineers assessed that competitiveness of cars in *option 3* could be ensured. And sales- and production managers emphasized its promising flexibility, what seemed to be an important aspect, as experts struggled to make reliable forecasts. If both electric and combustion cars were based on the same modular architecture, *AutoCompany* would be able to flexibly react to market requirements (for example changed demand of BEVs or specific regional mixes). The technical concept would enable *AutoCompany's* production plants to manufacture both combustion and electric cars on the same sites. Therefore, unforeseen market changes would not affect individual plants' production capacities.

During the first two *strategic management committees*, financial impacts were not in the focus, but an *AutoCompany's* controlling manager provided a qualitative estimation about fixed costs. He disclosed that *option 3* would outperform *option 2* with respect to development costs. He reasoned that *option 2* would require two platforms and two hats to get both electric and combustion cars for one segment. In *option 3*, an analogue portfolio could be realized with only one platform and one hat. In addition, a production manager argued that *option 3* would also be beneficial with respect to both production investments and variable manufacturing costs other than material costs. As the first meeting's conclusion, the management board

> *"takes note of option 3's shown advantages so far, [... and] confirms to follow up on option 2 and option 3 with the <u>task for a holistic technical-economical evaluation for a concretized target-portfolio [eight years after 20xz]</u>".*

Approximately four months later, the *strategic management committee* discussed the topic for the second time. The *project team leader* explained that there seemed to be no clear preference for a particular strategy among *AutoCompany's* competitors. How he gathered this information remained unclear to the controllers. Controlling's participation was still not intense. The *project team* disclosed *option 3's* benefits, such as reduced fixed costs and increased flexibility, and also defined these aspects as main requirements for the next modular architecture. On the other hand, engineers communicated several architectural-caused disadvantages for combustion cars in *option 3*: additional CO_2 emissions of few grams per km, additional weight of approximately 50 kg, and an increased height of a few centimeters. At this stage, the management board classified these impacts to be strategically less relevant, and formulated a task to reduce them. Moreover, the task instructed during the first meeting (to evaluate both option's impacts for the whole product portfolio) was simplified to a holistic technical-economical evaluation for just one particular sedan segment. As a conclusion of this second *strategic management committee*, *option 2* was assessed to be not affordable, and management board confirmed

> *"that an extensive implementation of option 2 is not expedient."*

From now on, the controllers were extensively involved. From their perspective, the options' evaluation was conducted in a unilateral way until that point, and participating departments, including the *project leader*, emphasized option 3's advantages without considering its disadvantages in an adequate way. Therefore, in preparation of the third *strategic management committee*, the controllers aimed to evaluate the two options in a holistic and balanced way. This was sometimes exhausting, as *AutoCompany's* controlling manager mentioned once after a work meeting:

> *"I am really tired of being the only one who talks sometimes against [option 3]. It is completely obvious that all the other departments already made a decision."*

Until that point, discussions about financial aspects were limited to development costs and production investments. The controllers started to quantify more of the options' impacts in monetary terms, which led, from their perspective, to a turning point. While there was no focus on variable cost differences between the options before, the controllers estimated additional variable costs of approximately $ 1.000 for combustion cars in *option 3*. A top manager who directly reported to *AutoCompany's* CEO reacted to the holistic evaluation during a *top management committee*:

> *"This [the fixed cost aspect] is not that interesting. But the thing about the variable costs, this is the thing that is really exciting."*

Subsequently, the holistic economic evaluation of *option 2* respectively *option 3* for one particular sedan segment was presented in detail during the third *strategic management committee*. As a consequence, the management board instructed the team to follow up on both options, but to find ways to minimize fixed costs and optimize profits of *option 2*.

In advance of the fourth *strategic management committee*, design engineers built design models for BEVs to illustrate design differences between *option 2* and *option 3*. The controllers could not join the presentation, but received feedback that models for *option 2* appeared more attractive to the management board. Afterwards, during the *strategic management committee*, the advantages and disadvantages of both options were discussed again, and finally, *option 2* was recommended for the particular sedan segment. The committee expected that the same arguments were valid for other sedan segments the modular architecture aimed to cover, so the same decision was confirmed for these segments, too. At this stage, some top managers were not convinced that the provided arguments could be transferred to the remaining SUV segments.

Consequently, the fifth and sixth *strategic management committee* discussed the future concept for the two SUV segments. Finally, the committee confirmed to follow *option 2* for the whole modular architecture.

In the following section, we present how the controllers generated and disclosed data and calculations during episode 3. In the first part, we describe the process until the second *strategic management committee*, and also mention the controllers' difficulties to generate concrete numbers. This limited their impact to qualitative statements during this stage. After that, we show how the controllers evaluated financial implications of *option 2* respectively *option 3* for one particular sedan segment, and how this evaluation was extensively presented and discussed (first to the *top management committee*, and subsequently to the *strategic management committee)*. And last, we present how additional arguments and hardening the existing arguments led to the final decision.

4.5.3.4 Zooming-in: Qualitative evaluation process during the first half of 20xy

As already mentioned above, the controllers' contribution to the task was limited during the first half of 20xy. They were part of the *project team*, but we would describe their role as rather passive. For the first *strategic management committee*, there was not much known about the option's specifications, and controlling's contribution was limited to a qualitative estimation about development costs. Figure 21 discloses that development costs for *option 2* were estimated to be higher than for *option 3*. The argument was that, per segment, two hats and two platforms were needed in *option 2*, while comparable models could be offered in *option 3* with only one hat and one platform. The diagram was shown to the management board during the first *strategic management committee,* and the controlling manager disclosed the expectation that a single hat respectively platform in *option 3* would require higher development costs than in *option 2*.

The first *strategic management board committee* instructed a holistic technical & economic evaluation of the future portfolio, but the *project team* noticed afterwards that this task was quite complex. The team worked on it during the following weeks, and the controllers realized that many questions needed to be answered in order to provide a holistic evaluation. To illustrate only a few uncertainties at this stage, it was not clear which car models the future portfolio was going to consist of, how the different options were going to impact total sales or cars' variable costs, how revenues or costs of BEVs were going to develop and differ from a combustion cars, or how the technological change was going to affect production capacities and investments.

Because of these unanswered questions, the controllers struggled to create or collect usable information. For example, they were aware of the importance of total sales units for their evaluation. As the product portfolio was going to somehow deviate between the two options, they expected differences with respect to this input data. But sales managers struggled to estimate sales numbers for *option 2* respectively *option 3*, and went on arguing qualitatively that they expected a significant sales risk if only BEVs (and no combustion cars) would be offered in particular segments. Again, they emphasized the need for flexibility to steer

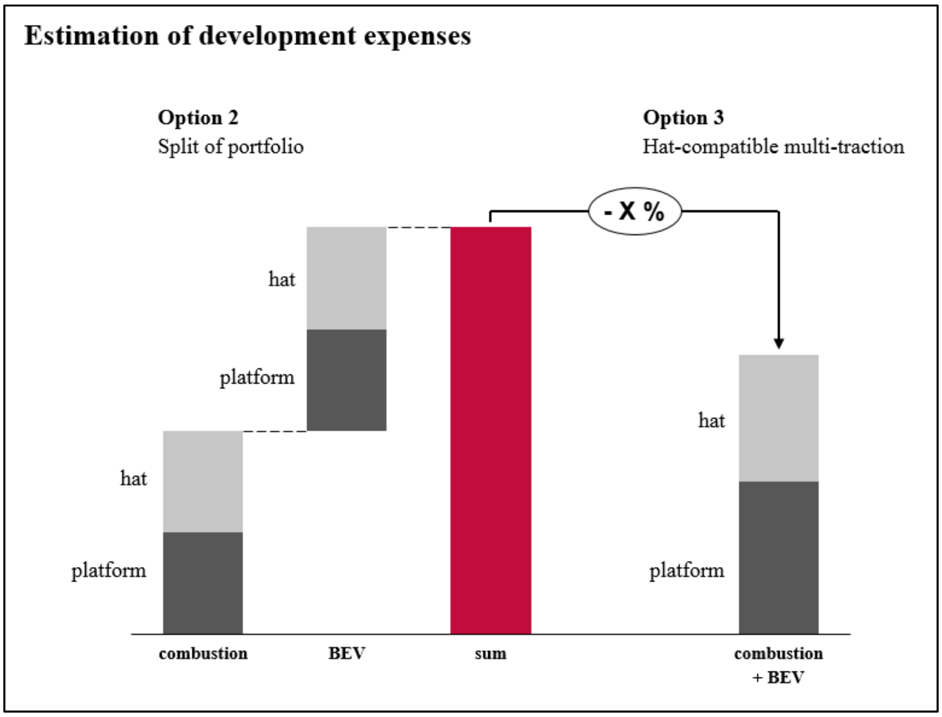

Figure 21. Qualitative estimation of development expenses of the two options

AutoCompany's portfolio towards CO2 compliance in each year respectively for every market. For them, this was the main benefit of *option 3*:

> *"[AutoCompany] has to be able to react flexibly to time shifts in contrast to the expected market trends."*

From the controllers' point of view, *option 2* offered the chance to enable *AutoCompany* to sell more (and more attractive) car models. But at this stage, neither the *project team leader* nor the sales managers estimated this aspect to be an advantage. In contrast, they went on to reason that *option 2* would increase complexity and fixed costs. More concretely, *AutoCompany's* sales department had different expectations about BEV's future requirements than other brands of the group, and did not predict additional sales potential if BEVs' outward appearance would significantly differ from combustion cars'. They argued that no additional BEV-specific car variants were needed:

> *"[AutoCompany] marketing is convinced: BEVs need no specific [...] variants. [The c]ustomer choses first body style and vehicle size, depending on his life situation, then drive technology. A turnaround is not expected because of BEVs. There is no need for autonomous, differentiating variants." [...][We] do not expect big sales differences between option 2 and option 3."*

The *project team leader* advocated this attitude also towards the group's other brands. He communicated that *option 3* was the preferred option for the next modular architecture, as

> *"many criteria plead for a multi-traction architecture. AutoCompany feels confident to realize many BEV-typical properties in a multi-traction architecture."*

Replying to that, representatives of *CarEnterprise* plead for a purpose car design, and officially communicated not to be part of *AutoCompany's* next modular architecture if *option 3* would be realized. And also some *VehicleFirm* managers argued to go for pure modular architectures:

> *"[There are e]fficiency disadvantages of a multi-traction platform because of complexity, weight, variable costs, […]."*

Engineers and production managers also went on and extensively emphasized advantages of *option 3,* while potential disadvantages were only briefly mentioned or ignored during discussions in the *project team*.

The controllers were skeptical and tried to get more information on costs. While there was no quantification about fixed cost differences during the first half of 20xy, potential variable cost differences were completely ignored at this stage. During a *project team* meeting, the other controller addressed the topic of material cost differences between *option 2* and *option 3*, but this was completely ignored. Before the second *strategic management committee,* the presentation provided by the *project team leader* stressed option 3's advantages, and another experienced controlling colleague commented on the status:

> *"This is all just power point until today. I just don't believe them [developers] that there won't be more complexity with any extra-costs. You just cannot name or quantify that today, but it will come up. And then, it will be too late."*

While the controllers could understand why sales or production representatives promoted *option 3*, they assumed that the considerable technical challenge was the motivation for the engineers to favor the multi-traction idea. A controlling colleague said:

> *"They want to show that they are the best developers in the world, so they can also invent such an all-in-one solution that is suitable for every purpose [eierlegende Wollmilchsau]."*

At this stage, the controllers could not gather any additional estimates for sales or variable costs. Therefore, monetary discussions remained on fixed cost differences between *option 2* and *option 3*. The controllers received estimates for the two options from the development, purchasing, and production experts. Their future fixed cost evaluation was based on current generation's costs in combination with multipliers, exemplary shown for two car projects in Figure 22. This figure was not provided or disclosed by the departments, but illustrates their proceeding. The table on the left shows the input data (fixed costs of a current model), and the experts' estimation of the two options' is shown on the right.

- million $ -	Development costs	Purchasing investment	Production investment
current platform	620	190	450
current hat	400	240	430

$$C_{option\,2} = \overbrace{(620 + 190)\,x\,1{,}9 + 2\,x\,450}^{\text{platform}} + \overbrace{(400 + 240)\,x\,1{,}9 + 2\,x\,430}^{\text{hat}}$$

$$= \mathbf{4.225\ m.\$}$$

$$C_{option\,3} = \overbrace{(620 + 190)\,x\,1{,}5 + 450}^{\text{platform}} + \overbrace{400 + 240 + 430}^{\text{hat}}$$

$$= \mathbf{2.735\ m.\ \$}$$

- disguised data -

Figure 22. Exemplary calculation of fixed costs for a BEV and a combustion car

Production managers multiplied current investments with the number of required platforms and hats. This approach resulted in twice as much production investments for *option 2* than for *option 3.* Development and purchasing managers estimated that *option 2* would require 1.9 times of a current product's costs. They argued this assumption with the split of the electric and combustion cars, and assumed a synergy effect of 10% between both car models. For the platform in *option 3,* they estimated a factor of 1.5 to realize a more complex multi-traction concept. The hat's fixed costs were considered only once.

These assumptions led to significant higher estimated fixed costs for *option 2*. During a work meeting, especially production managers justified their evaluation with the requirement to be fully flexible concerning a BEV sales ratio from 0-100% during the products' whole lifecycle:

> *"We just cannot say: Now we will build BEVs in [production site 1], and combustion cars in [production site 2] – and when the tipping point [jargon at AutoCompany for an unsecure point in time in the future when BEVs will be sold in significant quantities] is there, we have mass dismissals in [production site 2], because nobody is buying combustion cars anymore."*

The controllers were not satisfied with this proceeding, and estimated the method to be far too rough. *AutoCompany's* head of product controlling rejected to use this input for a financial evaluation:

> *"We want to provide decision alternatives to the management board. At the moment, we have two scenarios, but one of them is definitely not an alternative."*

Close to the second *strategic management committee,* the *project team leader* requested a diagram that disclosed the quantified fixed cost differences. But the controlling manager estimated the estimates' quality as too poor, and denied to communicate them to the management board. Therefore, the controllers again delivered only qualitative diagrams which indicated lower fixed costs for *option 3*.

Discussion of example 1: We believe the presented empirics already illustrate some aspects which are important for our theoretical framework. First, the example shows how actors dealt with the high uncertainty, and how they disclose this issue to the management board. For example, the controllers limited their disclosed data to qualitative figures, or the *project team leader* enabled *comparisons to a broader context* by disclosing information that there was no consistent strategy competitors aimed to follow.

The example illustrates the hardening process of the fixed cost estimation: discussing and disclosing data about the fixed cost aspect *enabled users to scrutinize*. At the beginning, actors could not provide any funded data, so the controllers argued with qualitative figures, common sense and "gut feel". In the course of time, the controllers gathered more data and discussed the data several times. At this stage, controllers were still not convinced about the numbers' quality and rejected to use them. We argue that the controllers reacted like that because the rough approach resulted in numbers that were far outside an acceptable "grey zone".

In addition, the example illustrates the controllers' agenda: in this case, the controllers did not prefer a particular strategy, but were irritated that other actors stressed the advantages of one particular option, while giving only weak attention to its potential disadvantages. The controllers were skeptical, as other actors seemed to have already made their decision without considering options' entire financial consequences. This impression was supported as the other actors ignored the controllers' question about variable cost disadvantages of *option 3*. Neither the *project team leader*, nor the marketing or production managers seemed to be interested in incorporating negative aspects into the evaluation of their preferred scenario. Consequently, the controllers seemed to understand their role as to evaluate the options in a broader and balanced scope.

4.5.3.5 Zooming-in: Quantifying & presenting financial impacts for one particular segment

The *project team* was assigned to execute a holistic economic evaluation of the two remaining options for one particular sedan segment by the second *strategic management committee*. Therefore, the controllers became more intensively involved into the task. With the following subsections, we explain how the controllers created, disclosed, and discussed the individual aspects of their evaluation.

4.5.3.5.1 Evaluating sales' & contribution margins' impact

From previous evaluations, the controllers were aware of the fact that differences in sales could have significant impact on scenario's financial outcomes. Also production managers argued that this is the most important input factor to evaluate impacts on production capacities. The *project team* discussed several portfolio scenarios for *option 2* and *option 3*, and defined particular BEV- and combustion models for each of them. The responsible sales manager was asked to estimate total sales for each model, but first, he rejected to do that and emphasized that uncertainty was still too high.

After several weeks, he finally agreed to quantify particular models' sales and applied a simple logic: in *option 3*, he divided total estimated sales for each segment into electric and combustion cars under the assumption of a CO_2 compliant portfolio. This implied a BEV-ratio of 37%, and he reasoned his approach with the full flexibility this option provided. For *option 2*, he decided to offer a few models only as combustion or BEV models, and reasoned that offering both types for every single car model would make no sense. He set a 50% substitution rate if a combustion car model would not be offered (compared to *option 3*). In other words, this assumption implied that the corresponding BEV models' sales increased (compared to

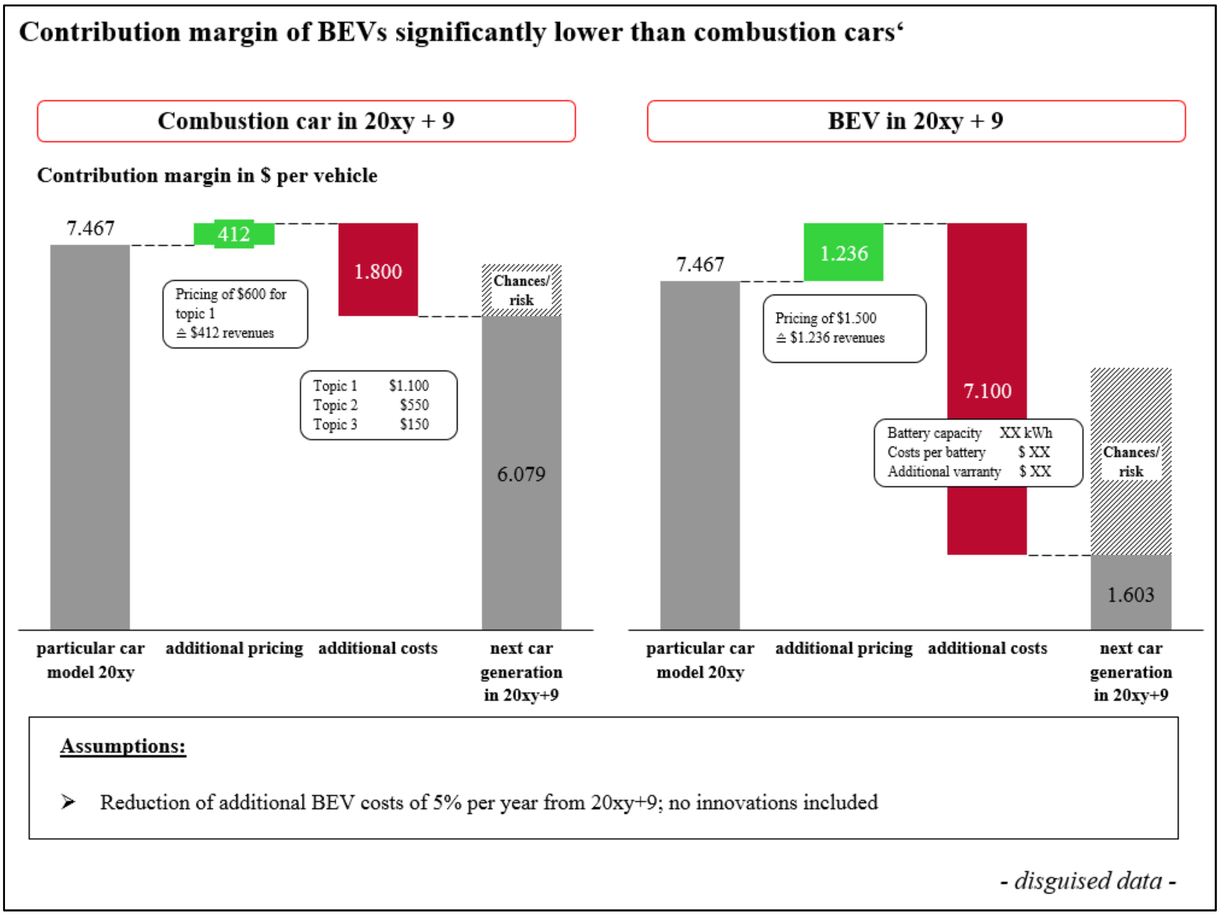

Figure 23. Estimated contribution margin for BEVs and combustion cars in year 20xy+9

Table 10. Evaluated scenarios in episode 3

	All car models as electric & combustion version	*Several car models only as electric version*
option 2	**scenario 2a**	**scenario 2b**
option 3	**scenario 3a**	**scenario 3b**

option 3), and 50% of the combustion car models' sales would be lost. The controllers received the detailed sales data in an excel sheet, and noticed that, in total, this proceeding caused a sales loss in *option 2* of 10%.

In a next step, the controllers combined the sales data with estimated contribution margins. They based their calculation on current models' contribution margins, and adapted the numbers with technology-specific cost changes a cost expert expected for the future product generation. This proceeding was also explained to the third *strategic management committee* - see Figure 23. It disclosed expected contribution margins for one particular car model in one particular year, and the project team leader also disclosed an assumption how the additional BEV costs were considered in the evaluation.

The controllers multiplied contribution margins with the sales data in order to calculate a total contribution margin per option. Analyzing the results, the controllers realized that total contribution margin differences between *option 2* and *option 3* were far higher than 10% (which could have been explained with the sales loss of 10%). Going more into detail, they found two effects that explained their findings. First, car models with the far highest contribution margins were lost. And second, the BEV ratio in *option 2* was far higher than in *option 3*. From the controllers' perspective, their financial results were significantly impacted by the sales manager's arbitrary assumptions, and this impeded a useful comparison of the option's contribution margin impacts. Consequently, the controllers asserted to evaluate both *option 2* and *option 3* with both sales unit data sets, and the number of options to be evaluated increased from two to four. The resulting four scenarios are shown in Table 10.

In order to increase transparency, the controllers provided a slide that disclosed total sales per scenario. The project team leader presented this slide to the third *strategic management committee*, and described the sales department's main assumptions below, see Figure 24.

Discussion of example 2: We argue that this example provides support for our theoretical framework in several ways. First, the controllers enabled *comparisons to numbers and sources* by disclosing the data they had incorporated into their evaluation. They showed

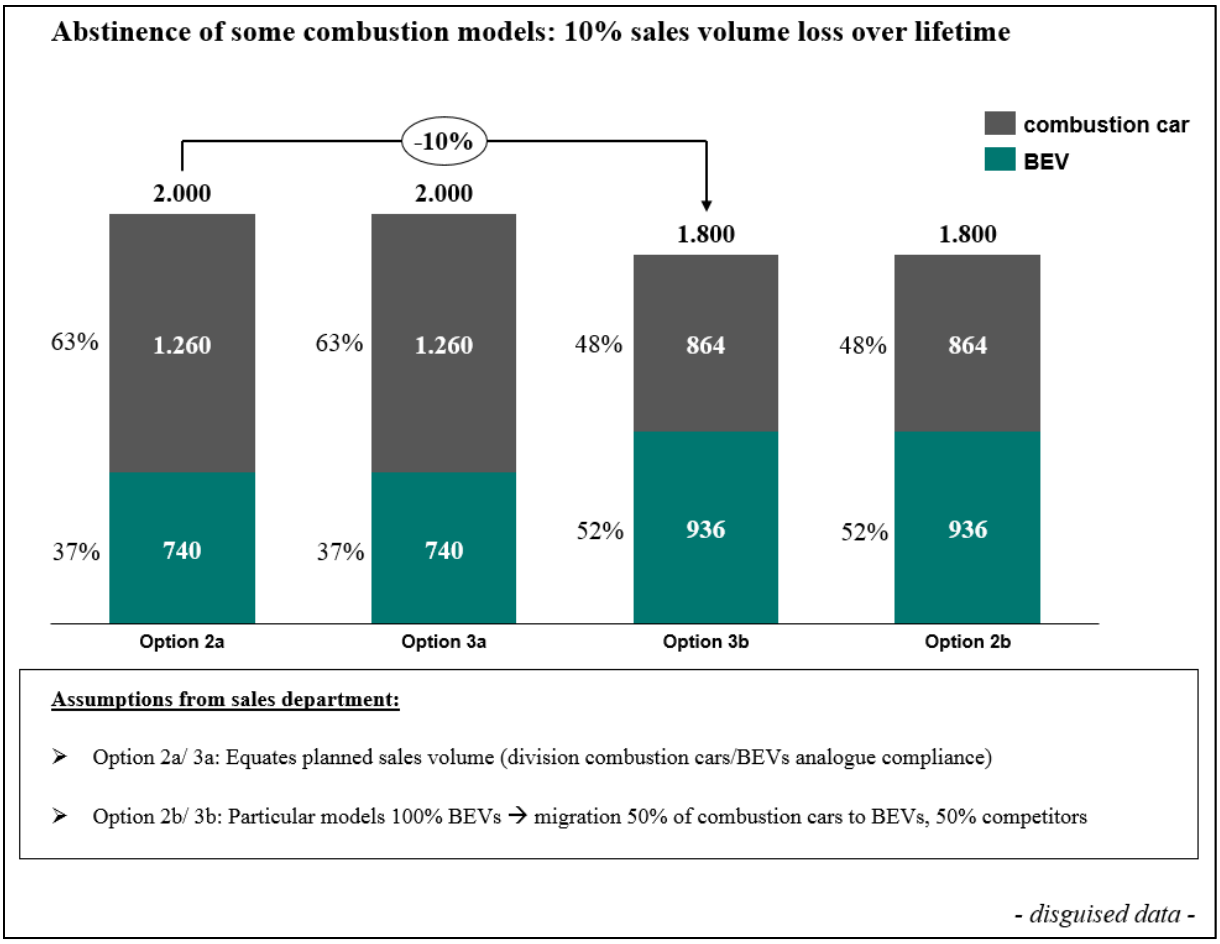

Figure 24. Disclosed data about sales units for the four scenarios

that their evaluation was based on contribution margin data from current car models, and this data seemed to be very hard. Moreover, the controllers provided a comprehensible illustration that disclosed total sales data for each option. This figure both enabled actors to compare sales incorporated in the evaluation with sales of the current product generation, and also to compare and discuss sales differences between the options.

Second, disclosing aspects how the contribution margin might change for the future car generation *implicitly expressed scrutiny.* The controllers could show and explain several details they had incorporated into their calculation. These details about estimated additional revenues and costs expressed that the controllers had examined those aspects – otherwise, they would not have been able to disclose them. The details enabled actors to zoom-into the calculation, and understand which aspects were considered to which extent.

Third, the controllers and the *project team leader* disclosed several assumptions and numbers that were part of the calculation. The partly rough estimates emphasized the high level of uncertainty, and by disclosing them, the controllers *enabled users to scrutinize.* For example, they showed that the calculation contained the assumption that BEVs' variable costs might decrease by 5% in each year from 20xy+9. The controllers made that assumption because it made sufficiently sense to them, but of course, assuming a cost declination rate of 3% or 8% might also seem appropriate. They were neither able to provide hard data for their assumption nor extensively interested in maintaining this particular assumption. Therefore, they implicitly invite other actors to provide better input data, as far as he would be able to argue for it.

And fourth, the sales manager's input data *opened the window of opportunity for challenge*. The provided sales data was obviously very soft, and the controllers' first evaluation's result was outside an acceptable grey for them. As they were no sales experts, they were also not able to provide better data. To overcome the sales manager's (un)intentional distortions, the controllers disclosed the delivered sales data to show that provided sales differed significantly. Doing that, they enforced to evaluate both scenarios with both kind of sales data, and therefore not to "compare apples with oranges".

4.5.3.5.2 Evaluating fixed costs' impact

In cooperation with the *project team*, the controllers tried to gather more reliable fixed cost estimates. But not all attempts were successful. In order to assess the scenario's fixed cost differences, the controllers analyzed the current car generation, and the *project team leader* tried to derive correlations among fixed costs, sales units, and vehicle models. Using these numbers for the scenarios fixed cost evaluation was not accepted by the other actors of the *project team*.

Therefore, development and production managers went on and tried to estimate future fixed costs in a more nuanced way than before. Finally, development managers presented their estimations on more than ten slides to *AutoCompany's* chief technical officer who accepted it. Afterwards, they provided and explained the analysis to the whole *project team*. The result of the more detailed analysis was that development cost differences between the scenarios declined significantly, and the controllers accepted to incorporate these numbers into their evaluation.

Production managers provided a more sophisticated proceeding, too. While their first approach had indicated twice as much production investments for *option 2* than for *option 3*, the conclusion of their evaluation update was that *option 2* would still cause higher production investments, but the extraordinary initial cost difference decreased significantly. The production managers emphasized that their evaluated fixed cost impact of *option 2* might be correct from a calculative point of view, but that the company's current facility area would not provide enough space to implement it. They also insisted to disclose that aspect for scenario 2a to the third *strategic management committee*.

The responsible purchase manager refused to execute any detailed analysis. He reasoned that, in order to get a reliable result, considerable efforts had to be made. The controllers suggested to apply the correlation between purchasing investments and development costs they had found for the current product generation. The purchase manager agreed, and the controllers did so in order to consider all relevant fixed costs.

From the controllers' perspective, development and production managers invested far more effort and expertise than before, and one consequence was that fixed cost differences had significantly declined. The controllers included these numbers in their evaluation. For the third *strategic management committee,* the controllers provided a slide that disclosed the estimated fixed costs for each scenario, see Figure 25.

Discussion of example 3: We believe this example provides support for our theoretical framework in several ways. First, the process of getting to the finally used fixed cost estimates *explicitly expressed scrutiny*. The hardening process started with qualitative reasoning and "gut feel", but while qualitative statements about fixed cost impacts were accepted during the first stage, their quantification lasted for several months. Through various meetings, discussions,

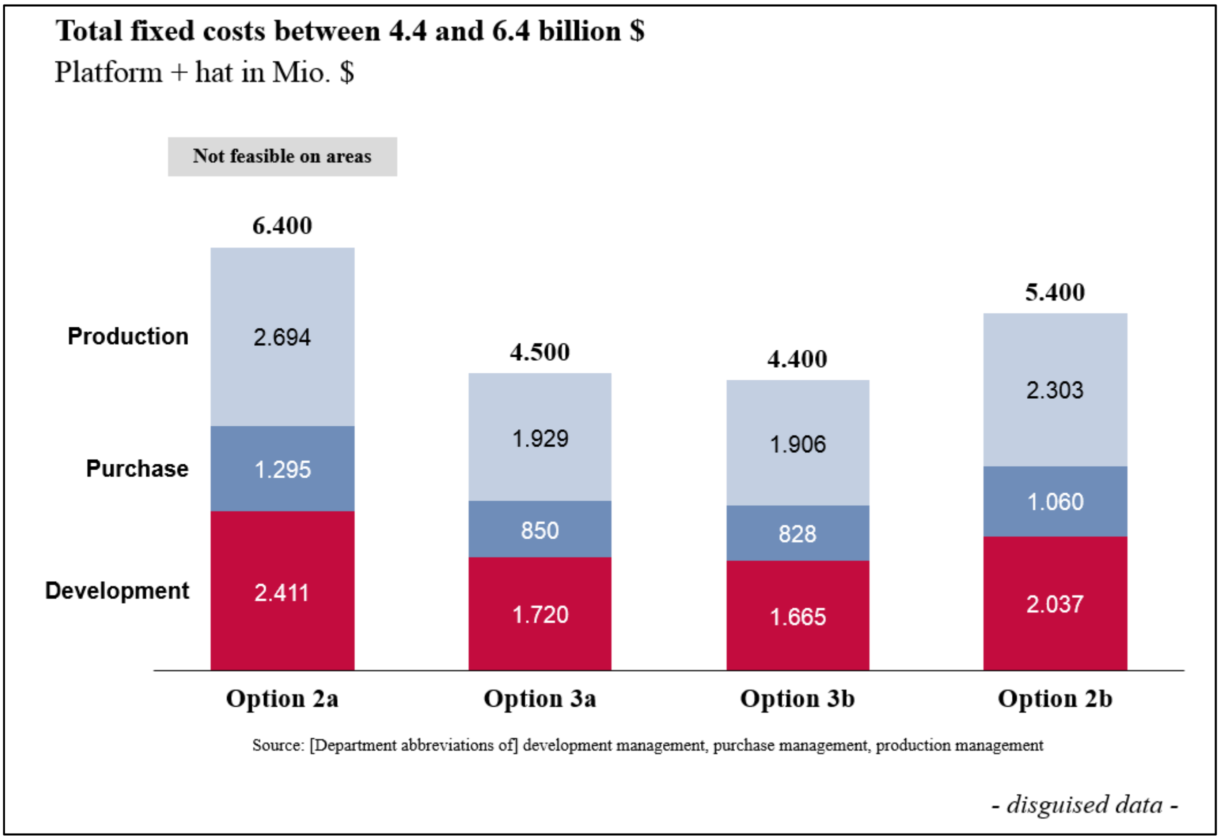

Figure 25. Fixed cost data for the scenarios

and rejection of several methods, the project team came to estimations all actors involved estimated to be the hardest available.

Second, the example illustrates the aspect of *enabling comparisons to numbers and sources*. On the one hand, the development managers could refer to the company's chief technical officer as a high authority who had already accepted their evaluation. This was a supportive aspect for them to argue that their evaluation was of sufficient quality. And on the other hand, the controllers disclosed the values and sources of the individual fixed cost estimates for several reasons. This detailed information enabled the *strategic management committee* to see that various departments were involved in the estimation, and also implied that fixed cost estimations were made on a detailed level. Disclosing these detailed numbers was also a means for the controllers to demonstrate that they had incorporated the individual departments' values. Managers from all departments involved could find their numbers as parts of the calculation, and enabling them to find their inputs as important aspects of the calculation was a means to increase its persuasiveness.

4.5.3.5.3 Evaluating scenario-specific variable costs

The controllers started to quantify variable cost differences between *option 2* and *option 3* several weeks before the third *strategic management committee*. As already mentioned above, one controller brought this aspect up in an earlier stage, but was ignored by the *project team*. With the concrete task of a holistic economic evaluation, the *project team* confirmed that concept engineers had to provide some input about the different concepts that might also impact variable costs.

The controllers received a spreadsheet with aspects of how the two options impacted BEVs' and combustion cars' attributes. The concept engineer explained that the main difference would be a "burden" for combustion cars in *option 3*. While BEVs and combustion cars would not impact each other in *option 2*, the multi-traction idea of *option 3* implied that a combustion car's hat (which was, per definition, the same for BEVs) needed to be a bit bigger and broader. According to concept engineers, negative impacts on BEVs were insignificant. More concrete, the negative consequences for combustion cars in *option 3* were an additional inch of wheels, a heavier and more robust body of roughly 35 kg, and an additional weight of roughly 10 kg because of a bigger vehicle shape. As the controllers started to quantify these impacts in financial terms and discussed them with the *project team*, the project team leader tried to doubt these values right away:

> *"That is too much for me – certainly, there will remain probably only ten to 15 kilograms."*

From the controllers' point of view, this reaction demonstrated the *project team leader's* agenda at this stage. They emphasized that there was no need for speculation, and insisted to incorporate these issues as long as there were no ideas to reduce the negative impacts.

As an additional negative impact of *option 3*, concept engineers estimated that CO_2 emissions for combustion cars would increase by 5g. The controllers expected that there would be additional aspects that negatively impact variable costs, and asked for additional input about *option 3's* higher complexity. The responsible concept engineer admitted that a higher complexity would cause higher material costs:

> *"Somehow, they [extra-costs caused to fulfill both BEVs' and combustion cars' requirements] will be there. I just cannot tell you in detail today which parts will be affected."*

The controllers evaluated the provided input with controlling experts, and also discussed their results with the project team several times. For some impacts, they relied on costs of the current car generation. For example, if the body of a current car project weighed 300 kg, and caused material costs of $1.200 in total, the controllers calculated with a variable cost value of $4 per kg. They calculated a negative CO_2 impact by multiplying the additional emissions with 95€ per gram. This value was well known to be the fine a car manufacturer had to pay if the emission goals in the European Union would be failed. Additionally, the controllers considered the additional complexity costs by multiplying material costs of a current car project with 3%. This value was an assumption, and not justified any further.

After several discussions and small adaptions with the *project team,* the controllers' evaluation showed additional material costs for combustion cars in *option 3* of approximately $ 800 - 1.000. The controllers disclosed many details during discussions and presentations in the *project team* (such as sources or more detailed assumptions). But in order to reduce complexity, the *project leader* decided not to mention too many details on the slide presented to the *strategic management committee* (see Figure 26), and to add these details orally.

Discussion of example 4: We argue that this example provides additional support for our theoretical framework. First, the disclosure of the detailed information *explicitly expressed scrutiny*. The controllers gathered many details, and discussed their evaluations with the project team several times. Even as not all of these details were provided on the slide, the *project team leader* was able to add and explain many details orally during his presentation.

Second, the several aspects that added up to the final result *enabled comparisons between various parts of the calculation*. Instead of mentioning a negative variable cost impact

Variable cost impacts on combustion cars in option 3

- in $ per car -	Scenario 2a	Scenario 3a	Scenario 3b	Scenario 2b
Size, wheels		210	210	
Risk (complexity)		270	270	
CO_2 impact		490	490	
Change of facility costs	130		350	350
Additional costs for combustion cars	130	← Δ 840 — 970	1.320 — Δ 970 →	350

→ Additional variable costs for combustion cars in option 3 (compared to option 2) of approx. $ 800 - 1.000 per car.

- disguised data -

Figure 26. Additional material costs for combustion cars in option 3

of $1.000, the controllers provided additional details to explain how this number adds up. By disclosing which aspects were considered, actors could get the impression that there existed a more profound evaluation behind that single number.

Third, disclosing and explaining details of the variable cost impact *focused the burden of proof*. The negative impacts of *option 3* were already discussed during the second strategic management committee. The controllers now translated those negative impacts into monetary terms, and actors tried to challenge them as the result was not in line with their interests. But the controllers did not accept to deviate from inputs provided by experts without comprehensible reasons.

And fourth, the example illustrates the *reversed burden of proof*. The controllers assumed 3% to be an adequate number to consider additional complexity costs for combustion cars in *option 3*. This amount seemed to be within an acceptable grey zone, even if they could not further verify it. There was no analysis or source they could defend their number, but only the engineer's statement that these costs "might somehow be there". Therefore, they staked their claim. Obviously, 2% or 5% could have been an adequate number to calculate with, too. If it would have been in line with their interests or expectations, they could have also ignored this aspect. And including a far higher number might have caused additional resistance. But they felt right to consider this aspect with this moderate rate.

4.5.3.5.4 Aggregating & presenting financial evaluation

The slide that summarized the controllers' results is shown in Figure 27. This figure was the final slide the *project team leader* presented to the third *strategic management committee*. Beforehand, he extensively explained the controllers' proceeding and the calculation's details by showing the slides already shown above. In the following, we explain in more detail how he presented the evaluation to *AutoCompany's* management board.

The *project team leader* started the presentation by disclosing the methodology and explaining the evaluation's logic step by step: he started to argue that total sales were estimated to be different between the scenarios. Next, he explained that the current product generation's contribution margins served as a basis that was adapted to consider future impacts for all scenarios, and that scenario-specific variable cost differences were estimated and considered as well. He went on and reasoned that scenario-specific fixed costs were deducted to finally calculate the financial result of each scenario.

After having explained the proceeding, the *project team leader* disclosed and explained the calculation's details slide by slide. He emphasized that the contribution margin of the

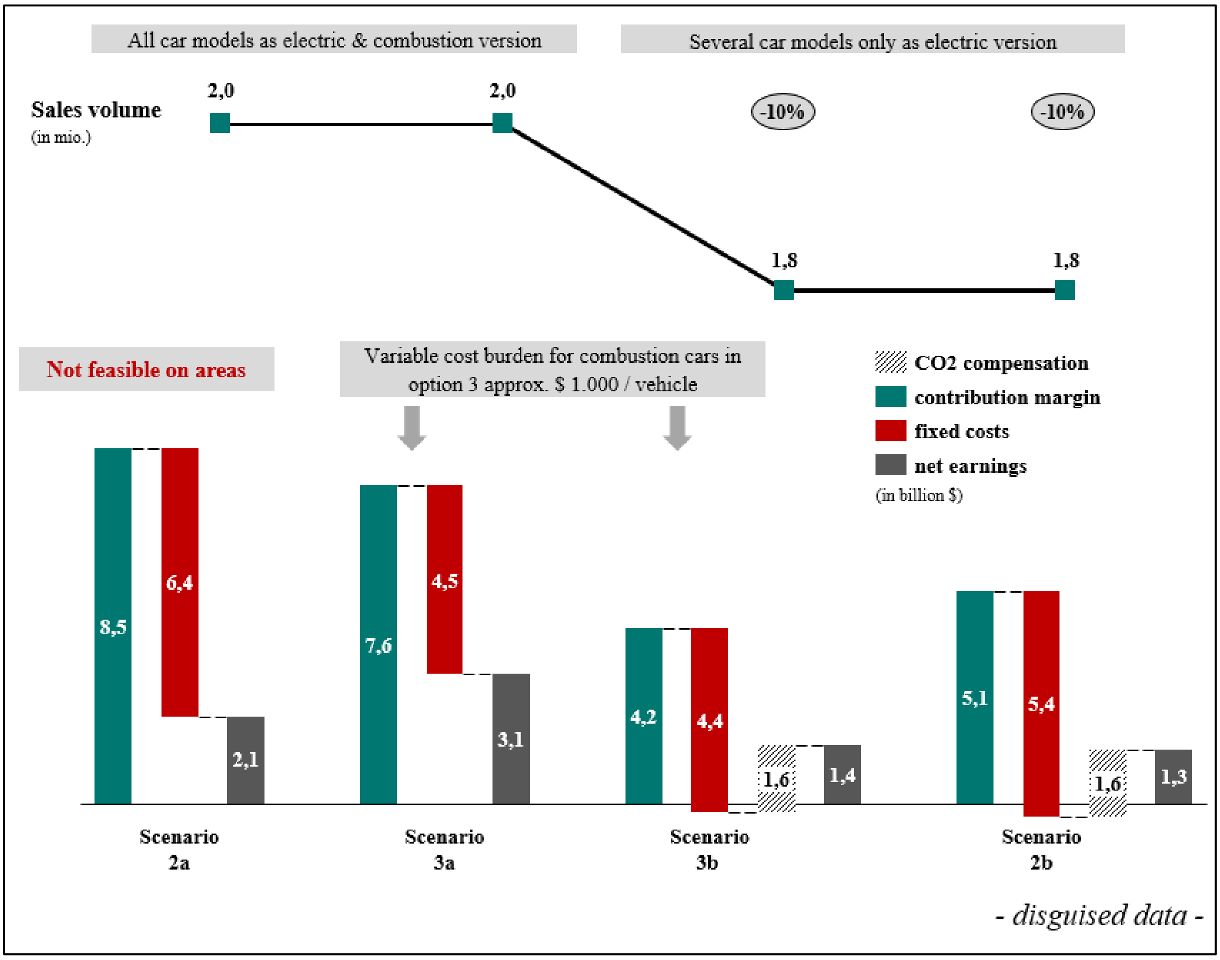

Figure 27. Summary of episode 3's financial evaluation

current product generation served as a starting point, and explained and reasoned the estimated changes for the next product generation (see Figure 23). Even as he did not directly mention that the input data was provided by the controlling department, this might have been quite obvious for the *strategic management committee* in this context.

Next, he explained the variable cost differences among the scenarios (see Figure 26). As he disclosed the variable cost disadvantage of *option 3's* combustion cars, *AutoCompany's* CEO became dissatisfied and expressed that he was surprised by this new aspect:

> *"But guys, I am extremely struggling with a burden of thousand euros for each combustion car. Then, this [option 3] is not really it, after all."*

The *project team leader* went on and presented two slides that disclosed the scenario's sales (see Figure 24) respectively fixed cost differences (see Figure 25). Sources respectively the providers of the input data were disclosed on these slides. Like this, it was also transparently shown to the relevant departments that their numbers were part of the evaluation.

As already mentioned above, the slide shown in Figure 27 summarized the whole evaluation. Orally, the project team leader explained that contribution margins in *option 2* were more advantageous, while *option 3* outperformed *option 2* with respect to fixed costs. In order increase the scenarios' comparability and therefore consider the higher BEV-ratios of scenarios 2b respectively 3b, the controllers added a financial benefit by multiplying the aggregated surplus with 95 € per gram.

From the controllers' perspective, the third *strategic management committee* marked a turning point. Before that meeting, the controllers had the impression that a majority of the *project team* favored *option 3* and led the management board into the same direction. But as a result of the third *strategic management committee*, the management board instructed the *project team* to find ways to reduce fixed costs of *option 2*.

In the following weeks, the controllers experienced that not every member of the *project team* was happy with this situation. For example, the sales manager expressed his dissatisfaction with the consequences of the third *strategic management committee* by complaining about the variable cost evaluation:

> *"The $ 1.000, I still do not believe them to this day!"*

Discussion of example 5: We believe this example provides support for our theoretical framework in additional ways. Having started the evaluation's presentation by disclosing and explaining the applied method *enabled comparisons to calculation method*s. The *project team leader* disclosed and explained the applied logic for two reasons: first, he had planned to explain each step in more detail in the following. So, he tried to structure his upcoming presentation by starting with an explanation of what the strategic management committee could expect to see. Disclosing the method was therefore a means to increase the management board's understanding, and enable them to follow the individual steps. Second, it showed that the controllers had applied a well-accepted method that was applied for a myriad of business cases before.

Beyond that, the way the *project team leader* presented and explained the calculation *enabled comparisons between various parts of the calculation*. On the one hand, he provided many slides with explanations and details about individual aspects of the calculation. And on the other hand, he disclosed a slide that summarized all the details in order to come to a result. Like this, he was able to express which aspects and details were considered in the evaluation, and finally zoom-out to a more aggregated result.

In addition, the *project team leader enabled comparisons to numbers and sources.* Disclosing many details and sources was a means to express the calculation's hardness. Where possible, the *project team leader* disclosed that the data used for the evaluation was based on the current product generation. With regards to fixed costs or sales estimates, it was disclosed that input data was provided by the departments of sales, production, development, and purchasing. These disclosed details expressed that the evaluation was not exclusively done by the controlling department, but that other relevant departments were intensively involved, too.

4.5.3.6 Zooming-in: Final decision

For the fourth *strategic management committee*, the *project team* did not execute a new evaluation. Again, every department investigated the topic, and mentioned their main arguments on an aggregated level. In the meantime, as already mentioned in Section 4.5.3.3, *AutoCompany's* designers had built different design models for the two *options*. The car models reflecting *option 2's* concept seemed to be more attractive, and this might have changed some actors' argumentation, too. For the upcoming fourth *strategic management committee*, even sales managers acknowledged that the

> *"realization of a differentiated design language for BEVs raises attraction and offers pricing potentials."*

The controllers went on to emphasize *option 3's* fixed cost advantages respectively variable cost disadvantages. In addition, they mentioned the high sensitivity of sales-impacts and variable cost risks, and estimated the high attractiveness of future car models as a means to realize additional sales and revenues. For that purpose, the controllers considered *option 2* to be more advantageous. Production managers still favored *option 3*, but stated that *option 2* could be realized in a feasible way under certain conditions.

Finally, the fourth *strategic management committee* made the decision to implement *option 2* for the evaluated sedan segment:

> *"After considering the different factors, [option 2] for [this specific sedan] segment is recommended. Option 3 for the high sales unit segments seems not beneficial after holistic evaluation."*

The management board expected that different architectural approaches in adjacent segments were not advisable if synergies and scale effects should be realized in the future. In addition, management board assumed that the same arguments were right for similar segments, too, and therefore, the decision was expanded to all future sedan segments.

For the remaining SUV segments, additional evaluations were instructed. This task lasted for several months, and the evaluation was conducted in an analogue way. With respect to some aspects, the evaluation was more detailed: for example, *option 3's* variable cost impact was examined in a much more extensive way, but the result of approximately $ 1.000 additional costs for combustion cars changed insignificantly. Therefore, after two additional *strategic management committees, AutoCompany's* management board decided to realize *option 2* for the whole future modular architecture.

Discussion of example 6: We believe this section provides additional support for our theoretical framework. Spending a few more weeks to check and examine options' benefits and disadvantages *explicitly expressed scrutiny*. All actors were instructed to harden their data, and nobody was able to provide additional evidence to attack the existing evaluation. Moreover, we argue that the evaluation's disclosed details, which were surrounded by a significant degree of uncertainty, stimulated a discussion process and made other actors to become more open minded. While most of them had rejected *option 2* beforehand, the evaluation activated discussions and ideas to overcome identified challenges. This did not happen before. For example, production management acknowledged that *option 2's* challenges could be solved, while beforehand, these people had emphasized it would not be feasible. And sales managers changed their argumentation as well, and started to identify chances in *option 2*.

We provide a summary of our empirical data and its connection to our frameworks' aspects in Table 11.

Table 11. Overview of empirical evidence & its connection to the theoretical framework

Framework's aspects		*Empirical examples*	*Numeration*	*Section*
Providing additional data and explanations to harden information	*explicitly express scrutiny*	*Providing qualitative argumentation for scale effects in episode 1*	*episode 1, example 2*	*5.1.4.2*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Disclosing fixed cost evaluation in episode 3	*episode 3, example 3*	*5.3.5.2*
		Disclosing details about variable cost differences between scenarios in episode 3	*episode 3, example 4*	*5.3.5.3*
		Additional scrutiny of major arguments before the final decision in episode 3	*episode 3, example 6*	*5.3.6*
	implicitly express scrutiny	*Disclosing material cost differences between AutoCompany and VehicleFirm*	*episode 1, example 1*	*5.1.4.1*
		Disclosing fixed cost estimation of scenario 3.1	*episode 1, example 3*	*5.1.4.3*
		Presenting and discussing the financial evaluation of scenario 3.1 and 3.2	*episode 1, example 6*	*5.1.4.6*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Disclosing fixed cost estimation for scenario 5.1	*episode 2, example 4*	*5.2.4.3*
		Disclosing estimated sales and contribution margin in episode 3	*episode 3, example 2*	*5.3.5.1*
	enable users to scrutinize	*Disclosing main assumptions for profit effect*	*episode 1, example 4*	*5.1.4.4*
		Disclosing aggregated financial evaluation of scenario 3.1 and 3.2	*episode 1, example 5*	*5.1.4.5*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Disclosing details during qualitative evaluation process	*episode 3, example 1*	*5.3.4*
		Disclosing estimated sales and contribution margin in episode 3	*episode 3, example 2*	*5.3.5.1*
	enable comparisons between various parts of the calculation	*Disclosing material cost differences between AutoCompany and VehicleFirm*	*episode 1, example 1*	*5.1.4.1*
		Disclosing aggregated financial evaluation of scenario 3.1 and 3.2	*episode 1, example 5*	*5.1.4.5*
		Presenting and discussing the financial evaluation of scenario 3.1 and 3.2	*episode 1, example 6*	*5.1.4.6*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Presenting and discussing the financial evaluation of scenario 5.1 and 5.2	*episode 2, example 7*	*5.2.5*
		Disclosing details about variable cost differences between scenarios in episode 3	*episode 3, example 4*	*5.3.5.3*
		Aggregating & presenting financial evaluation of episode 3	*episode 3, example 5*	*5.3.5.4*
	enable comparisons to numbers and sources	*Disclosing material cost differences between AutoCompany and VehicleFirm*	*episode 1, example 1*	*5.1.4.1*
		Disclosing fixed cost estimation for scenario 3.1	*episode 1, example 3*	*5.1.4.3*
		Disclosing aggregated financial evaluation of scenario 3.1 and 3.2	*episode 1, example 5*	*5.1.4.5*
		Presenting and discussing the financial evaluation of scenario 3.1 and 3.2	*episode 1, example 6*	*5.1.4.6*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Disclosing input data for scale effect evaluation	*episode 2, example 3*	*5.2.4.2*
		Disclosing fixed cost estimation for scenario 5.1	*episode 2, example 4*	*5.2.4.3*
		Disclosing estimated sales and contribution margin in episode 3	*episode 3, example 2*	*5.3.5.1*
		Disclosing fixed cost evaluation in episode 3	*episode 3, example 3*	*5.3.5.2*
		Aggregating & presenting financial evaluation of episode 3	*episode 3, example 5*	*5.3.5.4*

Framework's aspects		Empirical examples	Numeration	Section
Providing additional data and explanations to harden information	enable comparisons to calculation methods	*Presenting and discussing the financial evaluation of scenario 3.1 and 3.2*	*episode 1, example 6*	*5.1.4.6*
		Applying analogue calculation methods for episode 1 and 2	*episode 2, example 1*	*5.2.3*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Disclosing fixed cost estimation for scenario 5.1	*episode 2, example 4*	*5.2.4.3*
		Providing details about profit effect's evaluation in scenario 5.1	*episode 2, example 5*	*5.2.4.4*
		Disclosing aggregated financial evaluation of scenario 5.1 and 5.2	*episode 2, example 6*	*5.2.4.5*
		Aggregating & presenting financial evaluation of episode 3	*episode 3, example 5*	*5.3.5.4*
	enable comparisons to a broader context	*Disclosing material cost differences between AutoCompany and CarEnterprise*	*episode 2, example 2*	*5.2.4.1*
		Providing details about profit effect's evaluation in scenario 5.1	*episode 2, example 5*	*5.2.4.4*
		Disclosing details during qualitative evaluation process	*episode 3, example 1*	*5.3.4*
Providing additional data and explanations to advance own agenda	reverse burden of proof	*Disclosing fixed cost estimation for scenario 3.1*	*episode 1, example 3*	*5.1.4.3*
		Presenting and discussing the financial evaluation of scenario 3.1 and 3.2	*episode 1, example 6*	*5.1.4.6*
		Disclosing material cost differences between AutoCompany and CarEnterprise	*episode 2, example 2*	*5.2.4.1*
		Disclosing input data for scale effect evaluation	*episode 2, example 3*	*5.2.4.2*
		Disclosing fixed cost estimation for scenario 5.1	*episode 2, example 4*	*5.2.4.3*
	focus burden of proof	*Disclosing details about variable cost differences between scenarios in episode 3*	*episode 3, example 4*	*5.3.5.3*
	open/ close the window of opportunity for challenge	*Disclosing aggregated financial evaluation of scenario 3.1 and 3.2*	*episode 1, example 5*	*5.1.4.5*
		Presenting and discussing the financial evaluation of scenario 3.1 and 3.2	*episode 1, example 6*	*5.1.4.6*
		Disclosing fixed cost estimation for scenario 5.1	*episode 2, example 4*	*5.2.4.3*
		Providing details about profit effect's evaluation in scenario 5.1	*episode 2, example 5*	*5.2.4.4*
		Disclosing estimated sales and contribution margin in episode 3	*episode 3, example 2*	*5.3.5.1*

4.6 Conclusion

The underlying study discusses how the way of communicating soft and incomplete accounting information affects its persuasiveness. In organizations with a need for action, calculations and numbers represent estimates about an uncertain future. In our studies' context, a group of people, the players, creates and hardens accounting information. This group aims to persuade another group, the users, in order to act on that information. Therefore, the role of soft accounting information during decision-making is socially constructed. While accounting information can be incomplete and highly uncertain, it can either way impact the decision-makers choice. We focus on the role of details and explanations, and how their disclosure may help to harden information and make people act accordingly.

We develop a theoretical framework that aims to explain how providers of soft accounting information communicate in order to enhance their influence and persuade the audience. Based on literature about hardening information (Rowe et al., 2012), we firstly state that a calculation's persuasiveness can be increased by providing details and explanations that show that the calculation has undergone *scrutiny*. This can be done in an *explicit* way, for example by disclosing which steps the provided information has undergone. Or *implicitly*, as providing very detailed information only few people may have access to implies that the information provider must have talked to experts, consulted specific data sources, or conducted sophisticated evaluations. Additionally, providing details and explanations may also *enable users to scrutinize* the provided information themselves. By disclosing information in a non-technical and understandable language, actors can evaluate a calculation's individual aspects, and bring it into line with knowledge and experiences they already have.

Second, we argue that accounting information can be hardened by enabling users to compare it to other information or important and accepted reference points. This can happen in several ways: providing details about which elements a calculation or number consists of *enables users to compare between various parts of a calculation*. Information providers may also disclose details about where the data used to create particular information comes from. This *enables users to compare* the provided information *to numbers and sources*. Moreover, players can give more or less details about the *calculative proceeding*, and disclosing elements that do not only affect the specific organization, but refer *to a broader context*, may also help to increase numbers' persuasiveness.

We postulate that accountants are not neutral providers of information, but deliberately disclose details in order to increase their calculations' persuasiveness. They do so to support their objectives and help to advance their agendas. We argue that they can apply different instruments. First, accountants can anticipate uncertainty and stake their claim by setting and disclosing an arbitrary, but reasonable assumption. Doing that, they *reverse the burden of proof*. As long as the offered assumption is within an acceptable grey zone's boundaries, opponents need to argue why another assumption would increase the calculation's quality. Second, giving detailed information about a calculation's details makes the audience to focus on them. Instead of discussing the calculation's result, actors who do not like what the calculation suggests need to attack particular aspects the calculation is based on. Therefore, disclosing details may *focus the burden of proof*. And third, disclosing detailed information about a calculation *opens and closes the window of opportunity for challenging* it.

We provide empirical evidence from an interventionist research study we conducted in cooperation with a car company. During three years, one researcher was part of the company's controlling department, took an active part during three strategic episodes, and provided accounting information that was influential for the final decision. We extensively present our empirical data in order to illustrate our framework and increase our understanding of how the provision of details and explanations about a (soft) calculation affects its persuasiveness and impact on decision making.

The underlying paper also has some limitations. First, we base our theoretical framework on the idea of a practical arguments game (Rowe et al., 2012). This game entails quite a democratic and public decision process under an intensive participation of actors from different disciplines. Decisions are made in interdisciplinary committees, and the players' goal is to persuade at least the majority of users. This particular context is, of course, not given in every situation or organization facing decisions under highly uncertain circumstances. We cannot tell if or how our contributions could be transferred to other settings or "games" (see Rowe et al. (2012)). Second, the presented empirical evidence is neither reproducible nor representative, but serves as detailed practical examples. It does not only illustrate our theoretical framework, but also triggered the research's conceptualization and contribution as a whole. The researcher might have a biased perception, and therefore he might also have missed some relevant aspects.

We propose further research that may help to increase our understanding about how the way of communicating uncertain information impacts information receivers' acceptance to use it for their decision. While our study presents empirics from quite an established industry, we would be interested in how things may change in younger or different industries and branches. Moreover, while we collected data about interdisciplinary staffed decision processes, examining how other settings may confirm or change our findings could be a fruitful research opportunity. For example, how do things change in situations when heterogeneity of the players' group and users' group is much higher? If we leave the area of a practical argument's game, we are curious how a change of contexts and other determinants may impact the successful way of communicating a calculation's softness.

5 Conclusion

The purpose of this dissertation was to shed more light on practical cost management challenges for portfolio-oriented approaches, such as modular design, as well as to investigate how persuasiveness of management accounting technology could be enhanced by the provision of additional details and explanations. With a three-year research project in cooperation with a car manufacturer, we were able to generate three studies—a literature review, a method-oriented study, and a qualitative case study. Not all aspects of these three studies contribute to one central research question, as the research foci were also inspired and motivated by practical requirements and challenges the researchers identified while executing the project. In the following, we briefly summarize our main findings, discuss the studies' limitations, and suggest future research opportunities.

In our literature review study, we examined the use of product modularity for cost management purposes. The main contribution of this study is providing an overview of different conceptualizations of modularity and cost impacts of modular strategies during the different stages of a product's life cycle. We systematically scanned various literatures and found that much more has been published in the innovations and operations management literature than in the management accounting and control literature. We also found several holistic case studies that illustrate the concept of modularity in a pragmatic way. Yet most of the researched literature is not empirical, but uses rather quantitative models and address stylized settings.

Furthermore, we distinguished portfolio-oriented management approaches such as modularity, component commonality, and product platforming from target costing. We discussed a few studies that look at behavioral aspects, such as cost allocation and incentives for product managers to apply more common components. Moreover, we identified a few empirical studies that deal with the topic of practical challenges for accountability in modular contexts. These studies show that very accurate and detailed models may not work in practice, and illustrate how modularity can be achieved more realistically. However, we did not find much knowledge about cost management practice in the context of modular designed product families, and therefore identified this as a clear gap in the literature.

Second, we extended the scope of target costing and conceptualized a method to determine fixed cost targets for a modular designed product family. So far, the target costing literature has focused on a single product, and it provides scarce insights how cost targets beyond variable manufacturing costs can be defined and managed. Considering a few input parameters (such as the relevant product portfolio, as well as product-individual estimates for sales units, net revenues, and appropriate cost ratios), we were able to calculate and establish targets for R&D costs and manufacturing investments for a modular architecture. In a subsequent step, the method allowed us to determine fixed cost specific targets for individual elements.

We provided empirical evidence for the successful implementation and practicality of the method in a car manufacturing firm. We executed the method in order to increase organization-wide coordination efforts, to restrict unprofitable product variety and complexity, and therefore to realize significant cost reductions. We presented mixed reactions and arising challenges during the method's implementation, and we thereby offered a more realistic picture of how modular strategies and cost management efforts may look like in practice. With our empirical data, we were able to illustrate the consequences that may occur if a firm decides to move towards a modular strategy but fails to adapt its cost management systems in an adequate way.

Third, we conducted a qualitative case study. Calculations around product design decisions in the context of modularity are surrounded with great uncertainty and may be perceived as soft. We provided a theoretical framework that explains how disclosing additional details and explanations can help to harden soft accounting information, and therefore enhance the calculation's persuasiveness and make people act accordingly. Based on literature about harden information and persuasiveness of numbers, our data and experiences we gathered at our case company inspired us for the theoretical framework's conceptualization. To illustrate and substantiate our theoretical framework, we provided an extensive number of empirical examples that concerned decisions for the modular design of products.

According to our framework, disclosing additional details and explanations can be used to either *explicitly* or *implicitly* indicate that the information has undergone *scrutiny*, and also to *enable people to scrutinize* the information themselves. Moreover, the providers of soft accounting information can *enable* various ways of c*omparisons: to numbers and sources, between various parts of the calculation, to calculation methods, and to a broader context*. As additional means to advance their own agendas, providers of soft accounting information may deliberately disclose details and explanations. Doing that, they *reverse* respectively *focus the burden of proof*, and *open* respectively *close the window of opportunity for challenge*.

The dissertation's limitations are related to the applied research methods of the presented studies. We have already discussed the study-specific limitations in each of the three studies, and will briefly recap the main aspects. The literature review study entails the limitation that the results do not cover all potentially relevant studies. The topic of modularity is extensive, and even if we chose a quite structured and systematic approach and aimed to cover many relevant scientific journals, we do not claim to present a fully complete picture of all studies that deal with the topic of modularity, cost management, and NPD. But we believe that we captured a significant amount of studies that are relevant for the study's topic.

A second limitation of the thesis is caused by our empirical research approach. Conducting a qualitative field research study entails the risk of selective perceptions, as well as biased observations and interpretations. Our research cooperation with a real company also implies that we had low control over the empirical space. Challenges and requirements our cooperating firm would face during the course of the research project were not precisely known at the beginning, so upfront, we could not define a definitive, concrete and detailed research question. But we want to emphasize that this aspect also constitutes one of the most significant strengths of an interventionist research study: we could think of no other research approach that would have generated such detailed insights, research opportunities, and contributions than we could achieve with the current research design.

Another limitation of the thesis is that the empirical evidence originates from one firm. Our findings are therefore neither reproducible nor generalizable, but this is also not the objective of the current work. We aimed to provide detailed and realistic insights into cost management challenges a company that follows a modular strategy is confronted with. With respect to our qualitative case study, we conceptualized the theoretical framework and provide empirical examples for this particular setting. We would be curious to which extent it fits into deviating contexts and settings. Even though the underlying thesis entails the mentioned limitations, we emphasize the multiple contributions our research studies provide both to academia and management accounting practice.

The dissertation triggers many questions and opportunities for future research. In general, we found that management accounting literature tends to simplify practical challenges and complexity of both modularity and target costing. We are interested in a broader and deeper understanding of practical requirements that consider the multifaceted aspects current literature does not focus on. Conducting more studies that are inspired by real organization's work, we could generate a more realistic understanding how the mentioned cost management strategies and accountability operate in practice. For example, future research could build on our findings and further investigate how real organizations deal with quantitative models to capture cost management challenges around modularity. We would be highly interested in the design of cost management and incentive systems that use cost allocations in order to influence decision making and align individual and global agendas. We encourage research also to follow the interesting intersection of target costing and portfolio-oriented cost management efforts. While there exist plenty of "success-stories" about target costing implementation, to the best of our knowledge, there are few empirical studies that discuss cost management conflicts and challenges that arise if a portfolio-oriented perspective like a modular approach enters the system.

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