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CONTROL AND COORDINATION OF DESIGN-DRIVEN INNOVATION PROCESSES: CASE EVIDENCE FROM THE AUTOMOTIVE INDUSTRY

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ABSTRACT: The control and coordination of design and technological innovation pose a dilemma for design-driven organizations because the measurability of design and technological innovation differ. On one hand, a product's aesthetic value might increase if its design is separated from technological innovation and if design is controlled by means other than those used in technological innovation. On the other hand, tight integration is warranted because a product's design affects its cost, technical performance, and manufacturability. This dilemma is the focus of the paper. The paper contributes to extant literature in several ways. First, it conceptualizes control as a process that manages design and technological innovation through distinct, separate control mechanisms. Second, it analyzes and develops three modes of convergence through which the potentially contradictory concerns of design and technological development can be compared and evaluated. Finally, the paper suggests that coordination can be achieved through convergence processes that unfold and develop over time.

Keywords: Control mechanisms, innovation control, coordination, product design, target costing, competition, convergence.

INTRODUCTION

> *Dear Designer, You are just a small guy; behind you there are 500 engineers who have to bring the car onto the street. They check for homologation, for costs, 15 years' durability, and so on [...]. They are way more, and now you want to tell them to avoid the 2mm increase in the airbag rail? That will not work.* [Design Engineer]

Design is increasingly viewed as an important aspect of industrial companies' competitiveness. Unique designs can redefine users' experience of a product and the meaning they ascribe to it. Design-driven strategies enable companies to increase customer loyalty, increase turnover, and find new niches for their products (Verganti 2008; Dell'Era and Verganti 2009). However, managing design-driven innovation processes in industrial companies is problematic, as design and technological innovation are two different tasks.

On the one hand, designers try to develop new artifacts that can potentially generate new markets and demand. Designers interpret broad changes in society and culture and develop new aesthetical forms that are pushed on to the market in order to redefine a product's "language and meaning" among users (Verganti 2008, 436; see also Krippendorff 1989). Design is a creative process, and designers tend to be viewed as artists (Anderson and Sedatole 1998; Dell'Era and Verganti 2009; Jeacle and Carter 2012). Design-driven innovation processes are therefore highly uncertain, and design outputs are difficult to translate into cost and value (Hatchuel and Weil 2009).

On the other hand, technological innovation is related to strong notions of scientific knowledge, is based on explicit engineering knowledge, and concerns "functionalities and technologies" (Dell'Era and Verganti 2009, 1). Technological innovation is consequently a much more calculative, quantified process focused on managing knowledge translation in product development processes (Anderson and Sedatole 1998; Dell'Era and Verganti 2009;

Ayers, Gordon, and Schoenbachler 2001; Cooper 1990). Therefore, the tasks of design and technological innovation are different and potentially opposed to each other. These differences produce a control and coordination dilemma.

The control problem arises because utilizing the same control mechanism for fundamentally different tasks may generate dysfunctions. Due to the uncertainty surrounding performance outcomes, it is difficult to develop performance measures that adequately measure creativity (Cools, Stouthuysen, and Van den Abeele forthcoming; Holmstrom 1989; Holmstrom and Milgrom 1991; Merchant 2006). This makes it challenging to distinguish excellent from bad performances and therefore to incentivize effort for creative tasks. If control systems do not consider this, it could lead to a lack of effort in uncertain activities (Holmstrom 1989).[1] Research therefore suggests that design processes be separated from technological innovation and that design is controlled through different means than technological innovation (Dell'Era and Verganti 2009; Holmstrom 1989; Verganti 2008).

However, the use of different control mechanisms and the separation of design and technological innovation in turn generate a coordination problem, as design processes have a huge impact on product cost, function, and manufacturability (Anderson and Sedatole 1998; Bramall et al. 2003; Jeacle and Carter 2012). As this paper's opening quote emphasizes, designers need to coordinate their solutions with technological development, and they are positioned against engineers, who calculate value, cost, and technical criteria. Design must be insulated from technological requirements and cost issues through a separation of spaces and different control mechanisms. However, at the same time, design must be tightly integrated with technological innovation to coordinate cost and technical and aesthetic concerns. This control and coordination dilemma is the focus of this paper.

[1] Holmstrom (1989) argues that this separation is difficult to accomplish within a firm, and therefore, innovative companies are smaller, while larger, bureaucratized companies pursuing innovation largely decentralize responsibility financially or through spin-off innovative activities.

Several strands of research have produced insights relevant to this control and coordination problem. The literature on creativity and control tends to argue that control used in an appropriate manner can increase creativity. Control systems that employ "enabling bureaucratization" help firms to pursue both efficiency and flexibility (Ahrens and Chapman 2004; Jørgensen and Messner 2009). The literature further argues that the specific mechanisms used to control creativity produce different types of outputs (Kachelmeier and Williamson 2010). This literature, however, tends to downplay coordination problems among creative, cost, and technical concerns.

The literature on target costing focuses on how design can be coordinated with technological innovation. Coordination is achieved by making design choices subject to value and cost constraints in a tightly integrated process (Anderson and Sedatole 1998; Ansari, Bell, and Okano 2007; Carlsson-Wall, Kraus, and Lind 2009; Monden and Hamada 1991). However, such tight integration and the dominance of one particular diagnostic control mechanism (Simons, 1995) could reduce the creativity of design outputs (Cools et al. forthcoming; Davila and Ditillo forthcoming). Research in design management therefore suggests that coordination efforts be minimized and that design be prioritized over technological innovation (Verganti 2008). Both of these coordination approaches investigate how either design or technological innovation dominates the other in a sequential approach. The literature therefore does not investigate more intermediate solutions involving reciprocal coordination efforts or the development of coordination mechanisms over time.

In this paper, we will extend the extant research by focusing on both control and coordination problems. In particular, we will analyze the specific ways in which design and technological innovation can be coordinated through convergence processes that work on the reciprocal interdependencies between design and technological innovation. For this purpose, we pose following the research question: *How are aesthetic design and technological* *innovation controlled and coordinated as particular mechanisms and processes unfolding over time?*

To study this question, we conducted a longitudinal study of an automobile manufacturer over two years during which we attended more than 50 meetings, gathered relevant company material, and conducted 24 interviews. We followed two cases throughout their conceptual phases, detailing the processes of control and coordination. We drew on multiple studies to develop the paper's focus. In particular, Verganti's (2006, 2008, 2009) work on design-driven organizations and Callon's (1991) theory of techno-economic networks helped frame the control and coordination analysis. The literature on creativity and control (Davila and Ditillo forthcoming; Cools forthcoming; Jeacle 2015; Jeacle and Carter 2012; Kachelmeier and Williamson 2010) helped frame the problem of how to control the creative process.

We found that at Automotor Company design and technological innovation are separated in early design phases to foster creativity, and that design and technological innovation employ different control mechanisms. Design is controlled though a competition mechanism and through isolation from technological innovation, while technological innovation is controlled through target-based performance measurements.

We furthermore develop three convergence processes through which the difficult-to-compare outputs of design and technological development can be coordinated over time. The first mode—"domination"—makes one space concede to demands from the other space. The second mode—"full convergence"—is a processes of quantification that translate designs into financial values based on expected customer demand. The third mode—"joint evaluation spaces"—creates a space where both aesthetic and cost concerns can be evaluated simultaneously without creating one common quantified financial metric. Coordination is not imposed at the beginning or end of these processes but while they are ongoing. Moreover, coordination consists of multiple interventions that seek to address reciprocal interdependencies between design and technological innovation (Thompson 1967).[2]

This paper is structured as follows: First, we review extant literature and develop our approach to studying control and coordination problems. Second, we provide an overview of our research methods. Third, we analyze Automotor Company, focusing primarily on its general coordination and control mechanisms for design and technological innovation. We then analyze the coordination and control dilemma in depth and over time in two embedded cases.

THEORETICAL APPROACH

Control of Creativity, Design, and Technological Innovation

Controlling creative and innovative processes is a problem because a bureaucratic or diagnostic use of cost and performance management systems undermines intrinsic motivation, reduces creativity, and does not allow for sufficient flexibility in the development process (Adler and Borys 1996; Ahrens and Chapman 2004; Davila 2003; Davila and Ditillo forthcoming; Cools et al. forthcoming; Jeacle and Carter 2012). This problem has been analyzed in different ways in the extant research.

The literature on enabling bureaucratization argues that a bureaucratic use of control systems can generate dysfunctions of low creativity and flexibility (Adler and Borys 1996; Ahrens and Chapman 2004; Chapman and Kihn 2009; Free 2007; Jørgensen and Messner 2009; Mundy 2010; Wouters and Roijmans 2011; Wouters and Wilderom 2008). However, an enabling bureaucratization, which uses various processes, such as repair, flexibility, transparency, and accounting used as a “mode of thought” can help companies simultaneously pursue creativity, flexibility, and efficiency (Ahrens and Chapman 2004;

[2] We would like to thank the editor for input to this particular phrasing.

Jørgensen and Messner 2009). Cools et al. (forthcoming) find that the type of creativity that firms aspire to shapes the extent to which they use budgets interactively or in a more bureaucratic, diagnostic way. Expected creativity that focuses on open problems and use unknown methods benefits from an interactive use of budgets. Responsive creativity that focuses on closed problems and known methods is promoted by a diagnostic use of budgets. In general, the enabling bureaucratization approach importantly points to the significance of organizational processes and how the use of control systems can reduce problems with an imperfect control mechanism. The approach's focus on the *use of one* control mechanism, however, can be extended by detailing the elements of the control mechanisms used, as well as their interaction.

Another stream of literature directly focuses on the structure of control mechanisms for creative processes (Davila and Foster 2005, 2007). Kachelmeier and Williamson (2010) and Kachelmeier, Reichert, and Williamson (2008) analyze how the use of quantity- and creativity- focused control mechanisms affects creativity and output. Kachelmeier, Reichert, and Williamson (2008) find that quantity incentives produce the same quantity of high quality creative output as incentive schemes that reward only creativity or both creativity and quantity. However, quantity schemes increase the amount of mediocre output, which reduces its average creativity quality. Davila and Ditillo (forthcoming) find that control systems define the creative space, inspire creative people, and increase creativity. They further develop two types of systems: Inspirational systems "guide the creative process to enhance the novelty of the end results and generate the variation required to surprise the customer (and society more broadly) while developing consistent stylistic ideas and meanings" (6). On the other hand, directional systems "define the creative space within which the creative individuals work ... [and] also work as interfaces with the rest of the company" (7).

These two streams of literature thus argue that it is important to analyze both how a particular management control mechanism affects creativity and how the control mechanism is used. However, both predominantly focus on the control problem, deemphasizing coordination processes.

Coordination of Design and Technological Innovation

The problem of coordination between design and technological innovation has been studied in three sets of literature, which argue either that cost concerns should dominate design or that design concerns should dominate the innovation process.

The target-costing literature seeks to analyze how target-costing systems quantify design, making it subservient to technological innovation and cost control (Anderson and Sedatole 1998; Ansari, Bell, and Okano 2007; Monden and Hamada 1991). It thus focuses on how costs can be reduced and technical functionality can be enhanced through the rigorous application of comprehensive target-costing systems that define customer value and allocate that value to the product's functions and components (Ansari et al. 2007; Carlsson-Wall, Kraus, and Lind 2009; Monden and Hamada 1991). The literature focuses on how tight integration and the dominance of technical and calculative processes through target costing can help firms manage up to 80 percent of their total product cost (Anderson and Sedatole 1998; Ansari, Bell, and Okano 2007; Carlsson-Wall, Kraus, and Lind 2009; Monden and Hamada 1991). In this approach, design is thus deemphasized at the expense of technological innovation. This solution has been demonstrated to work in industries that are not design driven, such as airplane development (Anderson and Sedatole 1998), robotics (Carlsson-Wall, Kraus, and Lind 2009), and non–design-driven car manufacturers (Monden and Hamada 1991), but it can lead to motivation and creativity problems in design-driven organizations (Verganti 2009; Cools et al. forthcoming) or for firms where factors other than cost are more important (Davila and Wouters 2004).

Verganti (2009) advocates a different and contradictory approach. In this view, design should not only be controlled by mechanisms other than technological innovation; it should also be separated from calculative and technical processes in order to increase creativity in design processes. Verganti (2009) argue that design processes should "avoid being diverted by constraints emerging down-stream in development that can jeopardize the identity of the vision…they should not compromise its integral nature and personality" (186). Thus, design and creativity should be maximized through their separation from technological innovation, and design and technological innovation should not be coordinated. Instead, design should dominate technological innovation in a sequential process in which technological innovation develops solutions to a finished design.

Coordination has also been studied on a general level as coordination between accounting and professions with other objectives (Abernethy and Stoelwinder 1995; Kurunmäki 2004). These studies have mainly concerned the health care sector and investigated the relationship between professional and administrative controls. The problem is that professions pursuing objectives other than cost and profit might need to coordinate with accounting. This produces a conflict between the accounting department and the profession in question. In this context, Abernathy and Stoelwinder (1995) argue that output-focused controls increase role conflict, while Kurunmäki (2004) argues that professionals can learn to use management accounting techniques to such an extent that they hybridize their profession.

The literature on coordination discussed in this paper in general presents two extremes: a process of high integration from early phases through target costing or professional hybridization (Anderson and Sedatole 1998; Abernethy and Stoelwinder 1995;

Kurunmäki 2004), or a highly fragmented process throughout development (Verganti 2009). This divergence points to two important factors.

First, pursuing Verganti's reasoning to its conclusion would mean that design is isolated from technological innovation, no coordination of the manufacturability of design is analyzed, and cost consequences of designs are ignored. As argued in the extant target-costing literature, having an exclusive focus on design is potentially problematic, because of the high influence of design on cost (Monden and Hamada 1991; Ansari et al. 2007; Carlsson-Wall, Kraus, and Lind 2009).

Second, this disagreement points to the question of how to time coordination efforts. Whether a highly integrated process from the initiation of development or a highly fragmented process throughout is preferable is obviously an empirical question. However, it also overlooks the potential relevance of more intermediate solutions. Coordination efforts could potentially be imposed at various phases of the design and technological development process. Furthermore, while it is unlikely that development processes will be initiated without any coordination mechanisms, it is also unlikely that all eventualities will be contemplated *ex ante* in development processes spanning many years. Coordinating mechanisms are also likely to be developed during development processes. It is therefore important to analyze coordination both as a structural mechanism and as a process in which coordination mechanisms develop over time (Jarzabkowski, Lê, and Feldman 2012). To our knowledge, no management accounting paper has analyzed the process of coordinating design with technological innovation or how these aspects are coordinated over time.[3]

[3] Quattrone and Hopper (2005), in the context of implementing enterprise resource planning systems, discuss how accounting generates time and space in organizations. Their paper has some parallels to the issues we discuss, but it is based on a more radical conceptualization of time and space, which sits uneasily with our paper's focus on understanding how the different tasks of design and technological innovation are controlled and coordinated.

Callon's (1991) work on convergence in techno-economic networks supplies a conceptual apparatus for studying coordination as a process. Callon (1991) suggests that a techno-economic network consists of three different poles: scientific, technical, and market. These poles are "worlds apart" (135), meaning that they work in different ways and are measured by different means. Their interrelationship is defined through mechanisms[4] that coordinates and aligns the techno-economic network and can include anything passing among persons and groups and which thereby defines their relationships (Callon 1991, 134). Mechanisms help estimate what is valuable for each pole and, as such, both control its interactions and characterize it. The diversity among the poles and the lack of a common metric to measure value, however, make coordination difficult.

Other mechanisms are here used to create convergence among the separate poles of the network and to "create unified spaces" (Callon 1991, 133) that help build links between quantified and non-quantified elements. Such convergence processes develop coordinating mechanisms in the process of dealing with organizational challenges. When convergence is complete, the standards of the different poles are equivalent and measured in a similar manner (Callon 1991, 145). When this occurs, a joint metric is formed, and the output of the poles is measured as a value with a singular meaning. However, if convergence is incomplete, the question remains how the value of different poles, such as design and technological innovation, can be compared and converged. Whether one of the poles dominates the other is determined by the mechanisms used and is an empirical question.

This discussion points to a need for research analyzing the particular mechanisms through which design and technological innovation are controlled and coordinated. Furthermore, the arguments require a focus on how design and technological innovation is

[4] Callon (1991) calls such mechanisms "intermediaries." We have chosen to call them "mechanisms" to simplify the conceptual apparatus.

coordinated through convergence processes that develop over time. In the following section, we address the methodological approach used for gathering and analyzing our data.

RESEARCH METHODS

Empirically, we have chosen to focus on two embedded cases in which design and technological innovation converged. It would have been practically impossible to convey the complexity of the combined work of approximately 2,000 employees working on a particular car project. We therefore zoomed in on specific processes of controlling and coordinating design and technological development so detailed evidence of the general processes could be generated. This approach is also based on Callon’s (1991) recommendation to focus on detailed descriptions as a research method.

We have aimed for variety with the case types, which cover different aspects of car design and development. We have also placed significance on design as an element of the cases and thus specifically chosen cases with design issues. For some car components, such as screws and bolts, aesthetic design is unimportant, but for the majority of components, design has an impact on technological innovation or vice versa. This includes everything visible inside a car, lights, all components contributing to the shape of the car, and wheels. Even engines have a design impact through their size, which impacts the space inside the vehicle. The cases were also chosen based on availability. It was especially difficult to gain access to designers because access to designers is severely restricted.

The first case concerns the front design of a specific car, its selection process, and its problems meeting technological innovation criteria. The second case focuses on the selection of a dashboard design and its further development in one particular car project. The first case was selected because the car is a design icon, and there is enormous cost pressure on that car model; therefore, we expected both design and cost factors to be important. The second case was selected because dashboards are an important part of the interior design, and many options exist for both cost reduction and aesthetic expression. This choice also allowed us to analyze both exterior and interior car design.

Data Collection Methods and Analysis

The data collection and analysis proceeded in the following manner: We started out collecting internal documents (such as strategy papers, business cases, presentations, minutes, and memos). We then attended more than 50 meetings and conducted participant observation (of design presentations, decision circles, and cross functional teams) over a two-year period. Then, we conducted 24 interviews (Appendix 2), of which 22 were recorded and transcribed. The other two interviews could not be recorded due to confidentiality constraints, but careful notes were taken.

The first author was an innovation controller at Automotor Company,[5] so we were granted broad access to relevant material. However, as part of the technological development section, the first author was not allowed to observe design processes, and his access to the design department was severely restricted. The first author conducted eight of the 24 interviews; both authors conducted the other 16 interviews. In addition to the interviews specifically conducted for this paper, we completed another 49 interviews at Automotor Company in order to develop other papers, particularly on financial quantification in

[5] The employment of Author 1 with the case company (while pursuing a Ph.D.) entailed advantages and disadvantages for the research process. It was beneficial in the sense that we gained access to a setting that is probably inaccessible to any outside researcher from academia. The negative side was the potential for bias in the data collection and analysis (Hermanowicz 2002). We have worked with this limitation in the following ways. First, Author 2 also conducted interviews within the case firm, and second, Author 2 also coded the material and reviewed all analyses. Moreover, it may be argued that the reliability of the study has potentially been increased due to the employment of Author 1, because researchers not employed within the firm simply would not have gained access to this data and hence would have generated different data. This was directly experienced in the data collection phase when the corresponding Author started some interviews without Author 1 present. Respondents were then very reluctant to provide details. Later in these interviews, Author 1 participated and respondents provided many more details and were more direct and honest in their replies.

technological development. These interviews were mainly conducted before this study's data collection and have provided background knowledge that sharpened our focus for conducting the 24 interviews and gathering documents. The analysis was iterative, and further theory was added in the process. We read and analyzed interviews upon transcription, and they helped us focus the subsequent data collection.

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

In the following section, we analyze the mechanisms of control and coordination in the product development and design processes. This will be followed by presentation of the two embedded cases in which we analyze the control and coordination processes in more depth.

EMPIRICAL FINDINGS

Control of the Design and Technological Innovation Processes at Automotor Company

Product development (technological innovation) and design are two distinct spaces at Automotor Company. Technological innovation consists of several sub-units within research and development that report to the chief technology officer. Technological innovation is mainly concerned with research on innovative technologies, development of new car projects, technical production launch, testing, and quality improvement. Design is also a distinct organizational unit within research and development that reports to the chief technology officer, and it focuses on design and design development. The design unit, however, also has a head of design with extensive decision-making power. Employees in technical innovation cannot communicate directly with those in design. Design and technological innovation are instead connected through concrete car projects headed by a project leader. Representatives from purchasing, production, finance, and marketing also participate in these car projects.

Technological innovation and design have different focuses and control mechanisms. This is illustrated in the Table below:

	Design space	Technological development space
General control mechanism	*Competition between drawings or clay models. Aesthetic output control.* "You can draw the coolest sketches ten years long, but if your boss does not like them, you are out [...] the Head of Design is the boss here and he says, "No, I do not like that, I want to have this one and not that". The Management Board then comes into play when the clay models are there. Now they are more powerful than Head of Design. The final model is decided by the Management Board." [Designer]	*Target performance management: Cost calculations and technological feasibility studies.* "We have to calculate a business case, but first of all we have to check geometrical possibility and then we have to check boundaries for building the cars, and then we have to check for insurance and crash safety …And for that we have a test ... So these are all points we are trying to ask everybody in the whole process what may be problematical, how we could solve it and then we make a business case. I have made all the details with Financial Departments and with Development, because they have to build these parts, and then in the end we go to the Project Manager and we say OK these are the features, are we willing to spend this money or not?" [Developer]
Types of mechanisms and quantification	*Physical expression, models, and visualizations.* "That is different in Design, you have an immediate picture including every single detail. You look at a car and you see if you like the outer rear-view mirror or not. Or the trunk-lid… in Design, there you have a picture immediately." [Developer]	*Numbers (cost and engineering calculations)* "The problem is that in product development everything is measurable. Cost, or CO2 emissions, everybody has their own currency. Aerodynamics is the best example. They have their cx-value. They say to us: "If you do not believe the numbers, we do a nightshift in the wind-tunnel." And then they have the exact values and you may have to fight against this." [Designer]
Focus of the process	*Aesthetics and coherence in and among models.* "They have done studies and things. If you talk to experts, it's the biggest selling factor all together. It's not the six cylinder engine and it's not the 350 hp. It's people who see the new car and say, „Wow, that is so cool, I want to have it." It's not the 19" wheels, of course, the wheels have a say, but the design comes first, and then there are some other things that follow[...]many people at [Automotor Company] agree with this. Design is the key selling factor altogether." [Designer]	*Development of parts and components, technical feasibility, and estimation of value and cost.* "Manufacturing and all the upfront costs and investments. And I had to calculate [...] development costs for the supplier and for Automotor Company. From these costs, Controlling calculates the business case. And then we make an offer to our Project [Managers] and they decide, if they want to buy or order this prospect in their development department. [...] And the business case showed that we have a return on investment, equal to or better than the system we have at the moment."[Developer]

Table 1 Control mechanisms for design and technological innovation

In technological innovation, the general control mechanism was target-based performance measurement. Technological innovation was responsible both for the overall business case that estimated expected returns and for ensuring that performance criteria were developed and met. The performance measurement system had targets for overall costs, as well as a number of non-financial elements. Non-financial criteria and targets were developed based on benchmarks (e.g., quality ratings and car tests), customer evaluations (e.g., focus groups) and strategic goals (e.g., visions such as "we will always produce the safest and environmentally friendliest cars on the market"[6]). Space and storage, aerodynamics, or driving characteristics were typical non-financial criteria. Performance targets also pertained to broader cost and strategic issues in the organization (e.g., weight, CO2, and complexity).[7]

Typically, non-financial criteria affected financial performance criteria. For example, weight had an effect on customers' perceptions of cars when heavy cars were considered outdated, and it thus affected sales price. Weight was furthermore expected to be an important concern if and when electrical cars were implemented because weight has an impact on how far an electrical car can be driven before its batteries need to be recharged. Performance targets were selected and fixed shortly before the final design model was selected.

In addition to developing and complying with targets, technological development was responsible for developing car parts and concepts (e.g., material choice, engines, supplier selection). Teams with representatives from finance, purchasing, manufacturing, cost

[6] This is just an example and was not the vision of the case company.

[7] The weight target was the maximum weight of the car in the most likely combination of options to control maximum weight capacity, as well as to steer towards the CO2 target. The CO2 target was the CO2 level of the car in the most likely combination of options and was highly important for meeting the CO2 standards of specific regions, and hence, it affected target sales prices and cost. Crash criteria were important for the ratings of independent institutes with specific crash criteria, including passenger and pedestrian safety, which affected target sales prices. Driving characteristics were set based on different criteria, such as acceleration time, braking distance, or handling. Complexity was related to the number of parts, which affects efficiency overall in production, purchasing, and distribution.

engineering, and research and development developed parts and concepts based on performance criteria. Teams were coordinated by a project manager, who formed a decision circle in which the developed concepts were discussed and decided upon based on target costing (see Appendix 2 for interviews and description of various types of employees). The focus of technological development was thus the development of parts and components, as well as the development and achievement of both financial and non-financial targets.

Design was subject to a mechanism that generated aesthetic output control through competitions evaluating visualizations (i.e., drawings) and physical expressions (e.g., clay models) of designers' ideas. Approximately 20 designers initiated a project by drawing sketches. These sketches were then selected by the head of design for the creation of a life-sized clay model, with about five models of the exterior and four of the interior.[8] Selected designers developed their particular concepts in clay models, which were presented to the board in the second selection round, at which point the number of models and designers was reduced to two. The two winning designers then further worked on their models, and in the last round of the selection phase, the interior and exterior models were selected. Afterward, the wining interior and exterior designers worked with technological innovation to further adjust their models. The board of directors selected between the clay models. During this entire selection process, the clay models were increasingly developed and refined. The competition mechanism was intended to ensure that decision makers had numerous options available in the selection process. The mechanism incentivized designers to develop new, creative designs, as will be further discussed in the embedded cases.

The design process begins with a car's strategic documents and focuses on making the best aesthetic design in relation to these strategic directions. The strategic documents have a specific design language and refer to the specific model or type of car to be designed. The

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

design language is intended to frame the designers' work. Words such as "lightness," "dynamic," or "aggressive" were used as design characteristics for aspects such as shapes, materials, or textures. A dashboard, for example, should represent more "lightness" in successor models, resulting in slimmer dashboard layers and thinner decoy elements. "Roominess" was achieved by creating shadows and light spots on the dashboard. "Presence" was referenced in discussions on the rear ends of specific cars and referred to perceiving the trunk and tail lights as bigger. These language characteristics were transferred to cars, which then spoke a specific design language. This provided the designers with a broad direction and limited their creative space. Design language thus acted as inspirational and directional control systems (Davila and Ditillo forthcoming).

Nevertheless, the designers tried to individualize their designs and sought be visionary while creating designs that would last for decades:

> *Designers are specially trained for making a forecast for the next ten years. Who can say that of themselves? [...] Therefore, we have designers who do exactly this. What will the customer buy in five or ten years? Not what he wants today.* [Dashboard Developer]

Thus, the designers have to envisage future consumer preferences, which make design a highly uncertain process. Designers also want to create customer taste rather than merely respond to it. For instance, although customer reports showed that customers did not favor certain elements or concepts, Automotor Company retained these elements. Automotor Company did not follow the customer, but instead wanted to shape the customers' views. This often resulted in controversial designs that divided customers:

> *Yes. Our models are dividing people […] There are only two groups: one group says, "I like this car," while the other says, "I hate this car […]"; … they are polarized.* [Manager Controlling]

Consequently, design uncertainty did not lie in the ability to predict what the customer wanted, but in whether customer demand could be created for a given design. This made it impossible to evaluate the economic value of designs objectively, as consumer value and preferences would emerge only in the future when users encountered a specific design.

Design differs significantly from technological innovation in this respect. A design engineer explained:

> *In technological development, you have numbers; you can prove them scientifically and can convince everybody. With design, it is very hard [...] to say, "The curve or form has to be like this; it has to be like this, design-wise." It's not like you can prove it, like with mm in space or costs, or whatever. This makes it hard to argue our case in the decision meetings. You cannot just argue this design is not good looking; management will not understand this.* [Design Engineer]

From this account, technological innovation is quantified, whereas design is unquantified and relates to forms. The two spaces were valued in different ways and through different mechanisms. In design, forms and surfaces were assessed subjectively through a competition mechanism. Technological innovation, however, was subject to a comprehensive target performance measurement against which all options and alternatives were assessed quantitatively in relation to cost and technical criteria. In the following section, the general coordination process is discussed.

Coordination of Design and Technological Innovation

The coordination between design and technological innovation was problematic. Parts of the organization were of the opinion that the creativity of the designer should be protected from becoming sidetracked by cost and other constraints:

> *That's what I mean; design should not think about costs, never on the entire design floor. [...] [B]ecause cost is not everything. If you save money in the wrong place, then maybe you cannot sell the car successfully. [...] I don't think designers should care about costs. His only task should be creating designs, and if he cared about costs, designs would be uninteresting.* [Cost Engineer]

This statement followed immediately after the cost engineer's description of a perfect designer being someone who also focused on cost issues. The cost engineer was conflicted about whether design should be coordinated with technological innovation. Designers should think about cost in order to ease coordination, but should also ignore cost in order to develop innovative solutions. The cost issue was the most divisive issue between design and technological innovation, and even individuals had doubts about the right way to coordinate. These struggles were described as "fights" between the two different worlds (Designer interview). Two respondents argued:

> *Designers want to do whatever they want to do, no matter the costs, and we are turning every plastic part 10 times to save one cent. Then, they decide. We do not like this; it costs us millions.* [Cost Engineer]

> *Of course, money people are really focused on money, and the design people are really focused on design. That's their individual motivations; it's natural that these interests have their different focuses.* [Designer]

Designers were thus juxtaposed against the money people, that is, engineers and controllers.

Design engineers were responsible for the difficult task of coordinating design and technological innovation. They were responsible for illustrating and conveying the restrictions and criteria of technological innovation to designers and for showing technological innovation the intentions and language of design. Other employees from technological innovation were not allowed to talk with designers about their projects and had no access to the design space. Communications between the design and technological innovation sections were therefore severely restricted, and they constituted two distinct, separate spaces.

One design engineer stated that the design engineer position had the responsibility to bring together the blue sky of design and the down-to-earth approach of technological innovation:

> *It is not like this: "I, as a designer, determine the form, and technology has to come up with a solution." That would never work. I have to tell them, "This car primarily exists for driving, so it has to be able to drive." When I drive dynamically, then I need space for my knees. A designer needs to understand this; he has to be able to make compromises.* [Design Engineer]

The design engineer argued that designers had to be able to compromise their designs in order for performance criteria to be met. Design engineers sought to make designers understand the relevance of cost and technological criteria. In this process, they used traffic lights[9] as a mechanism to convey the extent of compliance with technical and cost criteria.

Design engineers described themselves as advocates for both design and technological innovation:

> *These [design] engineers go into the technical discussions, and they fight for the designs. On the other hand, they have to be realistic and guide designers in this tension of finding technical solutions and pushing the design through.* [Design Engineer]

Design engineers thus represented both cost/technological issues and design concerns, and their identity was mixed. A design engineer explained:

> *Within design, we are denounced as technicians; within technological development, we are denounced as designers!"* [Design Engineer]

Design engineers did not fit squarely with either department and were considered aliens within both design and technological innovation.

In summary, the design and technological innovation processes were divided into two separate spaces, had different objectives and focuses, and were controlled by different mechanisms. Design engineers were responsible for communication and coordination between these spaces.

In addition to its division into these two spaces, the development process at Automotor Company was divided into two characteristic phases: a "selection" phase and an "adjustment" phase. In technological innovation, during the selection phase, car parts and concepts were developed and performance targets were defined. In design, the selection

[9] Traffic lights in green, amber, and red illustrated the extent to which criteria from technological innovation, such as the cost and value consequences of designs, were reached. The traffic lights are a condensation of business case reports and numerous cost and technical calculations performed by technological innovation in relation to a particular design. The traffic lights thus convey an extensive body of calculations in a simple manner.

phase focused on design selection. The adjustment phase focused on adjusting the chosen design to specified criteria and targets while maintaining the aesthetic design. This is briefly and conceptually displayed in Figure 1, below.

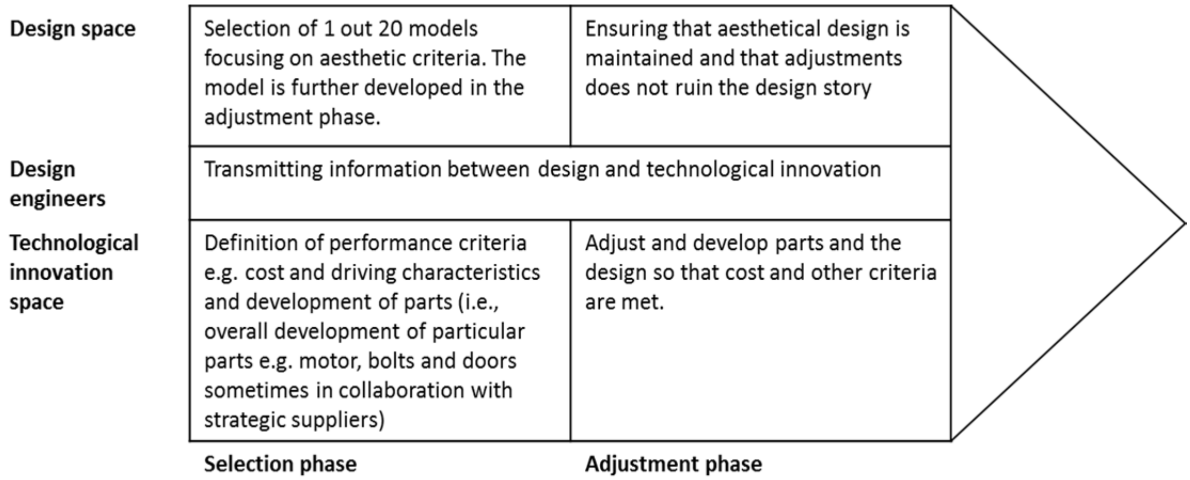

Figure 1 —The design and technological innovation space and development phases

Figure 1 illustrates the different processes in design and technological innovation and their focuses during the selection and adjustment phases. In the following section, we focus on the two embedded cases and analyze the processes of convergence in the two development phases in more depth.

EMBEDDED CASES

Case 1—The Front of a Car Model

The front of the car was one of the more contested and constrained parts of the car model in this case, as it was difficult to make it aesthetically appealing. A design engineer stated: “[it is] unbelievably [difficult] to bring design into the front of a car.” This was due to crash ratings, legislation, engine space, overhang, and lights, as well as the front being the most customer-exposed and sensitive exterior area. These issues will be analyzed below.

Selection Phase: Constraints and Compromises in the Front

The design competition started with 20 sketches that were developed based on design language.[10] In this process, the designers' understanding of form and aesthetics was paramount:

> *Basically, we are drawing without any strategy paper—very naive and blue eyed. It does not matter what the prerequisites are, just do it […]. Reducing is easier than adding.* [Designer of the chosen design]

In this sense, the sketches were purely the designers' interpretation and understanding of the model that was going to be built. They were familiar with the general constraints, but not in any detail. They also knew they would have to reduce the substance of their designs and their ambitions for the final model. For these reasons, the selection of design sketches focused mainly on aesthetics and design coherence.

From the 20 sketches, the head of the design department selected five models to be modeled in clay. This form of competition was motivating for the designers:

> *I work on my own; I have designed the coolest concept, and then somebody comes and says, "Let's make a model out of it; I like it," and then somebody comes and says, "Let's produce the car one million times and sell it worldwide." That is totally absurd. Of course, there are a lot of calculations, [but] the motivation [is] to bring it onto the street and to win the design competitions; that's the most awesome thing.* [Designer of the chosen design]

To see the materialization of their vision was a key motivation for the designers.

Performance targets and criteria were present in the selection among clay models, but they were not clearly defined as quantified financial and non-financial targets. However, as they gradually became clearer, the designers addressed them in collaboration with design engineers:

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

[10] The specific design language for this car is confidential and was not made available to the authors.

In the project, the crash-rating criteria were problematic but initially "fuzzy" (i.e., unclear and unquantified).

The criteria were gradually specified and quantified:

> *The point is that regulations are always moving. The development department cannot say at the beginning of the project: "These are the main criteria." They are also working on it; they are getting more details; they are making tests.* [Design Engineer on the project]

Thus, criteria were developed in the technological innovation space alongside the selection process. Design engineers started to work on criteria with the designers in the clay model part of the selection phase. Automotor Company set the crash-rating criteria for the front to 100 percent[11], based on the company's overall strategic target to build safe cars, as well as to achieve a specific sales price. The crash rating affected the safety ratings that the car was expected to receive from independent institutes. The safety ratings in turn influence consumer choice. Crash ratings thereby had an effect on the target sales price of the car, and a lower target price would increase the cost pressure on a car project.

At the beginning of the clay model part of the selection phase, none of the five designers incorporated the criteria exactly as addressed by technological development. It was then up to the designers to decide whether their designs would stay as they were, not complying with all criteria, or if they would adapt their designs to the demanded criteria:

> *The point is that every designer has to make it very interesting, very new, and very emotional, automatically destroying our criteria. [And we have to tell them], because then you do not comply with criteria; for example, you only have [a 75 percent crash rating]. […] When we have the selection, then we illustrate this on one page on the wall with kind of traffic lights, where we say, "OK, this car does not meet the criteria, you should know [...], two of the five will be taken out," so we can just tell designers which criteria their model can meet and which they cannot. And designers then decide, "Well, this point is so important for my design, I want to keep it."* [Design Engineer]

[11] The exact rating is hidden due to confidentiality.

Aesthetic design and technological innovation criteria were thus in opposition during the selection phase. As the five models were reduced to two through selection, traffic lights were presented to the management board showing the extent to which each design met the financial and non-financial performance measures. The crash-rating criteria were especially an issue. The two models eventually selected did not meet the crash-rating criteria 100 percent. Thus, the selected criteria from technological innovation were not decisive in selecting the chosen models. Instead, the models were selected mainly based on aesthetic criteria.

However, it was conveyed to the two winning designers that these criteria should be met in the subsequent round—that is, the final convergence between the design and its technological development was postponed. The board appreciated the emotions evoked by the design models:

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

In this fashion, decisions were focused on aesthetic criteria, and "the papers," meaning cost and technical criteria, were to be resolved afterwards.

Some of the criteria addressed were implemented after the selection of the two models. However, the winning model failed to achieve the required 100 percent crash rating, yet it was nonetheless selected due to aesthetics and the forms it communicated:

> *Because here we see a new Automotor Company face, it is a very good handling of the icons of Automotor Company; it was a very good new line [...]. You see the sides that the other guys do not have. One designer made it like landscaping of the door [...], and these are the reasons why we chose that, for example. [...] It comes more to emotions at this point, knowing what the technical is. If for example, we show them a model with 75 percent, like this one, [the board then says,] "We want this emotion in the car, but bring it to 100 percent."* [Design Engineer]

As in the previous steps in the competition process, aesthetics was a key decision criterion, while the value constraint operationalized in the non-financial crash-rating performance measure was left to be resolved later. The designer stayed with his form despite the fact that it did not meet the 100 percent crash criteria, and he won the competition nonetheless. The designer risked de-selection by not meeting the requirements, but the board sanctioned his choice with its design selection. The selection and competition process itself focused on selecting the "coolest" and "best" model in terms of aesthetics (Design Engineer interview). The two poles of technological innovation and design were thus divergent in relation to the project. How these debates were settled and convergence was achieved are discussed in the following section.

Adjustment Phase: Convergence Through Compromising Cost, Design, and Criteria

The car's front design was widely discussed, and it was remodeled after the selection of the final model. There were many constraints on the front design; however, the face of the car was to be compromised as little as possible. Figure 2 illustrates the most important constraints in this process.

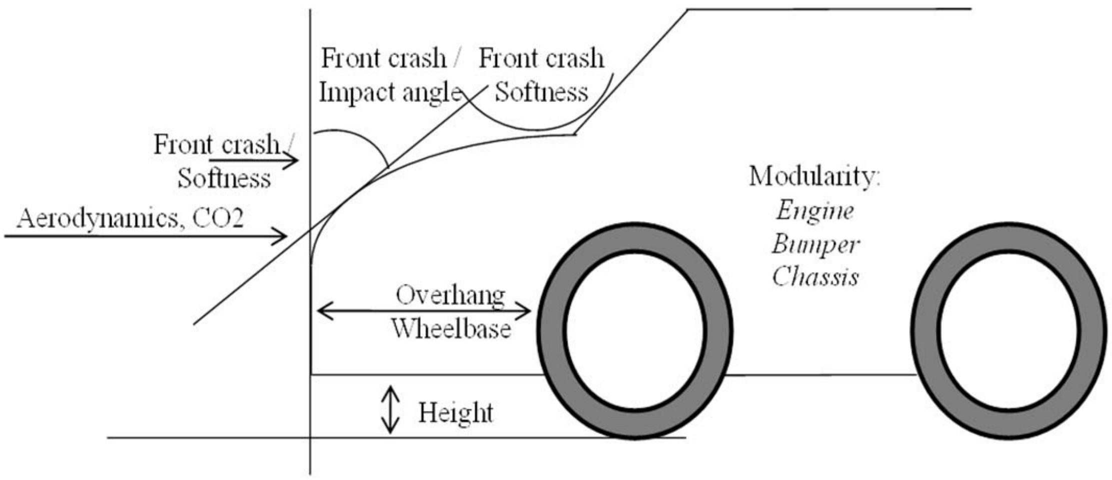

Figure 2 Constraints in the front design.

The outer form was subject to aerodynamic demands and crash ratings related to pedestrian impact and insurance ratings. Furthermore, it was important to maintain a certain height, and the wheelbase and the overhang were fixed through the engine and the chassis. Modular parts, such as the bumper mounting, also had an impact on the shell for which the front was to be designed. Thus, these constraints limited the available space in which the designer could develop individual forms.

Aesthetics and crash ratings. In the adjustment phase, the divergence between design and technological innovation in relation to the crash rating was resolved. A remodeled hood could reach 100 percent and thereby maintain target prices, but that would compromise the initial design. This could also have an effect on target prices and demand. The hood was a major issue for Automotor Company:

> *Everything has to be round. Everything has to be with a new radius. Everything has to be kind of curved. And the hood up front in the old model was also like this one, a big radius. This [crash rating] leads us to a very flat hood, and nobody likes that. [...] And now, this criterion leads us to lose the design story of the model, and everybody is very sensitive and nervous about that.* [Design Engineer]

The shape of the new car was widely debated at Automotor Company. The management board was unable to make a direct decision without further visualizations and models. A special cross-functional team was set up with participants from both design and technological innovation. They developed two models and presented the alternatives: the model with the initially selected hood and a 75 percent crash rating and a remodeled hood with a 100 percent crash rating:

> *We got a job to make a hood with 75 percent, to make it more [a design icon]. And we showed it to the board: "Look, here we have more 'design-ness' […]. We will not reach a 100 percent [crash rating.] [A]nd then, we also made a model with 100 percent. We do not have any decision yet.* [Design Engineer]

The designer who won the competition was not happy with the situation, as he felt that his model was being "destroyed" by the remodeled hood (Designer interview). He stated that the hood would not suit the model and would be too flat. To facilitate the board's decision, a shared evaluation space was created. In this shared space, both design and technological criteria were illustrated by making two clay models that complied 75 percent and 100 percent with the crash-rating criteria. For confidentiality reasons, we were not permitted to take part in the final decision-making process. However, the management board based its decision on the crash-rating criteria and selected the model that complied 100 percent. Top management weighed non-financial targets and aesthetic criteria in one space, and their decision converged the two poles.

Cost issues and design adjustments. Cost issues, such as modularity, also became increasingly important in the design process. These were considered minor issues, but they still had an impact on the car's overall design coherence. For example, the wiper blades were to have modularity, which had an impact on the form of the upper part of the hood that the designer had initially designed: "*This has a design impact on the hood. To win against the [extra] 40 cents with a nicer hood? I would never win*" [Designer of the chosen design]. Thus, during the adjustment phase, cost seemed to be more important than minor aesthetic design changes.

Furthermore, cost was the determining factor in decisions about material, size, and components. The prerequisite for this model was that it should have at least the same features and components as its predecessor. However, while finalizing the chosen model, target costs came into play, and small changes were made. For example, chrome elements were dropped or conceptualized differently. Design argued that the design was lost in the effort to reduce costs.

The winning designer became more sensitive to criteria such as cost after the selection process. He had just recently graduated and, subsequently, had been hired by Automotor Company:

> *At the beginning, I wanted to make the model longer. That would have cost 10€*[12] *more. "What, only so little?" I thought. "That is so cool." I fought and fought, but now I have learned that 40 cents is a lot; I would not be able to implement a feature like this. I have learned which role this plays. If I knew upfront [the cost], then I would not have designed it. And, in the beginning I thought, cool, 10€; this is not very much money.* [Designer]

The designer explains how he realized the significance of saving a few euros or cents per car in the adjustment phase. The language of euros and cents per car did not previously make sense to him, as he had not made the connection between the amount saved per car (e.g., 10 euros) and the millions of cars sold over a model's lifetime. This also illustrates how separated the winning designer was from technological innovation during the selection phase.

Through the process, the designer of the project began to appreciate the need for addressing constraints and cost issues:

> *It is not our job to design unaffordable things. Everybody can do that. No, despite all restrictions and rules and constraints, and cost pressure [...,] the people in the end do not see what kind of problems you had. You cannot show the model at an auto show and be defensive. And this is the cool stuff, although I am always upset when they say, "We have to save here, this is 30 cents more." […] It is in the interest of the whole organization to produce economically, and that overall the car is very good.* [Designer]

To win the design competition and show the design to the world—despite compromises—was thus a key motivation for the designers. In the end, this designer understood the constraints coming from technological innovation and started to adopt the view that designs had to be produced economically.

Case 1 illustrates several points about the coordination and control of design and technological innovation. In the selection phase, models were selected and technological criteria were developed. At this point, aesthetic criteria were more important than costs, as the models selected did not comply with the criteria set by technological innovation and were chosen based on design aesthetics. The winning designer, who came straight from design

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

school, did not understand the language of technological development and was partially separated from these concerns. Therefore, visualizations and clay models were mechanisms with immense power in the decision-making process. In this way, design was controlled through a competition mechanism focusing on aesthetic output. Thus, design was not merely controlled in an enabling manner, but also through a different control mechanism.

The case also shows two different accounts of convergence in the adjustment phase. First, prototypes illustrating the two models complying 75 percent and 100 percent with crash-rating criteria were used to create a joint evaluation space where aesthetics and cost/technical criteria could be evaluated. Second, in the adjustment phase after designs were chosen, project teams made minor adjustments to the design to meet manufacturing and other targets, and at this point, technological innovation dominated design.

Case 2—Dashboard

Selection Phase: Dashboards, a Difficult Design Area

In the following discussion, we analyze the interior design process for a dashboard for a specific car model. The dashboard is a difficult design area, as it is central to the driver's and front-seat passenger's fields of vision. It was also an area to which management paid close attention. Previously, Automotor Company had issues with their dashboards:

> *Six or ten years ago, an Automotor Company dashboard was not really nice. […] There, we still have to improve, image-wise. Our image lies with the chassis and with the engine, but we still have to catch up with regards to the dashboard.* [Dashboard Developer]

Automotor Company was increasing its emphasis on the dashboard to keep up with the competition. Dashboard sketches were also turned into clay models, and decisions were made in steps starting from 20 sketches to four clay models, to two clay models, and finally, to one selected design.

In this process, the design freedom appeared to be considerable, as the process for designing dashboards always started with a blank piece of paper. Designers had a "*tendency to more differentiation.... They never comply with our criteria*" (Dashboard Developer). Other car projects or predecessors seemed to offer no points of reference. Issues such as modularity or equal parts were mostly neglected during the clay processes. Using the same components was not an issue in the design phase: *"We had several decisions where we decided pro-design and against costs. Modularity in the fenders for example, was a big cost issue"* (Dashboard Developer). Designers strove for greater differentiation, while technological innovation engineers sought to limit their freedom. Often the designers won the battle.

The dashboard had been specified as one piece for the specific project, and the design language called for "lightness." Technological innovation therefore focused on estimating the criteria for a single-layered concept. However, in the design selection process, two of the four clay models were multi-layered dashboards.[13] In the selection of the clay models, information tags and traffic lights were provided. They stated that the multi-layered concepts presented were more expensive and did not comply with the criteria. The two designers argued that only a multi-layer concept would be adequate for this car project and that a more expensive solution was necessary. They pointed out that the car catered to a premium customer segment that desired and expected multi-layered concepts, whereas single-layer concepts were considered to belong to lower customer segments.

In the decision-making process moving from four to two models, the management board selected the two more expensive, multi-layered designs. With this decision, marketing promised to provide an increase in the target sales price, arguing that the customer would pay

[13] A multi-layer dashboard is a dashboard that consists of more than one ground body; that is, it has two layers: one upper and one lower. These can be layered and welded together in a complex production process. A single-layer dashboard is very simple (and standard). The difference between a multi-layer and a single-layer dashboard is thus between a premium design and a more standard, easy to produce, design.

more for the new design and pointing to competitors and to other Automotor cars and their sales-price positioning. The premium market price could be used to adapt the initial plan through a business case that covered the higher target sales price.

Going from two models to one, product development had to incorporate criteria such as cost, geometry, complexity, and weight into their concept. There were only marginal differences between the two final concepts in relation to performance targets, but they differed in their aesthetic forms. In the next section, we focus on the process following the final selection, in which smaller design changes became the key issue.

Adjustment Phase: Adjusting the Final Model

Lighting effect: Changing designs late in the process. After the design was selected, a recent trend in competitors' designs had to be incorporated. A lighting feature on the dashboard was needed to enhance the design and make it appear more premium. The head of design convinced the project leader, and they decided to implement the feature. This was despite the fact that the project was in the adjustment phase when important design changes should not be made:

> *And then there was a meeting between the project manager and the head of design. "This feature has to be realized; cost does not matter." Of course, we estimated costs, but it had to be realized. "We want to see scenarios that show how this is feasible. Can we shift development, tools, and prototypes? Can we make tools out of aluminum? Can we...?"* [Dashboard Developer]

The design feature had to be implemented irrespective of cost. The pressure came from the top, and the cost/benefit calculation for this particular feature was less comprehensive compared with the normal process. Furthermore, calculations were performed to support a decision that had already been made. Alternatives were thus not investigated, and the feature was "thrown into the development process," as one cost engineer stated. The pressure and the risk of overall cost overruns, however, had to be absorbed by technological innovation, which still had to meet its overall cost targets.

Adjustment of selected surface. The surface decorating the dashboard was also highly debated. Design demanded a particular surface that had to be developed by suppliers. Purchasing prices were very high for this surface, and supply was scarce due to its very high quality in terms of visual appearance and durability. Technological innovation suggested another surface that was cheaper but did not have the same quality standard as the one demanded by design:

> *It all makes sense. Because you do not see it much, we decided to have the cheaper supplier. And now, that's still not enough. And now, we have a meeting on Friday to decide whether to use the prototype from a more expensive supplier for the entire lower part […] And we try to fight against them, of course, because you have to look at the costs. And now we put together some figures to control design […] and then, it will be interesting to see who is stronger.* [Purchasing]

Purchasing wanted to use the cheaper material and used calculations to illustrate why its decision was superior to design's solution. The two different surfaces were presented on two models, and technological innovation's suggestion for the cheaper surface was selected. The model presented only marginal quality differences visually, but it was less durable. Marketing also did not see any drawback for the customer in this decision.

Deadlines and design. The convergence process for smaller changes in design, materials, and components took more time than planned. Some of the changes were costly because suppliers had already been nominated and changes needed to be made to their product development and to their prototype tools.

Technological innovation developed the chosen design model and discovered that specific layers could not be produced due to its specific form and because the dashboard did not conform to crash prerequisites. The design therefore had to be redesigned in meetings and in discussion with the design engineer. The dashboard was made slightly higher in certain areas and lower in others.

Instead of the five weeks planned and fixed for the convergence process between design and product development, it took about three months. A lot of compromises were made within this period, including several hundred minor changes. However, the inability to reach milestones on time was costly:

> *They do not hold the schedule and we get complications, more costs [...]. This is incredible, we do not believe in our own schedule.* [Dashboard Developer]

Technological innovation argued that this was a general problem and that design did this in order to incorporate the latest trends, while design argued that deadlines were too tight. Design was allowed to exceed deadlines and thus to overrule time and cost constraints, as it did in the case of the dashboard lighting effect.

In summary, the case demonstrated two things about the control and convergence of the design and technological innovation poles. First, in the selection phase, designers' interpretation of market trends was more important than the explicit criterion of a single-layer dashboard. When the process moved from four to two models, the single-layered designs were not selected. Thus, designers' aesthetic perceptions overruled explicit criteria. As in the first case, designers took chances by not complying with strategic and technological criteria and were rewarded for their gumption by being selected and then winning the competition.

Second, the dashboard case illustrates three instances of convergence. First, the multi-layered dashboard was fully converged through marketing's market analyses, which led to a direct increase in the car's target sales price. A joint metric was formed and used to make this decision. The convergence process did not take place through the initial, top–down business case and target-cost calculation, as argued in the target-costing literature (Anderson and Sedatole 1998; Moden and Hamada 1991); instead, it happened towards the end of the selection phase and as an outcome of coordinating efforts that were sanctioned by top management. Second, convergence on the choice of surface occurred by comparing prototypes of two different surfaces and their cost structures. Hence, cost and aesthetics were converged through the creation of a joint evaluation space in which both aesthetics and costs could be evaluated. Third, the exceeded deadlines and the new light included in the model illustrate how design was able to dominate technological innovation by not complying with financial and non-financial criteria.

DISCUSSION

In the following section, we discuss our empirical findings and develop a model of the entire process that takes into account structures of control and coordination, as well as processes of convergence. In Figure 3, we expand the depiction in Figure 1 of the two phases and the two spaces with empirical details from the analysis. The X-axis illustrates the different phases of selection and adjustment. The Y-axis illustrates the two spaces and their control and coordination mechanisms.

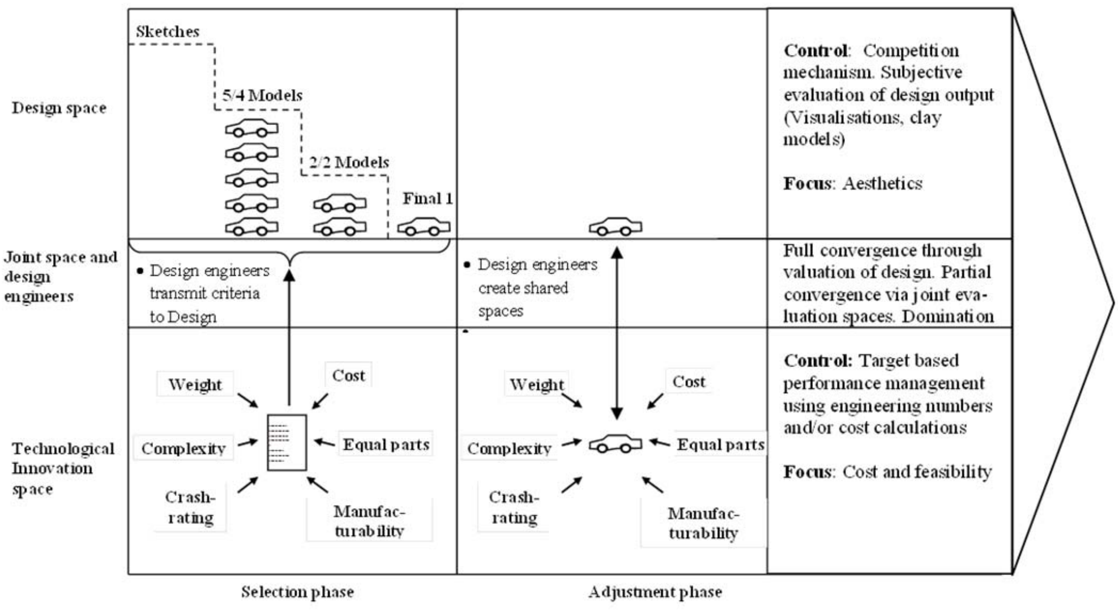

Figure 3 The combined process of control and coordination

Figure 3 illustrates how design and technological innovation were two separate spaces controlled through different mechanisms. Technological innovation was controlled through targets and criteria from a target-based performance measurement mechanism using both financial and non-financial targets. Design was controlled through a competition mechanism focusing on aesthetics. Designers' aesthetic output (prototypes, visualizations, and clay models) was selected based on its aesthetic value. A designer argued: *"The motivation [is] to bring it onto the street and to win the design competitions; that's the most awesome thing."* The competition mechanism worked directly on designers' extrinsic motivation and was designed to fit the setting instead trying to repair problems with the (design) control mechanism, as discussed in the literature on enabling bureaucratization (Jørgensen and Messner 2009; Ahrens and Chapman 2004). The structure and elements of the control mechanism were thus paramount in this case study. The board was not flexible about promoting designs that did not score high on the primary optimality criterion—that is, aesthetics—and the competition mechanism was used in a coercive manner. Yet, designs surpassed constraints and generated novel forms and aesthetical expressions.

This finding lends support to the view that the incentives embedded in a control mechanism are important for the outcomes of creative processes (Kachelmeier and Williamson 2010; Kachelmeier et al. 2008). The mechanism only incentivized creativity; mediocre designs had no value for Automotor Company (Kachelmeier and Williamson 2010). We thus supply field-based evidence for Kachelmeier et al. (2008) and Kachelmeier and Williamson (2010)'s claim that in some contexts creativity-focused incentive schemes are important because they can spur initial creativity and reduce the number of mediocre designs.

At Automotor Company, coordination was a gradual process achieved by making core design decisions early in the development process and then subjecting them to convergence with cost and technical concerns downstream. Coordination was carried out through three types of convergence processes.

First, we saw *full convergence* of design to technological criteria in the multi-layered dashboard case, where design went against the strategic and technological criteria by maintaining a multi-layered dashboard. Design made marketing concede to an increase in target sales prices, which fully quantified aesthetics into a financial value. This mode of convergence is similar to the processes of convergence analyzed in the target-costing literature (Anderson and Sedatole 1998; Ansari, Bell, and Okano 2007; Monden and Hamada 1991). We extend this research by analyzing how coordination efforts are not just a mechanism determined before processes are initiated but are part of and develop during those processes. Specific mechanisms are used and developed as information about concrete coordination problems is discovered. We therefore suggest that the timing of coordination interventions between creative and cost/technical processes is an important factor to consider in the management of design-driven innovation processes.

Second, we saw two instances of *partial convergence* through the creation of joint evaluation spaces where both aesthetics and cost could be used to evaluate designs. We saw this in the first case with two prototypes of the front adhering 75 percent and 100 percent to the crash-rating criteria. In the second case, two different surfaces were compared in conjunction with cost data. The joint evaluation space converged the network and enabled it to make decisions despite differences between the two poles' views on particular designs (Callon 1991). To our knowledge, no accounting paper has previously discussed this type of convergence.

Finally, we saw technological innovation *dominating* design in relation to minor design adjustments, such as in the case of wiper blade modularity where design wishes were overruled by cost concerns. Conversely, we saw design dominating technological innovation in the case of the new lightening feature for the dashboard that had to be used no matter what the cost, as well as time overruns by design that lead to cost increases. Designers in this process were not hybridized and did not take over the tools and values of technological innovation (Kurunmäki 2004). This was clearly illustrated, for example, by the designer who won the competition for the new car model. The designer was unaware of cost and technological criteria far into the process, as shown by the designer's unawareness of the profit impact of a 10€ cost per car of a longer hood. While this designer was probably increasingly made aware of technological criteria, he was nevertheless able to win the competition without a deep awareness of cost accounting.

The domination was thus not one-sided as presented in the target-costing literature (Anderson and Sedatole 1998; Ansari, Bell, and Okano 2007; Monden and Hamada 1991) and in the design management literature (Verganti 2008). Instead, either design or technological innovation dominated in specific episodes. The coordination process was not sequential in the sense that the output of one space was coordinated with the other. Coordination was rather a gradual process in which separation and a distinct control mechanism focused each space on its primary concern of cost or creativity. Their interfaces and mutual constraints were gradually worked out through multiple coordination interventions during the process.

The coordination process had enabling or interactive features (Jørgensen and Messner 2009; Ahrens and Chapman 2004; Cools et al. forthcoming). Intensive dialogue and decision reversals were part of the coordination process, which therefore was enabling and interactive. However, the particular mechanisms discussed in this paper—dominance, partial, and full convergence—extend this research by developing the specific ways in which coordination can be achieved.

CONCLUSION

Controlling design and technological innovation is a complex process of control, separation, and convergence. Hence, while the saying, "Function follows form or form follows function," indicates that one of the two must dominate the other, the approach chosen by Automotor Company seeks to find a balance through a process that maximizes both and maintains diversity through separate control mechanisms and spaces. But, at the same time, Automotor Company converges design and technological innovation through domination by either design or technological innovation, through converging aesthetics into a monetary value, or through creating joint evaluation spaces where aesthetics and performance criteria can be considered simultaneously. The reciprocal interdependencies between design and technological innovation were managed through a process in which multiple coordination efforts were imposed over time.

The design and development of cars is therefore subject to an intriguing control process that separates design and technological innovation to facilitate creative variability and efficient development, and that coordinates and converge the two over time through multiple coordination interventions employing the three modes of convergence. In the midst of these processes, control criteria and coordinating mechanisms are developed. So, while the designers are confronted with 500 engineers who calculate designs, parts, and functions and face challenges in getting their designs through, some design freedom and creativity is retained through the partial separation and final convergence of design and technological innovation.

This study is subject to several limitations. We have made use of qualitative data and observations within a single, complex production network and focused on design and technological innovation in two specific cases. This restricts the theoretical generalizability of our findings, which in most cases would be less relevant for research developed in relation to control of non–design-oriented companies or for innovation processes where creativity is not important. Furthermore, the mechanisms and processes investigated are comprehensive and lengthy (six years from strategy to the initiation of production), and the complexity and professionalism of a product development unit comprising 5,000–10,000[14] employees is high. This setting is very different from research developed in the context of smaller-sized companies with shorter development times and less complexity, such as fashion houses and restaurants.

Nevertheless, the paper's key findings on the importance of separation, multiple control mechanisms, types of convergence, and timing of coordination add to the way we can understand and structure innovation processes. Furthermore, while Automotor Company's success indicates that its processes are efficient, many other factors could explain its success. Further qualitative development and quantitative testing of the key variables in this study would be an interesting avenue for future research.

Another limitation of the study is that it focused on design in general and did not investigate the process of convergence between different financial and non-financial performance measures in technological innovation. We have not pursued this line of inquiry due to space constraints. However, the technological innovation pole transformed physical measures such as weight and CO2 into monetary terms so that the calculation of business cases and selection of alternatives could be carried out. Such analysis would link more tightly to the general literature on multiple non-financial performance measures in manufacturing environments (e.g., Datar, Kulp, and Lambert 2001; Lillis 2002), but it will have to await further inquiry.

[14] The actual number of employees in the product development unit is disguised due to confidentiality, but the real number falls within this range.

References

Abernethy, M. A., and J. U. Stoelwinder. 1995. The role of professional control in the management of complex organizations. *Accounting, Organizations and Society* 20 (1): 1–17.

Adler, P. S., and B. Borys. 1996. Two types of bureaucracy: Enabling and coercive. *Administrative Science Quarterly* 41: 61–89.

Ahrens, T., and C. S. Chapman. 2004. Accounting for flexibility and efficiency: A field study of management control systems in a restaurant chain. *Contemporary Accounting Research* 21 (2): 271–301.

Anderson, S. W., and K. Sedatole. 1998. Designing quality into products: The use of accounting data in new product development. *Accounting Horizons* 12 (3): 213–233.

Ansari, S., J. Bell, and H. Okano. 2007. Target costing: Uncharted research territory. In *Handbook of Management Accounting Research*, edited by C. S. Chapman, A. G. Hopwood, and M. D. Shields, 507–530. Amsterdam, NL: Elsevier.

Ayers, D. J., Gordon, G. L., and D. D. Schoenbachler. 2001. Integration and new product development success: The role of formal and informal controls. *Journal of Applied Business Research* 17 (2): 133–148.

Bramall, D. G., K. R. McKay, B. C. Rogers, P. Chapman, W. M. Cheung, and P. G. Maropoulus. 2003. Manufacturability analysis of early product designs. *International Journal of Computer Integrated Manufacturing* 16 (7–8): 501–508.

Callon, M. 1991. Techno-economic networks and irreversibility. In *A Sociology of Monster: Essays on Power, Technology, and Domination*, edited by J. Law, 132–162. London, UK: Routledge.

Carlsson-Wall, M. K. Kraus, and J. Lind. 2009. Accounting and distributed product development. *The IMP Journal* 3 (1): 2–27.

Chapman, C. S., and L.-A. Kihn. 2009. Information system integration, enabling control and performance. *Accounting, Organizations and Society* 34 (2): 151–169.

Cools, M., K. Southuysen, and A. Van den Abeele. Management control for stimulating different types of creativity: The role of budgets. *Journal of Management Accounting Research* (forthcoming).

Cooper, R. G. 1990. Stage-Gate systems: A new tool for managing new products. *Business Horizons* (May–June): 44–53.

Datar, S., S. C. Kulp, and R. C. Lambert. 2002. Balancing performance measures. *Journal of Accounting Research*, 18 (1): 75–92.

Davila, A. 2003. Short-term economic incentives in new product development. *Research Policy* 32 (8): 1397–1420.

Davila, A., and A. Ditillo. Management control systems for creative teams: Managing stylistic creativity in fashion companies. *Journal of Management Accounting Research* (forthcoming).

Davila, A., and G. Foster. 2005. Management accounting systems adoption decisions: Evidence and performance implications from early-stage/startup companies. *The Accounting Review* 80 (4): 1039–1068.

Davila, A., and G. Foster. 2007. Management control systems in early-stage startup companies. *The Accounting Review* 82 (4): 907–937.

Davila, A., and M. Wouters. 2004. Designing cost-competitive technology products through cost management. *Accounting Horizons* 18 (1): 13–26.

Dell'Era, C., and R. Verganti. 2009. Design-driven laboratories: Organization and strategy of laboratories specialized in the development of radical design-driven innovations. *R&D Management* 39 (1): 1–20.

Free, C. 2007. Supply-chain accounting practices in the UK retail sector: Enabling or coercing collaboration? *Contemporary Accounting Research* 24 (3): 897–933.

Hatchuel, A., and B. Weil. 2009. C-K design theory: An advanced formulation. *Research in Engineering Design* 19 (4): 181–192.

Hermanowicz, J. C. 2002. The great interview: 25 strategies for studying people in bed. *Qualitative Sociology* 25 (4): 479–499.

Holmstrom, B. 1989. Agency cost and innovation. *Journal of Economic Behavior and Organization* 12: 305–327.

Holmstrom, B., and P. Milgrom, 1991. Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design. *Journal of Law, Economics, & Organization* 7 (Special issue): 24–52.

Jarzabkowski, P. A., J. K. Lê, and M. S. Feldman. 2012. Toward a theory of coordinating: Creating coordinating mechanisms in practice. *Organization Science* 23(4): 907–927.

Jeacle, I. (2015). Fast fashion: Calculative technologies and the governance of everyday dress. *European Accounting Review* 24 (2): 305–328.

Jeacle, I., and C. Carter. (2012). Fashioning the popular masses: Accounting as mediator between creativity and control. *Accounting, Auditing, and Accountability Journal* 25 (4): 719–751.

Jørgensen, B., and M. Messner. 2009. Management control in new product development: The dynamics of managing flexibility and efficiency. *Journal of Management Accounting Research* 21 (1): 99–124.

Kachelmeier, S. J., B. E. Reichert, and M. G. Williamson. 2008. Measuring and motivating quantity, creativity, or both. *Journal of Accounting Research* 46 (2): 341–373.

Kachelmeier, S. J., and M. G. Williamson. 2010. Attracting creativity: The initial and aggregate effects of contract selection on creativity-weighted productivity. *The Accounting Review* 85 (5): 1669–1691.

Krippendorff, K. 1989. On the essential contexts of artifacts or on the proposition that "Design is making sense (of things)." *Design Issues* 5 (2): 9–38.

Kurunmäki, L. 2004. A hybrid profession—the acquisition of management accounting expertise by medical professionals. *Accounting, Organizations and Society* 29 (3–4): 327–347.

Lillis, A. M. 2002. Managing multiple dimensions of manufacturing performance—an exploratory study. *Accounting, Organizations and Society* 27 (6): 497–529.

Merchant, K. A. 2006. Measuring general managers' performances market, accounting, and combination-of-measures systems. *Accounting, Auditing & Accountability Journal* 19 (6): 893–917.

Monden, Y., and K. Hamada. 1991. Target costing and kaizen costing in Japanese automobile companies. *Journal of Management Accounting Research* 3: 16–34.

Mundy, J. 2010. Creating dynamic tensions through a balanced use of management control systems. *Accounting, Organizations and Society* 35 (5): 499–523.

Quattrone, P., and Hopper, T. (2005). A "time-space odyssey": Management control in two multinational organisations. *Accounting, Organizations and Society* 30 (7–8), 735–764.

Simons, R. 1995. *Levers of Control: How Managers Use Innovative Control Systems to Drive Strategic Renewal.* Boston, MA: Harvard Business School Press.

Thompson, J. D. 1967. *Organizations in Action,* New York, NY: McGraw-Hill.

Verganti, R. 2006. Innovating through DESIGN. *Harvard Business Review* 84 (12): 114–122.

Verganti, R. 2008. Design, meanings, and radical innovation: A metamodel and a research agenda. *Journal of Product Innovation Management,* 25 (5): 436–456.

Verganti, R. 2009. *Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean.* Boston, MA: Harvard Business Press.

Wouters, M., and D. Roijmans. 2011. Using prototypes to induce experimentation and knowledge integration in the development of enabling accounting information. *Contemporary Accounting Research* 28 (2): 708–736.

Wouters, M., and C. Wilderom. 2008. Developing performance-measurement systems as enabling formalization: A longitudinal field study of a logistics department. *Accounting, Organizations and Society* 33 (4–5): 488–516.

Appendix 2:

Date	T: Transcribed/ N: Notes taken	Position	Duration (in h)
2010-06-09	*T*	Manager Accounting/Finance	1
2010-06-09	*T*	Developer	1
2010-06-11	*T*	Developer	1
2011-07-28	*T*	Steering Convergence of Design and Technology	0.3
2011-07-28	*T*	Designer Exterior	1
2011-09-13	*T*	Manager Design	1.5
2011-09-13	*T*	Manager Accounting/Finance	1
2011-09-13	*T*	Design Engineer	1
2011-09-13	*T*	Cost engineer Door Panels	1
2011-09-14	*T*	Manager Design	1.5
2011-09-14	*T*	Design Engineer	1.5
2011-09-14	*T*	Idea Creator / Ergonomics and Comfort	1.5
2011-09-15	*T*	Dashboard Developer	1
2011-09-15	*T*	Cost Engineer Dashboard	1.5
2011-09-15	*T*	Manager Convergence of Design and Technology	1
2011-09-16	*T*	Cost Engineer Interior Components	1
2011-09-16	*T*	Manager Accounting/Finance	1
2011-09-16	*T*	Design Coherence with Technology	1
2011-10-19	*N*	Manager Modularity	0.5
2011-10-19	*N*	Coordinator Design Cost Convergence	0.5
2011-10-24	*T*	Designer Exterior (Front)	1
2011-10-24	*T*	Coordinator Light Strategy	1
2011-10-24	*T*	Controller Exterior	0.5
2011-11-22	*N*	Product Strategy	0.5

Different types of managers are part of the product development process. *Project leaders* are responsible for a certain car project and steer the development process towards all relevant targets and towards the start of production by making all decisions. *Product development engineers* are responsible for the technological development of certain parts of a car. They are held responsible for achieving given targets and, thus, must develop parts that correspond to those targets. *Process engineers* bring expertise in production and assembly processes and evaluate relevant alternatives regarding cost and feasibility. Furthermore, they have to implement the engineered concepts into in-house production. *Designers* draw sketches, make clay models, and provide design alternatives, which may then be chosen as the final design model. In this process, *design engineers* communicate targets between product development and design. *Marketing* is responsible for bringing in customer demands on the product's substance and discussing them in the product development network. *Controllers* calculate the business cases for decisions and steer the target cost management process. *Purchasers* have to find suppliers, which are then nominated to deliver a part or parts, and they estimate the costs of certain alternatives.