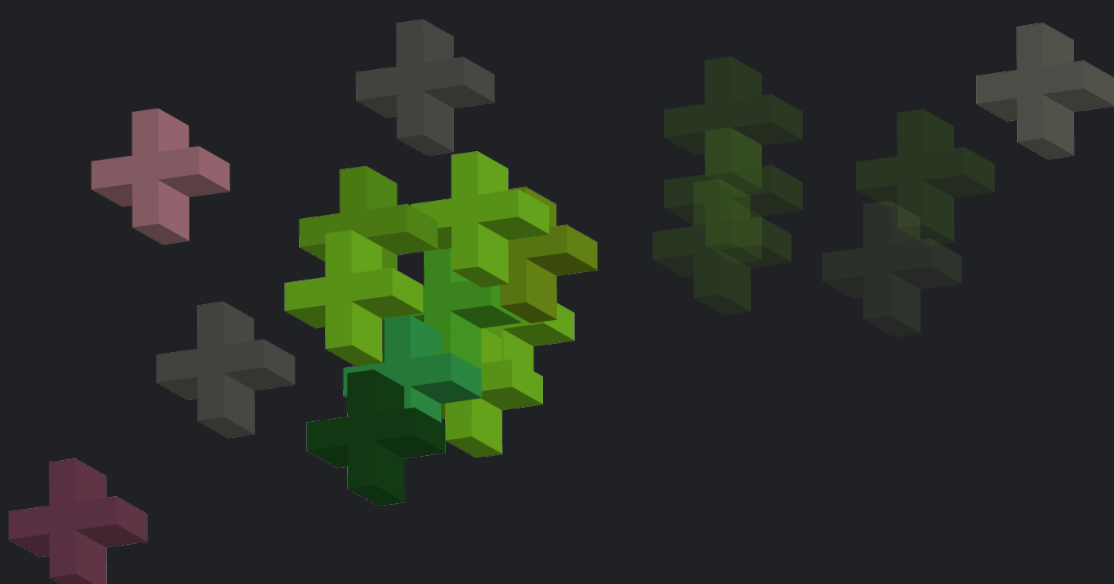


**Adaptive  
Design  
for Circular  
Business  
Models**  
in the **Automotive  
Manufacturing  
Industry**

**Thomas  
Nyström**



UNIVERSITY OF  
GOTHENBURG



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Thomas  
Nyström

Thesis for the degree of Licentiate of Philosophy in Design at HDK – Academy of Design and Crafts, Faculty of Fine, Applied and Performing Arts, University of Gothenburg, Sweden

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## Abstract

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The vision of a circular economy (CE) promises both profitability and eco-sustainability to industries, and can, from a material and energy resource flow perspective, be operationalized by combining three business and design strategies: closing loops; narrowing and slowing down resource flows by material recycling, improving resource efficiency; and by extending product life by reuse, upgrades and remanufacturing.

These three strategies are straightforward ways for industries to radically reduce their use of virgin resources. From a product design perspective, it is doable. However, from a business perspective, it is no less than a revolution that is asked for, as most Original Equipment Manufacturers (OEMs) have, over time, designed their organizations for capturing value from selling goods in linear, flow-based business models.

This thesis aims to contribute to the discourse about CE by exploring practical routes for operationalizing circular product design in a “stock-based” circular business model (CBM). The approach is three-fold. Firstly, the role of design as a solution provider for existing business models is explored and illustrated by case studies and interviews from the automotive industry. Secondly, challenges and possibilities for manufacturing firms to embrace all three strategies for circularity are explored. Thirdly, implications for designing products suitable to stock-based CBMs are discussed.

In spite of the vast interest in business model innovation, a circular economy, and how to design for a circular economy, there are still many practical, real-life barriers preventing adoption. This is especially true for designing products that combine all three of the circular strategies, and with regard to the risk of premature obsolescence of products owned by an OEM in a stock-based business model. Nevertheless, if products are designed to adapt to future needs and wants, business risks could be reduced.

The main findings are that CE practices already have been implemented in some respects in the automotive industry, but those practices result in very low resource productivity. Substantial economic and material values are being lost due to the dominant business and design logic of keeping up resource flows into products sold. The primary challenge for incumbent OEMs is to manage, in parallel, both a process for circular business model innovation and a design process for future adaptable products.

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## Other publications by the author

Williander, M, Linder, M. & Nyström, T., 2014. The Organizational Impacts of a Product-Service Based Business Model Innovation Process in an Incumbent Manufacturing Firm. Proceedings of the 22nd Innovation & Product development Management Conference IPEDM 2015. Available at: <http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1132492&dswid=-5965>

Nyström, T., Williander, M., 2013, Business Models: The silent ruler of firms, Proceedings of the 6th International Conference on Life Cycle Management – LCM 2013, Available at: <https://research.chalmers.se/publication/177627>

Nyström, T., Williander, M., 2012, A dead end or a way to prosperity? efficient and effective strategies towards ecosustainability in Swedish SME's, EIASM/IPDMC 2012 Available at: <https://research.chalmers.se/publication/162311>

## Preface

Many years ago, a colleague who was working on his Ph.D. at a Swedish university, in frustration, described his journey as “sitting in a small dinghy in the middle of the Atlantic sea with only one oar, without any sight of land, and not knowing in what direction to start paddling”.

In my case, I have found this research project to be quite the opposite. Instead of an empty horizon, I see a vast archipelago with many separated islands at close distance but without time to explore them all. Some of these islands are close to each other and possible to wade over to. However, others are far away and either must be visited by boat or by building a bridge. Moreover, I can spot some ongoing building activities to build such bridges.

In relation to the topic of this licentiate thesis, how to design products for and implement a circular business model, I have started to explore the main archipelago of what can be described as the circular economy and I have started to visit some of these islands in the vicinity, but without the time to explore them all.

*We need to remember that we are all of us, in Buckminster Fuller's great phrase, 'the crew of Spaceship Earth'. Thanks to the material successes of the two industrial revolutions we are a crew with rising expectations of high living standards. But we are increasingly aware that the wealth-generating machine may not be able to meet those expectations without doing unacceptable damage to Spaceship Earth, which, together with the free supply of energy from our sun, is the only given resource we have.*

*This triangle — of expectations, wealth generation, and protection of the planet — will have to be managed with great care at many different levels as we enter the 21st century if major disasters are to be avoided.*

(Checkland, 2011)

# 1 Introduction

## 1.1 Background to the study

Facing the severe sustainability challenges from a growing population and increased standard of living with more resource demanding activities, the next 30-40 years will be a critical time to not overshoot our planetary boundaries – especially considering the unclear thresholds of the earth’s overall ecosystem (Rockström et al., 2009). Nevertheless, many firms consider it crucial to explore new ways to profitably increase their resource productivity while simultaneously becoming more sustainable (Upward & Jones, 2016). In the best of worlds, high resource productivity arises when natural resources are used as efficiently and economically as possible (OECD, 2008), and this seems to be in line with most firms’ desire to maximize their profits. For manufacturing firms running linear business models (LBMs), such profits arise from margins between price and cost for developing, producing, and selling products times volume sold.

The dominant business logic (DBL) for making such profits is to produce products using large amounts of virgin material resources (often non-renewable), maximizing volumes, minimizing cost, and continuously designing new products that makes old products obsolete after a “just right” use time. In an attempt to maintain sales of new product models that are being released into today’s (mostly) saturated and highly competitive markets.

In contrast to this linear business logic, the vision for a circular economy (CE) has been proposed as a trillion dollar business opportunity for the industry to profitably go green and be without limits for continuous economic growth (Ellen Mac Arthur Foundation, 2012,2015). At first glance, CE seems to be a very promising concept. However, implementing a CE for firms running LBMs will be a radical challenge. Simply, CE can be defined as an economic system without waste, running on renewable energy, and where the value of products, materials, and resources is maintained in the economy as long as possible by firms that capitalize on their already sold stock of accumulated resources in the form of products, turning today’s “river economy” into a “lake and loop economy” (Stahel, 2006).

Seen from a resource efficiency perspective, the CE concept is a straightforward way for manufacturing industries to radically reduce their use of virgin materials by applying business and design strategies for closing and narrowing resource flows (Bocken et al., 2016).



From a product design perspective, it is relatively straightforward by using already available design tools e.g., circular design) or methods (e.g., Design for X Umbrella, Gatenby, & Foo, 1990; Ellen Mac Arthur Foundation & IDEO, 2017) to raise awareness and offer support to designers with practical guidelines for designing products with desired characteristics.

Therefore, a theoretical vision of a CE system should include incentives to design products to maximize resource efficiency and apply business and design strategies to slow down resource flows (Bocken et al., 2016). These two goals can be accomplished by systematically designing products that extend product life so that the products used in the CE system (in a sequence) are reused, upgraded and remanufactured. Only as a last resort, such circular products should be recycled and circulated back into new products. Furthermore, by adding a business perspective, such circular and adaptable products could be offered as value propositions where customers pay for the functions or performance of the products, while OEMs maintain the ownership and control of their products so they can maximize their products' utility in a so-called product service system (PSS) (Sakao et al., 2009). PSS studies have found that such systems profitably and significantly reduce resource consumption (Nasr & Thurston, 2006; Pearce, 2009; Tukker, 2004, 2013).

However, the business risk will be very high for OEMs to keep control of their products that traditionally have been designed to be sold to retailers and end customers and to become obsolete through rapid fashion and technology changes. It would be a radical step for a CEO of an incumbent OEM to abruptly abandon existing or planned investments in existing and new technology development, products, production facilities, etc., especially as most incumbent organizations have had plenty of time to optimize their organizations for capturing value from selling goods in fine-tuned flow-based LBMs. Here, an aggravating circumstance to change an existing BM is that there usually is no one part of the firm that has the specific responsibility for a BM and that is allowed to radically change it. Rather, a BM is often embedded into and operated by the firm's organization as a whole without an organizational structure for new product design, often represented in top management. Moreover, in large OEMs, BMs are coordinated by different departments.

Furthermore, the literature on eco-design, sustainability design, circular design, and design-thinking has extensively discussed the role of design as a process for change and the role of designers as change agents that can affect the overall life cycle properties of a product. In most OEMs, however, the use of design as a process or designers' possibilities to apply their skills to realize circular designs will to a large extent be restricted by the existing logic in doing business in that OEM.

Based on these challenges of high business risks, business model inertia, and designers limited operating space for implementing circular design, where does change/design managers in an incumbent OEM start to dig if committed to moving in a more circular direction?

## 1.2 Purpose, aims and research questions

This thesis will discuss how an OEM can theoretically maximize resource productivity and reduce business risks in a stock-based CBM. The emphasis will be on the circular business and design strategy for slowing down resource flows by extending product life and by designing products that can adapt to future changes. These new product designs will have the potential to radically reduce environmental impact while simultaneously retaining or increasing the economic value from a product or system.

In order to explore these topics, the following research questions have been formulated:

RQ 1: What are the challenges and possibilities for an incumbent manufacturing firm to embrace all three business and design strategies for CE (closing, narrowing, and slowing down resource flows)?

RQ 2: What does a change/design manager need to be aware of when proposing an adaptable product to top management in an incumbent OEM?

To address these broad questions, two exploratory sub-questions have been formulated

RQ 1.2 What factors drive obsolescence of different types of vehicles today?

RQ 2.1 How can OEMs operationalize business and design strategies for CE with the aim of identifying a CBM that combine profitability and low business risks through adaptable design in the early development phases in incumbent OEMs?

The topics presented above have been explored based on interviews and workshops with actors in the automotive industry, combined with interviews with two SME firms running circular business models. The central concepts and terms used in this thesis and their abbreviations are summarized in Table 1.

### 1.3 Central concepts and abbreviations

Table 1. Definitions of major concepts used in this thesis and appended papers

|          |                            |  |
|----------|----------------------------|--|
| AP       | Adaptable product          | A product "that can be changed-adapted, such as reconfigures and upgraded, during a product operation stage to satisfy different requirements of customers" (Zhang et al., 2015).  |
| BL       | Business logic             | A logic for capture (economic) value(s).   |
| BM       | Business Model             | The logic of doing business, reflecting the management's hypothesis about how to create, deliver, and capture value.   |
| BMI      | Business Model Innovation  | "BM innovation involves finding a new way of creating, proposing, or capturing value and implementing changes to the existing model, or adding a new BM". (Fallahi, 2017 p.16).  |
| DL       | Design logic               | A logic for creating and delivering material and immaterial values in form of physical products, processes, and services. (Adapted from Joore, 2010)   |
| DBL      | Dominant (Business) logic  | An (economic) information filter where managers (in a firm) conceptualize their business and make critical resource allocations decisions by filtering such data that they see as relevant and ignoring others. (Adapted from Prahalad & Bettis, 1986)   |
| LBM      | Linear Business Model      | A transactional based business model, based on using virgin resources, digested in a linear cradle to grave manufacturing flow based system of "take, make, use and lose". (Adapted from Raworth, 2017)  |
| CBM      | Circular business model    | "A circular business model describes how an organization creates, delivers and captures value in a circular economic system, whereby the business rationale is designed in such a way that it preserves product integrity to a maximum extent minimizes leakage and resorts to the use of resources in the process of creating, delivering and capturing value only when the options for using resources have been exhausted, in order to achieve the most complete cycling of materials within the larger economic system possible". (den Hollander, 2018p) |
| CE       | Circular Economy           | A vision of an economic system without waste that runs on renewable energy. (Adapted from den Hollander, 2018)   |
| EV (BEV) | Electrical Vehicle         | A summary of drive train technologies being reliant on an electric motor as main propulsion in a vehicle, including battery electric vehicles (BEVs) or fuel cell vehicles (FCs).  |
| ICE      | Internal combustion engine | A mechanical engine running by combustion of petrol, diesel, etc.  |
|          | Product life cycle         | "The duration of the life of a product starting from acquisition (new or second hand) and ending at the moment of replacement". (van Nes and Cramer, 2006)   |
|          | Product life extension     | Prolonging the useful product life in time, e.g., by several use phases that maximize the product's life cycle, i.e., by preserving product integrity.   |
|          | Product architecture       | "The structure of a product's components and the interfaces among them". (Engel et al., 2017)  |
|          | Obsolescence               | "A measure of a product's loss in value resulting from a reduction in the utility of the product relative to consumer expectations". (Rai and Terpenney, 2008)   |
|          | Incumbent OEM              | An OEM that has been well established in the market and for a long time used the same business model. In the automotive industry, there are many of these incumbents that have been producing cars since the advent of the car.  |
|          | Premature Obsolescence     | "Products with built-in defects designed to prematurely end a product's life". (EESC, 2018) <sup>1</sup>   |
|          | Resource productivity      | "The quantity of good or service (outcome) that is obtained through the expenditure of unit resource". <sup>2</sup>  |
| PSS      | Product Service System     | A business model combining both products and services and using results as a basis for innovation. (BS 8001:2017 p.17)   |

### 1.4 Outline of the thesis

The first chapter gives a brief background to this research project being in-between the established logic of doing business and designing products and an altered logic for doing business and designing products for a circular economy in the incumbent automotive manufacturing industry. Moreover, chapter one further presents research questions, the main concepts used, and delimitations.

Chapter two describes the research process where the various empirical field studies have been used as the main "vehicle" for exploring barriers and possibilities for routes towards CE, CBMs, and circular product design.

Chapter three presents findings from the literature that provide explanations of why today's logics in business and design exist, theories that provide support for overcoming these barriers, when implementing CBMs and take action in the industry.

Chapter four summarizes the two appended papers with an emphasis on the role of design as a solution for the existing business model (Paper I) versus various challenges and possibilities for manufacturing firms to embrace strategies for circularity to achieve radical eco-sustainability (Paper II).

Chapter five presents findings from the empirical field studies that compare business and design logic in the incumbent automotive industry with OEMs that challenge this traditional logic.

Chapter six analyses and discusses the empirical and theoretical findings of main barriers for changing from an LBM to a CBM and describes how rising trends in business, technology, and design can offer opportunities for the incumbent automotive industry towards exploring routes for a CE with CBMs. Chapter six also suggests a framework as a route for how incumbent OEMs can explore and implement a CBM. Chapter six ends with a discussion of possible implications by choice of research methods and provides some reflections about the specific use of research methods in the empirical field studies.

Chapter seven summarizes the thesis and provides recommendations for avenues for further research for operationalizing adaptable product design in incumbent OEMs.

<sup>1</sup>European Economic and Social Committee, "Tackling premature obsolescence in Europe", 12 October, 2018, <https://www.eesc.europa.eu/en/agenda/our-events/events/tackling-premature-obsolescence-europe>

<sup>2</sup>[https://en.wikipedia.org/wiki/Resource\\_productivity](https://en.wikipedia.org/wiki/Resource_productivity)

## 1.5 Delimitations

This thesis builds on the assumption that product design can reduce business risks in a CBM (where an OEM keeps ownership of its products) with a design that better can resist obsolescence as these new products are designed to adapt to future requirements. The choice of theory and methods and suggested approaches are built on this assumption.

This study begins by looking at automotive manufacturers of heavy, light vehicle interiors and personal cars as well as a range of start-up companies involved in changing the automotive industry through design and manufacturing of innovative EVs and production methods. A further focus is on one car OEM and OEMs that use circular business models.

Although the main empirical findings are the result of studying the automotive industry, the results are not limited to the automotive industry. That is, the results can be generalizable to other product areas and types. And that the automotive products represent complex manufactured products with the main eco-sustainability impacts allocated to the usage phase, making them relevant examples for studying product adaptability as a main driver for significant increases in resource productivity.

# 2 Method

## 2.1 Research approach

Organizations are complex with many factors influencing managerial decision-making in business development and product design. Therefore, this study provides research that gives a multifaceted picture of the dynamics within and across organizational levels (Martin & Turner, 1986). According to Alvesson and Sandberg (2011), researchers typically look for gaps in existing literature that can be filled by more research. This study, however, takes existing knowledge that can be adjusted and combined to develop a theory that provides structure in a systematic learning process when a change from LBM to CBM in the manufacturing industry is explored. The aim is to build a theory that not only explores casual relationships and ideas as well as the order of events (Sutton, & Staw, 1995), but also explores the “design and taking action” in incumbent organizations when exploring how CBMs can improve and affect business and design logic (Gregor, 2006).

In practice, this exploration is done by comparing the logic of doing business and designing products in incumbent firms running LBMs with start-up firms running CBMs. These two logics have been studied both in how they are described by practitioners responsible for the early phases of business and design activities of new business development and product design in OEMs as well as in how they are represented in the OEMs’ products and value propositions available in the market. This way of comparing the existing situation (the linear business and design logic) with an alternative one (a circular business and design logic) is according to Slife and Williams (in Alvesson & Sandberg, 2011) crucial when problematizing and to being able to contrast new ideas with implicit ones.

This study uses a research approach that is based mostly on abductive reasoning in a parallel and iterative process of systematic combining, “going back and forth” (Dubois & Gadde, 2002 p.555) between activities such as empirical observations, comparing findings with theories that offer credible explanations and practical support in building an extended theory that gradually has evolved throughout the research.

To some extent, this research is also based on inductive reasoning based on the fact, for example, that many consumer products (in various degrees) seem to be designed for premature obsolescence either by going out of fashion after a short period on the market, by requiring costly repairs, by making it difficult to upgrade, or by making material recycling difficult. An everyday example is e.g. the lawsuit against

Apple for intentional short battery time in old iPhones (Girard & Gibbs, 2018), issues further described in chapter four. The research approach has further been inspired by the soft system methodology (Checkland, 2000) using an action research approach (Checkland & Holwell, 1998) and grounded theory (Glaser & Strauss, 1967 in Martin & Turner, 1986) based on memoranda and categorization to structure empirical findings but without following the recommended procedures in every detail.

## 2.2 Research process

Here, the research process relies on a mixed set of qualitative research methods combined with parallel activities (Figure 1). The research started in 2016 with a pilot pre-study aimed at finding general possibilities and barriers for CBMs in the automotive industry in general. This initial broad approach was then funnelled down to focus on one incumbent OEM’s business and design logic (field study A1). This initial approach was followed by an interview study of the automotive industry in general (field study A2). In practice, along with a review of the literature, the empirical field study of the incumbent OEM was a starting point in the research process. Next, the empirical findings resulted in further questions and the formation of hypotheses. Literature was searched for to find possible support of these hypotheses, which were tested in an iterative process of systematic combination. Furthermore, actors representing alternative business and design logic (i.e., not incumbent OEM logics) were also investigated (field study A3), represented by two start-up firms with an aim to become automotive OEMs.

Finally, interviews were performed with companies claiming to already run CBMs (field study B). These interviews were used to compare the business and design logics of companies running CBMs with the business and design logics of traditional incumbent OEMs.

According to Gregor (2006), theories can describe, explain, and understand the world in many ways as well as be used as a basis for intervention and action in many ways. Moreover, as the aim of this thesis lies in finding ways to improve knowledge about barriers and possibilities for CBMs, a literature search was done in parallel with the field studies and interviews to support theory building based on empirical findings. The aim of this literature search was to find theories, support, and tools that could be applicable for building a theory that can give explicit prescriptions of how circular business and design practices can be improved.

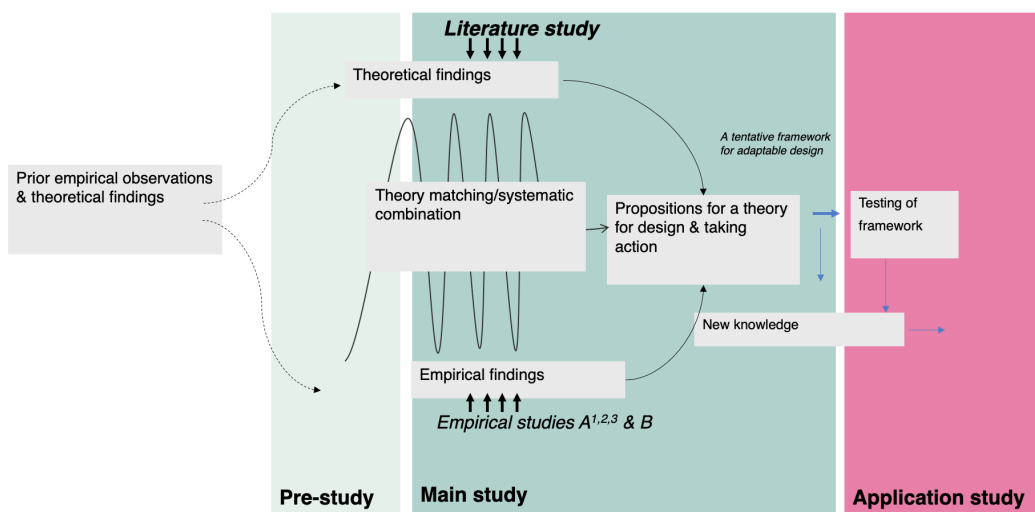


Figure 1. Illustration of the overall research process combining theoretical and empirical findings. Activities covered in the main study (green box) will be described and discussed in this thesis.

The choice of case companies for the empirical studies has been based on what Flyvbjerg (2006 p.230) defines as “information-oriented selection” with “extreme/deviant” variations in the form of one large incumbent OEM situated in Sweden and China, representing the traditional linear way of doing business and designing products. This OEM participated in the pre-study with expressed interest to explore possibilities with a CBM in their organization.

Study B showed that it was difficult to find examples in the automotive industry representing a BM that systematically combined all three business and design strategies for CE (Bocken et al., 2016), i.e., with an expressed vision to achieve a degree of circularity as high as possible and to have circular value propositions available in the market. Incumbent automotive firms with circular business models relevant for this study are very rare. Therefore, this study compares two OEMs running CBMs, one smartphone manufacturer and one manufacturer of lighting solutions for commercial buildings. Both these companies are in the Netherlands.

## 2.2.1 Initial pre-study

The initial pre-study was carried out in collaboration with three incumbent manufacturing OEMs in the automotive industry, which included OEMs of heavy and lightweight vehicles and cars as well as one large fleet owner of commercial vehicles. All of these participating firms had initially expressed interest in exploring implications of a CBM, mainly from a product design perspective. The main findings from the pre-study are reported in Paper II and have formed the basis for understanding general barriers and possibilities for CBMs and circular product design. The pre-study also formed a base for further research questions addressed in Paper I and II, but will not be further discussed in detail in this thesis.

## 2.2.2 Literature study

A literature search was conducted to increase understanding about aspects deemed relevant for the broad and multidisciplinary topic of CBM. Because CBM research encompasses business, design, engineering, and sustainability, this literature search included organizational logics, decision making, design theory, design-thinking, business modelling and innovation, circular economy, eco-sustainability, and product service systems.

In the first stage of the literature search, papers were reviewed that referred to logics of business and design of CEs as well as to barriers for implementation of CEs. Based on the learnings from this initial review, themes related to adaptable products were identified and used as input for the second iteration of literature collection. In this second stage, literature was collected that refers to sustainable design, eco-design, longevity, adaptable design, adaptive products, or design for adaptivity. Finally, in a third stage, design methods were reviewed that were deemed relevant when designing for CEs and methods for organizational change. Although this thesis focuses on the automotive industry, the literature search included other industries to make it possible to generalize the findings other product fields.

The theories and methods deemed relevant (Paper I and II and in Chapter 3) were used to compare the empirical findings. An objective was to find theories, supportive facts, and tools that could be applicable for building knowledge that could speed up exploration of circular business and design practices in the industry.

### **2.2.3 Empirical field studies A1, 2, 3: The dominant business and design logic in the automotive industry**

This study aims to better understand ongoing discourses (Parker, 1992) about current business and design logic in the automotive industry as well as to better understand how such discourses are affected by emerging global trends. To adapt to technology and market trends, such as digitalization and servitization, CE is being proposed as relevant for the automotive industry.

To this end, this study aims to find empirical data that could help answer the following research questions:

RQ1: What are the challenges and possibilities for an incumbent manufacturing firm to embrace all three business and design strategies for CE (closing, narrowing, and slowing down resource flows)?

RQ 2: What does a change/design manager need to be aware of when proposing an adaptable product to top management in an incumbent OEM?

This study relies on three field studies, A1-A3. The first field study (A1) focused on an incumbent global automotive OEM in Sweden using on-site interviews with twelve representatives from the OEM's business and design organization and three internal workshops conducted separately from interviews. These workshops explored possibilities for an improved circular business and design logic and included participants representing functions for business development, design management, product development, innovation, and environmental affairs in the OEM. The workshops used the soft system methodology in action (SSMA), (Checkland, 2006) to encourage a collaborative learning process between practitioners and researchers. See Appendix B for more details.

Study A2 took a broader and more general perspective of the automotive industry. To collect data, five employee interviews were conducted either at the researcher's location, at the employee's office, or via video chat. All the respondents had extensive work experience in the automotive industry and three respondents had experience working in the OEM studied in A1 as a concept developer, designer, or design manager. In addition, a journalist was interviewed who had a design background and had followed the automotive industry for almost two decades. This interview was conducted to relate the findings to the automotive industry in general.

In Study A3, two actors were interviewed who could provide insights into existing adaptable designs in the industry. These actors had developed modular automotive products and applied innovative ways for design, product development, and production to extend product life as a way to be competitive. Table 2 provides an overview of the interviews, including functions, dates, and lengths of the interviews.

### **2.2.4 Empirical field study B: Companies running circular business models**

Study B aimed to find companies that run circular business models that implement all three strategies for CE (closing, narrowing, and reducing resource flows). The study compared business and design logics in circular firms with the business and design logics in the participating OEMs running LBMs, especially their current design activities.

## 2.3 Methods for data collection

In-depth semi-structured interviews with several participants at each company were held to identify ongoing discourses that could help understand the current logic in business and design and the interrelationship and power relations (Parker, 1992; Kvale, 2006) between the two logics. The interviews, which took place during a period between Spring 2016 to autumn 2018, were mostly held at the company or in some cases conducted online. The interviews lasted from 30 minutes to 1 hour. The interviewer gathered information about the interviewee's responsibilities with design, product planning, business strategy, and marketing/customer relationships (Table 2).

These semi-structured interviews addressed three general themes (Appendix A). The first theme included questions regarding the current way of doing business and product design in the industry in general. The second theme addressed how the company conducts business and designs products. The third theme dealt with possibilities and barriers to changing both business and design logics based on a hypothetical proposition of a circular business model and a product designed to extend product life by product adaptivity.

In the three workshops conducted in Study A2, the soft system methodology was used to include steps for data collection according to the steps in the SSMA approach (See section 3.3). All interviews and conversations were recorded and fully transcribed to form a base for interpretation of relevant connotations (Parker, 1992).

## 2.4 Data analysis

The fully transcribed interviews were coded and divided into two main categories related to responses with annotations that captured the value(s) related as business logic and responses related to creation and delivery of value(s), defined as design logic. These responses were further categorized according to what respondents noted as barriers and solutions for a circular business and design logic, including activities related to a CE that respondents described already being implemented in their organizations.

| Field study & Type of company   | Function   | Type of interview & location | Date             | Time     |
|---------------------------------|--|------------------------------|------------------|----------|
| <b>Empirical field study A1</b> |  |                              |                  |          |
| Incumbent OEM                   | Project leader platform development  | Personal interview on-site   | 1 February 2018  | 01:09:21 |
|                                 | Concept developer  | Personal interview on-site   | 1 June 2018      | 01:16:29 |
|                                 | Concept developer  | Personal interview on-site   | 29 August 2018   | 01:19:45 |
|                                 | Attribute Manager  | Personal interview on-site   | 16 May 2018      | 0:44:37  |
|                                 | Program Leader   | Personal interview on-site   | 9 September 2018 | 01:12:04 |
|                                 | Innovation Manager & Trainee   | Personal interview on-site   | 8 March 2018     | 01:01:00 |
|                                 | Innovation Manager & Trainee   | Personal interview off-site  | 15 March 2018    | 01:00:00 |
|                                 |  |                              | 23 November 2018 | 01:00:00 |
|                                 | Manager Strategy & Business  | Personal interview on-site   | 16 June 2017     | 01:00:00 |
|                                 | Project Leader Finance   | Personal interview telephone | 4 December 2017  |          |
|                                 | Manager aftermarket (REMAN)  | Personal interview on-site   | 11 May 2018      | 01:05:00 |
|                                 | Manager platform<br>Innovation manager<br>Product developer<br>Manager remanufacturing<br>Manager market | Workshop on-site             | 15 June 2016     | 01:43:24 |
|                                 |  | Workshop on-site             | 30 May 2017      | 01:10:01 |

Table 2. Details of interviews and workshops for the empirical field studies.

| Field study & Type of company   | Function   | Type of interview & location | Date             | Time     |
|---|--|------------------------------|------------------|----------|
| <b>Empirical field Study A2</b>   |  |                              |                  |          |
| Self employed   | Taxi driver, owning and using an EV  | Personal interview in car    | 7 November 2017  | 0:40     |
| Incumbent OEM   | Design manager   | Personal interview on-site   | 17 August 2016   | 01:51:39 |
| Design consultancy  | Design manager consultant with experiences in many branches (including automotive) | Personal interview on-site   | 22 February 2016 | 01:00:33 |
| Incumbent OEM with long experience from Automotive both Incumbent & start ups | Design manager interior  | Personal interview Online    | 28 June 2018     | 01:35:57 |
| OEM subsidiary  | Attribute leader   | Personal interview           | 1 September 2017 |          |
| Branch Expert   | Automotive industry journalist   | Personal interview           | 30 May 2018      |          |
| <b>Empirical field Study A3</b>   |  |                              |                  |          |
| Local Motors  | Head of product development  | Personal interview Online    | 27 October 2017  | 00:43:18 |
| Open Motors   | Founder  | Personal interview Online    | 4 June 2018      | 00:35:43 |
| <b>Empirical field study B</b>  |  |                              |                  |          |
| Led Lease   | Founder  | Personal interview on-site   | 27 June 2017     | 00:52:34 |
| Led Lease (study visit)   | Founder  | Personal interview on-site   | 20 October 2016  | 00:30:00 |
| Fairphone   | Manager product development  | Personal interview on-site   | 27 June 2017     | 01:07:03 |
| Fairphone   | Head of product development  | Personal interview on-site   | 1 December 2015  | 00:40:01 |

Table 2 (continued). Details of interviews and workshops for the empirical field studies.

# 3

# Theory



The literature presented in this chapter focuses on theories regarding barriers and possibilities for designing products that can extend the product life by adapting to changing requirements, defined as adaptable products. The choice of theories and methods presented and discussed is based on a heuristic approach. The aim is to find theories that help explain why existing situations are perceived as problematic in industry (i.e., why some CE strategies seem to be more difficult to implement than others). In addition, the aim is to find theories that can be extended to explain how internal change agents/managers (Volberda et al., 2014) within the business and design fields can apply CE and CBM to their OEMs.

### 3.1 Theories regarding business logic

As presented in Paper I and II, several scholars view business models as a firm's image or a blueprint of its "core" logic of doing business. Business models reflect management's hypothesis about value creation by appealing to potential customers' wants and needs and identifying how to organize, get paid, and make a profit for delivering such values (cf. Foss, & Saebi, 2015; Teece, 2010; Zott, & Amit, 2010). See Fallahi for a more comprehensive overview of other BM definitions (2017 p.12).

Many factors influence managerial decision making in business development, as the worldviews of the people involved build on and are affected by the flux of events and ideas when these people try to act in what they consider deliberate and purposeful ways (Checkland, 2010 p.130). Over time, actions form ways of working, build organizational cultures or "institutional logics", and describe how specific social worlds work (Greenwood et al., 2008, p.101).

The theory of the dominant management logic (Paper I) offers an explanatory model of mechanisms that shape a firm's managerial decision making over time with the dominant management logic acting as an information filter where managers consider data they consider relevant and ignore data they consider irrelevant (Bettis & Prahalad, 1995). Relevant data are then incorporated into the organization's strategy, values, systems, and routines. The result is a resource and capability infrastructure that will influence the firm's further search for growth, diversification, and strategic experimentation. The dominant management logic is not fixed. It can change based on how the firm's managerial thinking develops or changes –based on, for example,

current resources and capabilities (Altman & Lee, 2015), its path dependency (Heffernan, 2003) on previous achievements in incremental technological development, and the ongoing struggle for power and status (Clegg et al., 2006 p.755). These norms or rules build on various patterns of response to form routine responses to specific problems. These rules become the norm as people in the organization follow them without reflection on the optimal response to a specific situation (Heffernan, 2003 p.47) and will resist radical attempts to change the norms. Heffernan further gives two reasons why rules remain. First, rules are maintained because changing rules is costly. Second, people may not know how to change rules or do not think changing rules is an option as they take them for granted.

The process of generating alternative business models – i.e., business model innovation (BMI) – has been seen as a vital component for the transition to a sustainable society (Sarasini & Linder, 2018). Chesbrough (2007 p.16) emphasises that changing an existing business model is difficult and highlights what he describes as the "leadership gap": a lack of a dedicated responsibility, capacity, and authority for BMI. This condition leads to maintaining the status quos, growing the business within the existing BM rather than relying on innovation (Kaplan, 2012).

British standard exemplifies such inertia of the BM as: "Where a strong business case exists, established organizations (e.g., a car component manufacturer operating for many years) are more likely to re-engineer existing business models to deliver their main value proposition alongside chosen circular economy objectives". (BS 8001:2017 p.43). Although, British standard further put forward: "that Implementing any one business model does not necessarily equate to a shift to a more circular and sustainable mode of operation", as the connection between the business model and its environmental and societal benefits can be very different, and may be of secondary importance to the firm's value proposition (BS 8001:2017 p.43).

### 3.1.1 The dominant business and design logic in the automotive industry

According to Mills et al., the normal BM in the automotive car industry is that “the OEM design and manufacture cars to be produced at volume, delivered through a dealer network and serviced at a dealership” (2016 p.57). The automotive industry exemplifies an incumbent sector with more than 100 years of practice that has evolved to its current form through a series of technical, organizational, and market innovations. This evolution has occurred in combination with a set of corporate rules. According to Nieuwenhuis (2014), the most central rules include the following:

- the introduction of the mass-production in standardized and centralized assembly lines by Ford;
- the introduction of the Budd and Ledwinka “unibody” where stamped plates of steel are welded together, forming self-supportive vehicle body-frames;
- the internal combustion engine (ICE) that burns petrol or diesel to generate mechanical energy;
- the market innovation of yearly model changes with multiple brands and consumer credits for vehicle purchases; and
- the development of franchised distribution networks

Proponents for eco-sustainability, such as Wells and Nieuwenhuis (2006), argue that only reducing volumes or only making cars more efficient does not make the industry more sustainable. The automotive industry if considered being a “regime” (Geels, 2002), has since the 1960s been argued to be unsustainable by representing a very large source of global air pollutions from vehicles being produced and used, fuel production and maintenance etc. (Mayyas et al., 2012), but has so far been very successful in being stable and resisting major transitions towards Eco-sustainability. Proponents of a CE, such as Ellen MacArthur Foundation, describe the current “linear business logic” in the global automotive industry as significantly dependent on material resources that are mainly based on non-renewable and virgin resources such as steel. As car use increases, more fuel and material resources will be needed, resulting in even more air pollutants (Mayyas et al., 2012 p.1846). Moreover, in the strive for improved fuel efficiency, comfort, and safety, the increased use of lightweight materials such as fibre reinforced

plastics are making the end of life treatment via material recycling more complicated (Soo & Doolan, 2016; Go et al., 2011). Furthermore, Zapata and Nieuwenhuis (2010) describe a set of mechanisms that they consider prevent the automotive industry from achieving radical changes towards sustainable mobility. These mechanisms include the dominant business model, continuous incremental improvements (e.g., minor eco-efficiency improvements of emission control), improved fuel efficiency, and a deeply embedded cultural status built around car ownership. The car has also become firmly established as a consumer durable, cultural icon, and a symbol of individual freedom and a functional tool for mobility (Wells, & Nieuwenhuis, 2012).

Because automobile production requires massive investments in research and development, equipment, manufacturing facilities, etc., the development and diffusion of more eco-sustainable vehicles such as electric cars goes very slowly (Wells & Nieuwenhuis, 2012). For example, statistics from the European Automobile Manufacturers Association (ACEA) show that the 19,6 million motor vehicles produced in the EU in 2017 emitted an average of 118,5g CO<sub>2</sub>/km and have an average lifespan of 11 years (ACEA, 2016). Although the global stock of vehicles with alternative drive train technologies such as electric vehicles (EVs) reached 2 million in 2016 (IEA, 2017), EVs still represent only a small percentage of the global total stock of vehicles.

Proponents for radical transitions of the current automotive industry (e.g., Nieuwenhuis, 2014) emphasize that the business-as-usual in the automotive sector is far from being “future proof” due to sustainability challenges such as the coming emission legislation in EU<sup>3</sup> as well as other local initiatives such as zero-emission zones in cities.<sup>4</sup> Nieuwenhuis further proposes that the future car industry must slow down production volumes while relying on designs that increase modularity and longevity and use lightweight platforms that are easily remanufactured, are accessible, and upgradeable. Nieuwenhuis further emphasizes that such reductions are even more relevant with a possible massive diffusion of EVs due to more embedded raw materials and resources from the production of EVs than for ICEs.

<sup>3</sup> Accessed 14 December 2018: [https://ec.europa.eu/clima/policies/transport/vehicles/cars\\_en](https://ec.europa.eu/clima/policies/transport/vehicles/cars_en)

<sup>4</sup> Accessed 14 December 2018: <http://urbanaccessregulations.eu/news-archive?id=2043:zero-emission-zones>

### 3.1.2 The circular business model from a product obsolescence risk perspective

This section explores various dimensions of how products can become obsolete and can from a product design perspective be defined as a product's loss in value in the utility of the product relative to what consumer expects. However, the usefulness of the product can still remain and the value can increase (Rai & Terpenney, 2008 p.881) if the owner finds the obsolete product attractive due to changing fashion trends or if a new owner sees something in the product that the previous owners overlooked.

Throughout history, manufacturers have understood that products designed with longevity in mind negatively affected new sales; therefore, designing products to ensure a limited life span could help a firm survive, especially during a deep recession (London, 1932). Over the years, business strategies for selling more products have come to include strategically designing for obsolescence (Rivera & Lallmahomed, 2016; Longmuss & Poppe, 2017). From a customer and user perspective, product obsolescence is a double-edged sword, as new products with new functionality, design, and performance can add value to products, but well-functioning products can break prematurely and be too costly to repair (Guiltinan, 2009). In addition, it may be difficult to find spare parts for obsolete products, a situation that EU policymakers have recently addressed (EU, 2017). For example, in France the "Hamon Law" allows citizens to bring class action law suits if companies do not support their products with reasonable access to spare parts<sup>5</sup>.

The following sections present and discuss from a CBM perspective what Burns (2010) identified as four modes of obsolescence: aesthetic, social, technological, and economic. A fifth dimension, functional obsolescence, is added to this palette to separate these five modes between technological advances driven by companies and the industry and changes in functional requirements driven by consumers' basic needs or wants.

<sup>5</sup> Accessed 7 December 2018, <https://www.lexology.com/library/detail.aspx?g=c91cbd78-0eb8-49d8-9fc3-1da4e8a37e39>

#### 3.1.2.1 Aesthetic obsolescence

According to Burns (2010), aesthetic obsolescence occurs when a customer discards a product because it looks worn out, dirty, old, faded, or is no longer fashionable. In many industries, planned obsolescence via aesthetics has been practiced for a long time by continuously introducing products with a new shape, colours, fabrics, and so forth to distinguish new versions from old versions of the product. An example often used of this practice is from the clothing industry with what has become to be called "fast fashion", where, for example, Zara and H&M have been targeted in the media for their fast fashion and associated unsustainable practice. The practice of aesthetic obsolescence by continuously launching new products with new aesthetics is well established in the furniture, automotive, and consumer electronics industries.

Zafarmand et al. (2003) argue that reusable products need both new aesthetics as well as aesthetics that can evoke and stimulate reuse of products. Here, for example, many luxury products in fashion or high-quality furniture often are used for a very long time, as they "aesthetically" last long and thus create a profitable second-hand market as vintage or antiques and stay alive through several purchasing cycles. Such aesthetic values are often strengthened if products are associated with well-known designers, product history, and provenance.

When recirculating products, designers have to expand their target from aesthetics at the beginning of the product's life when customers select and purchase the product to aesthetics over the whole life cycle of the product, including multiple cycles (Zafarmand et al., 2003). Some customers are more sensitive to new fashion updates than others (i.e., the early adopters). These customers will demand product updates or replacements more frequently (McCollough, 2010). Many of the aesthetic attributes for sustainable design as proposed by Zafarmand et al. (2003) can enable the postponement of aesthetical obsolescence in adaptable design:

- Aesthetic durability: timeless simplicity and minimalism or neutral design with natural forms might help keep customers attached to a product longer.
- Aesthetic upgradeability and modularity: adding modular design aspects that customers can quickly change to make the product look new or fashionable.

- Individuality and diversity: a design that covers the taste of a range of users and can be suited to individual taste via aesthetic variations, modular design, and product serviceability.
- Logicality and functionality: a product's "type form" can integrate a product's functions with its aesthetics, resulting in products that are easy to understand and use and thus contribute to longevity.

The Volkswagen Beetle is an automotive example of aesthetic durability in combination with logicality and functionality where the lack of exterior updates was successfully used in marketing in the US in the 1950s and 1960s. The Volkswagen Beetle was advertised using "anti-obsolescence" campaigns, presenting each year model of the Beetle "with no visible changes" (Slade, 2006 p.175).

### 3.1.2.2 Functional obsolescence

Caccavelli and Gugerli (2002) define functional obsolescence as "the lack of ability to provide a sufficient level of services to the users concerning their needs and expectations". In a commercial office building, such needs could comply with the user's activities, flexibility, divisibility, maintainability, and compliance with new regulations. Others, including, Gurler (2011) and King et al. (2006), put physical failure in the functional obsolescence category. In this thesis, functional obsolescence will be associated with situations where products are discarded because the product no longer provides the required functions, a view also taken by Caccavelli and Gugerli (2002). A practical example of such functional obsolescence was the massive change among consumers switching their existing mobile phones to smartphones when accessing the Internet with much more intuitive and user-friendly smartphones products became available.

Similarly, the invention of the electric starting motor in 1912 introduced a new functionality that replaced the obstacle for the driver starting the engine manually by cranking the engine.<sup>6</sup> This cranking could be very dangerous if the crank lever was not properly set and the engine misfired. In the case with the electric starter, Charles F. Kettering was moved to design a safer way to start an engine as the result of a death attributed to manually starting a car engine.<sup>7</sup> According to Slade (2006), women desired a way to start an engine without manually cranking the

engine. These pressures, the need for a safer and more easily operated product, resulted in the electrical starter replacing the manual crank starter. This example also illustrates the close connections between functional and technical modes of obsolescence.

### 3.1.2.3 Technological obsolescence

Technical innovation that replaces another product with the same function results in technological obsolescence (Burns, 2010). Consumers are attracted to new models as the result of technological advances (Rai and Terpenney, 2008; McCollough, 2010). For example, floppy disks were replaced by new storage technologies such as CD-ROM, DVD, and later cloud computing (Amankwah-Amoah, 2016). Closely related to the technical mode is also what Guiltinan (2009) describes as physical obsolescence, where products can be designed for "death dating", that is, where at a point in time or after a specific amount of usage time or distances a product will be worn out or completely stop working (Slade, 2006). Cooper (2004 p.423) describes such product failure as "absolute obsolescence" and possible for manufacturers to affect. Examples of this is the plan for life length of light bulbs, tires, or electronic equipment. In this thesis, technological obsolescence includes wear, tear, and physical breakdowns as well as new technology making a product obsolete or stop working.

### 3.1.2.4 Social obsolescence

Changes in social norms and customer behaviour can reduce or eliminate the need for certain products due to changes in long-term desires and needs of customers and users. Cooper (2004 p.423) defines these changes as "relative obsolescence", decisions based on the consumer's desire to discard products. Social obsolescence can occur due to both societal changes in preferred aesthetics (Teo & Lin, 2012) as well as new customer behaviour related to new service offerings such as renting rooms through Air B & B or buying transportation services from DIDI or Uber via the Internet. Social obsolescence can also be due to new laws, regulations, and voluntary standards or pressures for environmental or health awareness (Burns, 2010). For example, purchases of diesel cars have declined as the result of coming diesel bans in European cities and tougher emission standards. Many other types of products are also vanishing due to social obsolescence, for example, phone booths, ashtrays, bank offices, and post offices. Diener (2017) emphasises that the end user plays an important in determining whether a product becomes obsolete. That is, customers decide whether a product is no longer trustworthy or interesting enough for further use.

<sup>6</sup> Accessed 7 December 2018, <https://patentyogi.com/this-day-in-patent-history/first-self-starting-automobile-engine/>

<sup>7</sup> Accessed 7 December 2018, [https://en.wikipedia.org/wiki/Charles\\_F.\\_Kettering](https://en.wikipedia.org/wiki/Charles_F._Kettering)

### 3.1.2.5 Economic obsolescence

According to Cooper (2004), economic obsolescence occurs when economic factors are considered to make a product not worthy to keep; this decision could be due to depreciation, high cost of repair, or high cost of maintenance in relation to costs for replacement, low performance/cost ratio, or other price trends in the market that prompt customers to replace an established product with a less expensive product (Rahman and Chattopadhyay, 2010). Customers might replace a product if the total cost of ownership (e.g., operational and repair costs) exceeds the purchase price for a new product. For products such as cars, the costs are significant for maintenance, consumables, spare parts, insurance, fuel costs, and depreciation. That is, the purchase price is only a part of the total cost of ownership. Nevertheless, even with a higher purchase price for a product, the most expensive product can be the most cost-effective product when considering the expected life-time of the product. This is the case for electric cars (Hagman et al., 2016) and energy-saving light sources.

From a producer perspective, an extended warranty is a strategy to reduce risks for economic obsolescence and makes customers more assured in the reliability and longevity of a product as well as offering customers peace of mind. Such extended warranties can extend warranties for the whole product life or service contracts (Rahman & Chattopadhyay, 2010 p.204).

### 3.1.2.6 Product longevity; The time factor

Time has an essential role for all modes of product obsolescence as time influences all that humans create and all that they do (Thompson et al., 2011). Therefore, knowledge about product life span and planning for an extended use of products will play an important role when designing for resisting obsolescence. Once upon a time, design and production were done at the individual craftsman's pace (Thorpe, 2007), where large and complex projects like cathedrals could take decades or even centuries to complete; however, today efficient production methods and digitalization have greatly reduced the time it takes to move from product idea to market.

In the fashion industry, some brands have reduced the time it takes to move from idea to market from years to months or even days.<sup>8</sup> It takes Zara for example approximately 15 days to go from a design concept

to a product in the store. The average time to market is six months. In the automotive industry, development cycles are much slower where the development of a car or construction equipment could range from three to seven years. During that development time, a lot can change regarding technology, aesthetics, etc. The Long Now Foundation<sup>9</sup> wants to encourage long-term thinking through the design of a clock with a 10 000-year lifespan (Brand, 2000). The design process for the clock is relevant for designing adaptable products as it provides practical knowledge about choosing materials that can withstand wear and corrosion for a very long time.

### 3.1.3 Lean entrepreneurship

According to Sarasvathy (2001), achieving human intention is considered to be an act of effectuation in imaging a possible outcome an exciting idea, a desire of earning a lot of money, building something that lasts, or wanting to change a whole industry.<sup>10</sup> When entrepreneurs aim for “the stars”, they usually do it without a fixed set of established preferences, often with only general knowledge of possible barriers. Effectuation is further described as logic for decision making under uncertainty (Read et al., 2009) and as an entrepreneurial logic for designing artefacts (Sarasvathy et al., 2008) that create markets that do not exist. This is the case for start-up companies as they often do not know initially who will pay for their pioneering ideas.

As a contrast to effectuation, a process of causation starts the other way around, optimizing an outcome by selecting optimal strategies with a specific activity or venture. However, Sarasvathy emphasizes that both causation and effectuation are and can be used simultaneously in decision making, where an entrepreneur interacts with the surrounding environment.

In contrast to the start-ups, incumbent firms face the challenge of developing new business models within their existing organizational structures and value networks that are optimized for their existing business models. Thus, it is important to understand how top management makes decisions without prior experiences of making a profit and existing metrics (Birkinshaw & Ansari in Foss & Saebi, 2015). A general problem here lies between the requirements on an established firm's organization optimized for execution of the existing BM and the requirements of an organization to find a new BM. This problem

<sup>8</sup> Accessed 7 December 2018, <https://www.tradegecko.com/blog/zara-supply-chain-its-secret-to-retail-success>

<sup>9</sup> Accessed 6 December 2018: <http://longnow.org/>

<sup>10</sup> See Fairphone mission statement; Accessed 14 December 2018: <https://www.fairphone.com/en/our-goals/>

emphasises the need for searching and learning (Govindarajan and Trimble, 2010).

There are reasons for incumbent firms to focus more specifically on BMI processes, especially processes optimized for search and learning such as lean start-up methodologies developed for rapid and cost-effective design and validation of BMs in start-up companies such as “Customer Development” (Blank, 2006; Blank and Dorf, 2012), “The Lean Startup” (Ries, 2011), and “The other side of innovation” (Govindarajan & Trimble, 2010).

These methods share the goal to design and validate a feasible and profitable BM in a lean and “learning” oriented way based on a hypothesis-driven approach to BMI. Customer development and Lean Startup emphasise small start-ups with a focus on and a history with high tech, products, and services. Govindarajan and Trimble, on the other hand, focus on making innovation happen in incumbent organizations, proposing approaches to identify and handle what they describe as “the performance engine”. That is, the established way of doing business in the firm has been optimized and fine-tuned to deliver profit by the established BM, making conflicts with the innovation endeavour and the established operations inevitable (Govindarajan & Trimble p.11).

In Customer Development and Lean Startup, the starting point is a basic BMI that then through a learning process evolve with iterations (pivots) of the initial value propositions in accordance to customer interest and willingness to pay for the intended value proposition. During this process, the BM evolves as a result of hypotheses and learnings from testing those hypotheses during the BMI process. The resulting business model can thus be much different from the initial one, as early hypotheses probably are wrong in regard to one or several important aspects. Thus, the cycle-time and lean approach to hypotheses generation and hypothesis testing affect the possibility of success in finding a feasible BM within the firm’s financial limits.

Lean Startup methodology has also been reported to be useful as a research method and has been used as means to explore and facilitate CBMs in interventional research studies in both SME context (Nyström & Williander, 2013) and in large established firms. With the hypothesis, Lean Startup methods in large established firms can help them rapidly and at low costs develop and test radical BM changes, making LSMs become essential tools in an industry shift towards a CE (Williander et

al., 2014). However, even if findings from these studies indicate that the Lean Startup approach is feasible as an exploratory method, it requires a conscious setup of a dedicated project team that jointly participates in the BMI process. This is especially important in large incumbent organizations, where participants are restricted by the firm’s existing BM and dominating actors in the firm’s value network (Govindarajan & Trimble).

## **3.2 Theories regarding eco-sustainability**

In their framework for implementing CE, British standard states that “[t]o ensure the availability of resources that can sustain society in the future, current patterns and volumes of production and consumption need to change dramatically so that they are brought back within planetary boundaries” (BS 8001:2017). Such eco-sustainability concern for contemporary society put expectations on firms to consider and manage their effects on society via the eco-sustainable way they do business and use natural resources such as water, materials, and energy (Lovins et al. 2007). Therefore, most manufacturing companies now address eco-sustainability issues in their vision and mission statements.

### **3.2.1 Relative versus absolute approaches towards eco-sustainability**

Some companies execute their eco-environmental vision through an eco-efficient approach while other firms take an eco-effective approach with the eco-efficient route primarily being reductionist and the eco-effective route primarily being emergent/radical. Since the industrial revolution, the eco-efficiency approach (i.e., making things using fewer resources) has been a cornerstone in the production of goods and services (Lovins 2008 p.39). This approach was formerly introduced by the World Business Council for Sustainable Development in 1992 (WBCSD 2005). WBCSD describes eco-efficiency as a management philosophy that “encourages business to search for environmental improvements that yield parallel economic benefits”. Today, this eco-efficient management approach is applied in the industry through standardized frameworks promulgated by the Environmental Management Systems ISO 14001, including the use of the Life Cycle Assessment (LCA). In addition, this approach is supported by umbrella concepts in product design and manufacturing such as Design for X (Gatenby & Foo, 1990), lean manufacturing, and Six Sigma (Lovins 2008).

Opponents to eco-efficiency as, the Factor 10 Club (1994), Lovins et al. (2007), and Manzini (2003) claim that much more radical decrease in energy and resource use is necessary. Eco-efficiency has also been criticized for being a tool-driven approach (Rossi et al., 2006), with emphasis on metrics, only leading to relative changes, that hinders companies to become genuinely sustainable (Dyllick & Hockerts 2002). Könnölä and Unruh (2007) further argue that there is a risk that Environmental Management Systems leads to lock-in effects and hinders radical innovation. Braungart et al. (2007 p.1338) argue that eco-efficiency goal of zero waste and emissions hinders imagination by stating that being a little less bad is not the same as being good. That is, instead of focusing on being a little bit more eco-efficient, industry should become “good” by aiming at eco-effectiveness from the start of the design of new products. However, even with the huge differences between these two concepts, the concepts share the same overall focus and goal of “making the ‘right things’” or to go beyond eco-efficiency (Figge and Hahn 2004).

However, the main differences between them lie in the “relative” eco-efficiency approach and the “absolute” eco-effective approach. The relative approach allows generation of waste with a focus on waste minimization, incremental reduction of energy use, and improved material efficiency towards zero. The absolute approach, on the other hand, aims at creating closed material flows that do not generate waste and using renewable energy through the management of resource flows using cradle-to-cradle design principles (den Hollander, 2018).

Although each of these two approaches towards eco-sustainability have its proponents and opponents, both routes might have an unreachable visionary goal: zero impact for the eco-efficiency approach versus entirely closed material loops without creating waste with the eco-effectiveness approach. However, with the important notion that there is and will never be any industrial system that is entirely closed, as there always will be losses of gasses, solvents, or materials due to dissipative wear during product use (Cullen, 2017). This thesis focuses on the eco-effective strategy, striving towards an absolute goal of eco-sustainability in line with den Hollander (2018) with the vision of a CE being a route for realizing such an “absolute” goal of eco-sustainability.

The concept of CE, considered as an “eco-effective” strategy (McDonough & Braungart, 2002), is based on several schools of thoughts (BS, 2017 p.4) and can be considered as an “umbrella concept” (Hirsh & Levin, 1999), offering a discursive space and

structure for debate about resource life-extending strategies (Blomsma, et al., 2017) for limiting the flows of material and energy through the economic system (Korhonen, 2018 in Den Hollander, 2018 p.201). The CE concept is sprung from mimicking basic principles of sustainability studied in nature such as the reliance on solar energy, biodiversity, population control, and nutrient cycling (Miller & Spoolman, 2009 p.18). In the 1960s, scholars such as Boulding (1966) laid the foundation to CE by problematizing the industrial open system as, for example, a “reckless, exploitative Cowboy economy” that must be changed into a “spaceship economy” with continuous cyclic reproduction of materials, minimizing throughput in the form of natural resources. This view was further developed into the field of industrial ecology being inspired by natural ecosystems when designing industrial systems (Frosch & Gallopoulos, 1989). In addition, Ayers, studying industrial material flows and industrial metabolism, is understood to be the intellectual founder of industrial ecology as a research field (Daly & Holling, 2013).

From the perspective of CE as a tool for saving resources and waste and minimizing environmental impact, it will be rather straightforward to align it with a traditional industrial logic of saving resources (Lovins et al. 2007) if, as Kirchherr et al. (2017) propose, CE is a systemic change. A change to a CE in manufacturing firms will imply a shift from what Zink and Geyer (2017) define as “primary production” with extraction and processing of raw materials into products that increase activities in “secondary” production such as reuse and remanufacturing. Such a shift will result in fewer products produced and will thus challenge a flow-based linear business model.

To conclude this section, the CE concept means many different things, from being about material recycling eco-efficiency being in line and supporting traditional industrial strategies and activities to coping with scarce resources by using them in an incrementally efficient way. However, CE is also considered as a vision to radically change today’s industrial system (Kirchherr et al. 2017) by aiming at an absolute goal of closed material flows (den Hollander, 2018). Based on the previously described approaches towards eco-sustainability, eco-efficiency and eco-effectiveness also represent two different design approaches for achieving eco-sustainability that is embraced under the CE umbrella. Because there is often no clear separation between these approaches, there is confusion regarding the relative versus the absolute CE goal in product design (den Hollander, 2018) and without clear hierarchies (Kirchherr et al., 2017) that suggest design approaches. As a practical way forward in clarifying these discrepancies, Cullen (2017 p.484) suggests relabelling the “ideal” or absolute CE to a “theoretical” CE,

which is better suited to measuring circular progress. Attempting to simplify CE definitions, Bocken et al. (2016) summarises several lines of thoughts from industrial ecology and CE scholars into three simple business and design strategies for CE: closing, narrowing, and slowing down resource loops/flows. However, with the notion that narrowing and slowing down resource flows can lead to the same outcome -less flow of resources in the system over time, (but with two different approaches to time), where the narrowing strategy accepts a high speed of resource flows over time.

### 3.3 Facilitating transformational organizational change

Based on the previous theories regarding entrepreneurship and the suggestion that a CBM requires a radical and architectural change to the existing BM and face the same uncertainties as entrepreneurs when approaching the BMI, Sarasvathy et al. (2008 p.337) propose three elements for describing boundaries for what they describe as the “Entrepreneurial Design Space”, where they suggest effectuation as a suitable strategy for handling future uncertainties entrepreneurs will face:

- Knightian uncertainty: it is not possible to calculate probably future consequences;
- Goal ambiguity: it is not clear which preferences are needed for entrepreneurial venture or which are well ordered;
- Isotropy: it is not clear which elements in the environment that the entrepreneur needs to pay attention to and which elements can be ignored.

Based on these three types of uncertainties, a structured method for addressing future uncertainties is backcasting. The British standard defines backcasting as “working backward from a desired future state of a process, product, service or organization (or aspects thereof) to determine both its feasibility and what actions need to be taken to reach that state” (BS 8001:2017 p.8). With an origin in the 1990s (Robinson, 1990), the backcasting methodology has come to be associated with creating sustainable futures with the aim to help organizations to focus on their long-term challenges instead of focusing on small incremental

improvements. This helps the organization identify their major gaps in obtaining sustainability, formulating a transformative vision and solutions for systematically moving towards their vision (Holmberg and Robert, 2000). The organization The Natural Step in collaboration with academic partners has developed a framework and a method for using backcasting in organizations of various sizes and branches using the “Framework for Strategic Sustainable Development” (Broman & Robert, 2017). The process is divided into four steps and starts by defining a future normative and desired vision. This vision is formulated with the help of guiding system principles setting a boundary for the envisioned outcome. In the second stage, the baseline in the company or organization is analysed in comparison to system principles or criteria. In the third stage, the design of an operational solution, acting as stepping stones that are needed to reach the outcome, must be conceived, and here backcasting is done from the future state to the present. In the fourth stage, an action plan is produced that prioritises alternatives that can help the organization reach a sustainable future and have a high degree of flexibility.

Another approach to explore and facilitate transformational change in organizations is the use of the Soft System Methodology (SSM). SSM structures learning around problematic real-life situations in the flux of everyday life where people are involved, inevitably having different “world views” that are not fixed over time in which people deliberately are trying to take “thought-about purposeful action” (Checkland, 2010). SSM provide a structure for observing and organizing a “debate” about how these problematic situations could be improved, aimed at finding actionable solutions that for those involved are both desirable and feasible regarding their current culture, history, and political situation (Checkland, 2006). Such solutions could regard structural changes, process changes, attitudes, etc. (Watson, 2012).

The initial development of SSM was a response from Peter Checkland based on his practical experiences using a system engineering approach in tackling organizational problems based on the idea of analysing, designing, and implementing organizational systems in the same way as developing technical systems. According to Checkland, such a “hard system approach” was the common way of handling organizational problems in the 1960s (Checkland, 2011); he started to question this approach by appealing to the idea of a “true” system (as in



systems engineering), one that actually exists in the real world. Instead, Checkland started to consider that the idea of a system being present in the researcher's head could represent something real in the world and that this idea of a system could be used to mediate exploration in a learning process (Checkland 2000).

In practical use, SSM is described as a methodology (“a principle of a method”) rather than a method (a set of steps), indicating a general approach that should be open to new learning and give room for other methods under the SSM umbrella. Scholars have been using SSM for different purposes as a framework of ideas, a brainstorming tool, or as a guiding process (Železnik, et al., 2017, van de Water et al., 2007). The original SSM process has changed over the years; since the 1990s, SSM has consisted four main stages in an iterative process described as soft system methodology in action (SSMA) (Checkland, 2006):

1. Finding out about a problem situation, including social and political aspects;
2. Formulating relevant purposeful conceptual activity models;
3. Debating the situation, using the models, to identify feasible and desirable changes; and
4. Taking action to bring about improvement.

Checkland himself argues that an exact following of these steps in a chronological order is not necessary (Checkland, 2000; 2010) and should not be seen as a prescriptive model or recipe. Rather he argues that the use of SSMA should foremost be situation oriented rather than methodology-oriented, always being open to new learning (Checkland, 2010) based on the participant's ideas of solutions that could result in changing the “real world problem situation” initially being addressed.

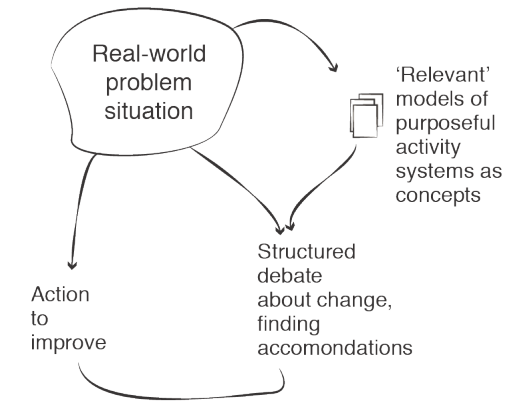


Figure 2. The Soft System Methodology in Action (SSMA) learning cycle via four steps. Illustration adapted from Checkland (2000; 2010).

### 3.4 Theories regarding design logic

Over 100 years, the concept of design has slowly transformed from an activity most related to decoration of mass-produced artefacts by shape, colour, surface finishes, and decoration of objects. In a manufacturing company running an LBM model, fashion, technology, functionality, economic, and social aspects are used to create attractive product offerings and are used as tools to sell more products by creating expectations from customers that manufacturers continuously introduce new styles. At a minimum, this approach is expected by the manufacturers as a continuous renewal of their products usually is seen as the strategy for being noticed by customers and staying relevant in the market.

According to Guiltinan, (2009 p.20), there are two significant problems in product design that result in product obsolescence. First, the continuous introduction of new products gives customers incentives to replace still functioning products. Second, the possibilities of restoring or recycling an obsolete product depend on the attributes being designed into products from the start. These two aspects further influence the customer's replacement behaviour, leading to a specific disposal behaviour – i.e., when a product is finally discarded.

This product model change strategy has been successfully implemented in many domains with a “design logic” based on continuous facelifts. In many of today's fast moving consumer product markets such as electronics or fast fashion, product-designs often are pristine, fragile, and inviolable (Cooper, 2004), resulting in functional and aesthetical obsolescence or breakdowns with few possibilities for successful product recovery. According to Slade,

(2006), design and marketing have come to play a central role as the engine of continuous product innovation and a tool for planned obsolescence.

Nevertheless, over the years the role of design has slowly started to change from design merely as a powerful tool for boosting sales in difficult business climates to modern notions of design emphasizing “the multi-faceted qualities of objects, processes, services and their systems in whole life cycles, (Joore, 2010 p.3). These evolved views of design have challenged design as only being an obedient servant for DBL, as illustrated in Paper I, and have emerged to being considered as a strategic tool (Brown & Martin, 2015). Alternatively, design has evolved to being seen as a tool for servitization (Vandermerwe et al., 1989), with service design (Costa et al., 2018) driven by an increased urge from manufacturing companies to transform themselves from pure manufacturing to becoming more service-based (Godlevskaja et al., 2011).

This broadening of the design concept has its roots in the 1960s (Brown & Martin, 2015), but started to emerge more clearly in the 1990s with Buchanan (1992), among others, who wanted to see design as a process within liberal arts. In this discourse of a broader design concept, Herbert Simon, with his often referred to “The Sciences of the artificial”, first published 1969, was a point of departure. Simon put forward that “Engineers are not the only professional designers, as everyone designs who devises courses of action aimed at changing existing situations into preferred ones” (Simon, 1996, p.111). However, Simon did not aim specifically to define the more artistic based design as his discussion of the design concept was from an engineering design perspective, highlighting and discussing the differences between natural sciences and artificial sciences (i.e., those sciences where people are active agents such as in design, management, and law).

However, this broader view of design further paved a path for the development of the concept Design Thinking in 2000s (Brown, 2008; Martin, 2010; Liedtka, 2014), offering managers a human-centred approach to innovation, business strategies, and organizational change, inspired by the way designers think and work when solving “wicked” problems (Buchanan, 1992, Brown, 2008). In this thesis, a further focus will be on design as a problem-solving process, as a plan or “recipe” for accomplish goals (Hashemian, 2005 p.18). In line with how Kroes (2002) describes design methodology as normative in developing both the design process and the outcome of this process in form of physical artefacts.

### 3.4.1 Design approaches to extended product life and minimizing risks of products becoming obsolete

In the first decades of the 1900s, product design (or styling) became a powerful tool for boosting sales such as by annual model changes in the automotive industry. This strategy was first used by General Motors (GM) during the 1920s, encouraging car owners to trade in cars before their useful lives were over. Using this strategy, GM distinguished themselves from their competitors and took an increasing market share over the years (Slade, 2006).

In the theoretical vision of a CE (Cullen, 2017), GM logic is turned on its head as it suggests ways to slow down resource flows (Bocken et al., 2016) by extending product life and designing for repair, maintenance, upgrade, reuse, and remanufacturing (Linton & Jayaraman, 2005), or recontextualization (den Hollander, 2018). This is using an existing product or its component in a new role. Material recycling, on the other hand, where much of the embedded product values and energy disappear (Cullen, 2017), should according to CE principles only be used as a final solution when all useful product life is exhausted. However, today the main activities in the manufacturing industry that relate to CE are geared towards material recycling and eco-efficiency and not product life extension (Ghosh et al., 2017; Cullen, 2017). Moreover, according to Bakker et al. (2014), this is also the case from a research perspective.

### 3.4.2 Design for X

Design for X (DFX) is an umbrella term that covers many design philosophies and practices (Gatenby & Foo, 1990) as well as methodologies with the aim to help raise designers’ awareness of the characteristics that are most important in the finished product such as quality, modularization, assembly, disassembly, manufacturability, reliability, and environment. Hashemian (2004 p.4) describes DFX as a design paradigm with a theoretical framework for design activities, including rules, guidelines, specific procedures, and software tools.

The DFX umbrella provides practical guidelines and checklists for designing products that achieve desired characteristics over the whole product lifecycle (Malinowski & Nowak, 2007). Mayyas et al. (2012 p.1848) and Ijomah (2007) identify such guidelines for designing for sustainability established by Jawahir et al. (2007). These guidelines use the DFX umbrella to develop a set of methods that can be used to analyse and redesign a product for better sustainability over a product’s life cycle. This

framework comprises many DFX strategies for designing products that have extended life spans and minimize risks of products becoming obsolete through, for example, designing for functionality, modularity, maintainability, upgradability, reliability, manufacturability, re-manufacturability, durability, and improved service life. Furthermore, Rossi et al. (2016 p.368) make an overview of various benefits and weaknesses of some of the DFX approaches compared to other designs for sustainability tools.

### 3.4.3 Adaptable design

The field of adaptable design has its main base in the engineering field and is described as a DFX paradigm by Hashemian, (2005 p.4). Its main focus is on strategies for designing alternative product architectures and has a significant role for the sustainable design process, which affects the overall life cycle stages of a product (Bonvoisin et al., 2016). Adaptable design is closely related to modularization as a primary enabler for physically allowing (modular) components to be assembled, disassembled, repaired, remanufactured, upgraded, and finally recycled.

Uckun et al. (2014) emphasize that adaptable products should be able to respond to changing requirements over a long lifetime, taking into account possible future changes when developing products. According to Li et al. (2008), there are three main criteria for adaptable products. First, an adaptable product must have the possibility to extend its functions, either obtained within the existing parts or due to the replacement of parts and components. Second, new technologies and improved performance should be integrated via upgrades. Third, components should have to be customizable to meet the needs and requirements of individual customers. In addition to modularity and changeability, Uckun et al. (2014) argue that adaptability also includes reliability and robustness. However, there is an important difference between a durable and an adaptable product. Even if a durable product can be used for a long time, it may not result in eco-sustainability benefits for all products if new technologies and functionalities with better environmental performance cannot be integrated over the products' life cycle. This is especially relevant for energy-using products such as vehicles (Bakker et al., 2014; Mayyas et al., 2012 p.1849). However, for other non-energy using product categories such as furniture, durability is an important enabler for long and extended product use (den Hollander, 2017).

According to Gu et al. (2004), adaptable products could be divided into two categories, a specific and a general one. A specific adaptable product is defined as "the ability of a product or its design to be adapted for potential applications that can be foreseen at the time the product is initially designed" (Gu et al., 2004 p.7). An example of specific adaptability is a

laptop with the possibility to upgrade with more RAM or with a larger HDD. The definition of a general, adaptable product is more vaguely defined but could be described as a product designed with a potential to adapt to future unknown needs and requirements. For example, an aircraft can be designed with empty areas that could be used for future unknown upgrades (Engel et al., 2017 p.876). Designing for general adaptability will require a much more holistic approach than for specific adaptivity and will also add more complexity to the design process regarding balancing between present and possible needs. However, as Engel et al. (2017) point out, adaptivity can give future benefits if it enables upgrades on an existing product. Gu et al. (2004 p.6) propose that reuse of benefits in the form of adaptable products can reduce costs in manufacturing and post-sale services and improve environmental benefits and usability, all qualities that can be used in marketing products as environmentally friendly.

However, even if, as Hashemian (2005) argues, modularization will be the prime method to increase product adaptability, it may not necessarily have adaptability as the main purpose over the product's whole life cycle. Baldwin and Clark (2000) divide modularity into three types: 1) Design modularity, 2) Production modularity, and 3) Use modularity. These three types of modularity have different goals such as making production more efficient by reusing previous designs or designing modular components for efficient production purposes as well as modularity for ease of repair and disassembly for the end of life of the product.

Also, another enabler for adaptable products is "piggybacking": when an existing product gets new functionality by an add-on module that provides a specific functionality and has been proposed as a strategy suitable for prolonged use of obsolete electronic equipment (Rai and Terpenney, 2008). By using piggyback modules, components with fast innovation cycles can be replaced with modules with more advanced technology while slow technological advancing components remain part of the product. A practical example of such piggybacking is the start-up I-Blades<sup>11</sup>, which has developed add-on modules for smartphones in the form of "smart cases", providing extra memory and battery capacity to existing smartphone models.

Even if adaptable design has a heritage from the design-engineering field with a strong emphasis on modularization, there is no general contradiction in using an adaptable design approach in more artistic based design. However, the artistic design tradition in the automotive industry mostly is represented by "styling" of products with a preferable emphasis on aesthetic manipulation of surfaces, colour, material, and textures, (Boradkar, 2010) rather than designing products that can adapt to future needs. Furthermore, based on the current business logic for achieving market differentiation and increased profits in the automotive industry, this could be considered a gap

in the theoretical potential for product adaptivity, and how it to some extent is applied today to strategies for relentless product change (Guiltinan, 2009). This issue will be discussed further in Chapter 6.1.

### **3.5 Products and service systems, a mediator between business, design, and eco- sustainability logics**

In discourses about how BMs can facilitate a more resource efficient society, selling services is often proposed as a critical business strategy for dematerialization by reducing requirement for materials where, for example, physical products can be replaced with digital services (Tukker, 2013; Mendoza et al., 2017). In the literature on BMI, the case of Xerox is often used as an illustration of how a BM can act as an enabler for innovation, imposing a different focus in capturing value from selling services with a combination of products and services (PSS) (Chesbrough and Rosenbloom, 2002). In PSS, a combination of tangible physical products are combined with intangible services, forming a customer offering that jointly fulfils the needs of customers by offering the utility of a product as a service, giving the customer or user access to a specific function(s) or performance (Tukker, 2004). The ownership of such a PSS is retained by the producer or service provider. According to Tukker (2013), since the 1990s PSS has been proposed as a promising route for transforming society towards a “resource revolution” driven by a logic where owners of products in a PSS, i.e., the service provider, will have high incentives to use a logic of intentionally prolonging the useful product life by keeping products at their highest utility over time and thus reduce resource and energy consumption from materials in production and during product use (Tukker, 2013). Scholars such as Manzini and Vezzoli (2003) propose that a PSS-based business model can alter the business and design focus towards resource optimization by capturing economic and material values via reuse and remanufacturing as well as being able to differentiate themselves from competitors (Chowdhury et al., 2018).

Moreover, PSS is considered a key enabler for implementing a CBM to achieve a circular economy (Bocken et al., 2016; Tukker, 2015; Bakker et al., 2014; Linder & Willander, 2015). Williams (2006 p.176) exemplifies this PSS logic: “If the lifetime of a product is extended, more potential profit is available via the increased sale of ‘functional units’”.<sup>12</sup>

The PSS field can further be considered as an attempt to bridge business and design logic and could establish closed-loop manufacturing systems capable of closing material flows “by intention rather than by chance”

(Lieder et al., 2017 p.1953) through the design and implementation of “post-use” strategies for reuse, remanufacturing, and recycling. Such logic has been implemented in the design logic at Xerox, with focus on increasing utility of products by designing components for multiple lifecycles and for remanufacturing and reducing the need for consumables (Gray & Charter, 2007).

The development of PSS research field and of the adaptive design field has to most extent been two separate fields, although they overlap regarding aspects such as modularization and upgradability. However, Wang et al. (2011) have explored the combination of modularity and PSS, arguing that modularity can provide customized products over several use cycles thereby providing services during the whole lifecycle of the product and resulting in environmental benefits. Romero and Rossi (2017) and Bakker et al. (2014) have started to bridge the PSS field with adaptable design and CE. Moreover, the concept of “smart” PSS, with implementation of digital technologies introduced by Chowdhury et al. (2018), highlights the potential of extended value creation and customer services using predictive maintenance enabled by Internet of Things that can monitor product health (Ellen MacArthur Foundation, 2016).

<sup>11</sup> Accessed, 7th of December, 2018, <https://i-blades.com/>

<sup>12</sup> For an overview over some PSS based business strategies and relations to CE, see British Standard examples (BS 8001:2017 p.49).

# 4

## Summary of appended papers

## 4.1 Introduction to the summary of papers

This licentiate thesis is based on one journal article (Paper I) and one conference paper (Paper II).

Paper I is submitted to a scientific journal, and Paper II was double-blind peer-reviewed and published in the conference proceedings. In Paper I, the author designed the study, collected material, and wrote the paper with methodological help from the two supervisors, Williander and Svengren Holm. In Paper II, the author together with van Loon designed the study and collected and analysed data. The author wrote the paper with language support from Svengren Holm.

## 4.2 Paper I: Aiming for circularity by product life extension, a radical activity requiring top managers to become business model designers

### 4.2.1 Purpose and aim

Paper I provides an overall theoretical orientation about what aspects might affect manufacturing companies that use CE to be a profitable eco-sustainable embracing three strategies for CE: closing, narrowing, and slowing down resource flows. The approach is also to refine the discourse about CE as mainly being a trillion dollar business opportunity (as often being expressed by its advocates) by problematizing how interactions between the business and design logic in the manufacturing industry are related where the business logic often is the dominant one, relegating design as a solution provider to the existing business model.

### 4.2.2 Method

Paper I is a conceptual paper based on theory from the business model literature regarding various dimensions of Business Model changes as being either incremental, radical, versus modular, or architectural (Table 1). A comparison example regarding business and design logic between two consumer products (Table 2) illustrates that the business logic is dominant whatever linear or circular business model there is in the firm. This comparison is based on the argument that economic survival is prioritized by top management with the dominant business logic acting as an information filter for decision making. The role of design is further argued to be relegated as being a solution provider to the existing business model based on its historical role of being in harmony with the existing business logic, for example, boosting sales by continuously introducing new aesthetics and user experiences in products being designed.

Furthermore, using the master and slave relationship between the business and design logic, Paper I explores various possible barriers for a manufacturing firm running a linear Business Model aimed at implementing a CBM based on all CE strategies for closing, narrowing, and slowing down resource flows. In Table 3, these three CE strategies are problematized from the perspective of needed business model changes, business challenges, and the potential of eco-sustainability.

### 4.2.3 Results

Findings are that strategies for closing and narrowing resource flows by enabling products for material recycling or producing them more eco-efficiently will pose fewer challenges compared to approaching strategies for slowing down resource flows by product life extension. The reason for this argument is that the product life extension strategy will challenge the existing BM by requiring both architectural and radical BM changes. This requires a deep engagement by top management due to increased business risks such as cannibalizing existing sales, increasing costs for making products more durable and modular therefore more suitable for remanufacturing.

However, if a firm implements all three strategies for closing, narrowing, and slowing down resource flows in a CBM, the eco-sustainability potential would be much higher than if only approaching the closing and narrowing flows strategies.

Paper I also argues that the main barriers for implementing CE strategies that pose architectural and radical challenges to the existing BM in an incumbent OEMs are mainly related to managerial capabilities in getting the top management onboard as BM designers, not primarily about capabilities for circular product design.

This assumption challenges the often used argument in the design for environment field that designers have the most crucial role in the realization of eco-sustainable products. A role that designers, in theory, have but only as long as their design proposals do not challenge the firm's existing DBL.

## **4.3 Paper II, FUTURE-ADAPTABILITY FOR ENERGY AND RESOURCE EFFICIENT VEHICLES**

### **4.3.1 Purpose and aim**

Paper II illustrates business risks related to products becoming obsolete as the result of various drivers in the automotive industry. These industry drivers can make three categories of vehicles obsolete in a CBM.

### **4.3.2 Method**

Paper II assumes that product-related business risks are much higher in a CBM than in an LBM because of the increased responsibility a manufacturer or a service provider takes in a CBM over a products life cycle. That is, products traditionally sold to customers in a CBM with ownership maintained by the consumer will risk becoming prematurely obsolete. Thus, products suitable for a CBM will need to be designed with a logic emphasizing flexibility, durability, manufacturability, and adaptability. Based on the theories about planned obsolescence, design for adaptability, and CBM design combined with an empirical case study of firms in the automotive industry, Paper II problematizes current product design and proposes an extended theory for designing products suitable for a CBM.

### **4.3.3 Results**

Paper II illustrates various risks of vehicles becoming obsolete by aesthetical, functional, technical, and economic drivers over time, with B2C products being mostly affected by fast fashion and social changes. Compared to B2B products, B2C products risk becoming obsolete mainly due to wear and new functionality and technologies introduced by the manufacturers. Furthermore, theories of adaptable design are discussed in relation to existing logic in the automotive industry today. Main findings are that there are many islands of knowledge and applicable examples that can enable product adaptability already implemented in the industry (Table 2). However, these knowledge areas are isolated and used to support the existing linear business logic. For example, even if modularity, being the primary enabler for product adaptability, is well implemented in the automotive industry today, modularity has the main role of an enabler for cost-efficient production.

Paper II also proposes a conceptual framework where drivers for obsolescence are turned into enablers for future adaptable design, a condition exemplified with industry cases. Paper II finally argues that future adaptable vehicles have the potential to be both profitable and energy and resource efficient during use and in end of life in a CBM. However, this will challenge today's business models as the design logic rewards longer and more flexible product life. Current barriers are legislation, standards and certification, consumer acceptance, organizational barriers, and a general reluctance to changes.

# 5

**Findings  
from the  
empirical  
field studies**



This section presents the four empirical field studies with the aim to get an understanding of the dominant business and design logic in the automotive industry regarding overall barriers and possibilities for circular business and design strategies for manufacturing firms embracing all three strategies for circularity: closing, narrowing, and slowing down resource flows. These studies focus on one incumbent OEM of passenger cars (A1) and is followed by an overall view of the incumbent automotive industry in general (A2). Furthermore, the picture of the incumbent OEMs is compared with emerging automotive start-ups (A3) and followed by actors representing a CBM (B).

## 5.1 Empirical field study A1: Barriers and possibilities for circular business and design in an OEMs of cars

In this field study, an incumbent global OEM of cars in Sweden was studied using on-site interviews with twelve representatives from OEM's business and design organization together with three internal workshops conducted separately from interviews. These workshops aimed at exploring possibilities for an improved circular business and design logic and included a group of participants representing functions for business development, design management, product development, innovation, and environmental affairs in the OEM

For almost 90 years, the studied OEM has been designing and producing durable cars for the premium segment, claiming to be in the forefront of safety and with environmental concerns. Some of the OEM's car models have become iconic for their outstanding load capacity, reliability, and longevity, with good access to spare parts, serviceability, and well-spread knowledge on how to keep the cars running for a very long time.

Respondents describe the company as profoundly affected by global trends such as digitalization and stricter environmental legislation and target customers who have started to consider other things being more important than owning a car. Also, the trends of increased demand for connectivity, electrification, and autonomous driving technologies are described as a driver for adding significant cost for future models being developed.

The OEM has experience with mobility services via its carpool subsidiary that since the end of the 1990s has used the OEM's products for its

car pool business. The OEM is also involved in different collaborations with mobility providers such as exploring possibilities with self-driving vehicles for mobility services with UBER. Regarding servitization, the respondents describe how the OEM in recent years launched a service where private customers can get deliveries of different goods such as groceries placed in their parked cars. Also, during 2018 a new service was launched offering customers access to a personal car via a subscription service with the ability to swap to other models on short notice or when the customer's needs change.

### 5.1.1 The current business logic

The current business logic is described as aimed towards the production of cars to be sold in large volumes through the OEM's dealer network in a transaction-based business model with the future economic risks of the cars sold transferred to the owner after purchase. Discussions of changing the business model in initial phases of new product development are not frequent, and the existing BM is taken for granted. If a new BM is to be considered, the CEO will have to make the decision to do so. The development of service offerings such as access to a carpool, delivery services, or a personal car by a subscription model is described as still being based on the same purchase based business logic and such approaches do not affect the design logic of the vehicles:

*"We are still in the linear paradigm, and we want the customer to buy a new car for a lot of money; that's our business model" (Program leader 2018).*

An essential part in the described business logic is to obtain economy of scale by producing volumes planned for in the development phase if a new product is to have a chance to remain in the OEM's product portfolio.

A central part in getting such economy of scale is using already established production facilities and networks of subcontractors in the value chain as well as by sharing vehicle platforms and components between many vehicle models that can be offered at different price segments. A problematic aspect of NPD is that all new projects must bear their own cost for added technologies. This issues together with an overall drive to remove solutions that do not lead to revenues in selling the products developed create internal barriers when new and often more expensive technologies are introduced, making the innovative products or solutions more expensive. This is described as being a barrier in the development of electric vehicles (EVs) since batteries as well as autonomous driving (AD) technologies are expensive:

*“Project managers are measured to deliver within the cost frames, and everything that does not guarantee to create revenues is removed” (Project Manager, 2018).*

## 5.1.2 The current design logic

Design and safety are described as the most important drivers for developing new models with the design department having a significant say in the decision to produce new car models. The start of developing a new model is described as starting with a business brief from the client; this brief initiates a new car project, specifying general attributes desired for the planned model. These attributes are set up based on car shows and contact with customers during “customer clinics”, where they are shown early representations of a new model, and the OEM’s overall lifecycle plan that sets the pace for new models being developed. The initial business brief also defines intended basic features such as which platform the new model will be based on and an intended target price based on the price of competitors’ products. This brief is further developed into a set of attributes desired for a new model, such as safety, aesthetics, driving performance, comfort, perceived quality, and durability that can be used to compare with competitors’ models in the same price segment. This list of desired attributes is not static and can change depending on new technologies, functionality, and customer behaviour. Further steps in business development are to develop an order base for a complete car to the developing organization, i.e., a more detailed list of specifications. Based on this order base from the business side, a project leader is appointed to lead a project team from the design and product development organization, starting the realization of the new model. The project team is responsible for the budget and product realization but has to negotiate with the top management regarding costs and performance issues as well as between the different attribute areas:

*“All attribute leaders want to design the best possible vehicle, but we have neither the time nor the money to do that and then the negotiations to find compromises between the desired attributes starts” (Project Manager, 2018).*

Continuously designing new vehicle models is described as an essential way of keeping up with competitors and not losing customers’ interest in the brand and the products. A Scandinavian and human-centric design language is described as important enablers for achieving the intended expressions of the various car models:

*“It is design and safety that sell our cars” (Project Manager, 2018);*

*“Things change, that is what makes life interesting” (Business Developer, 2017);*

*“We live on making continuous model changes and people get bored too fast” (Design Manager, 2017).*

## 5.1.3 Main described barriers for adaptability and circularity

The workshop interviews revealed a focus on the developing organization as making cars ready to be launched on the market. How the cars perform used is not as important. However, the notion that most of the revenues come from the aftermarket activities with regular car services, repairs, accessories, and spare parts is repeatedly mentioned.

The current business models are often mentioned as being based on sales of produced vehicles as fast as possible, with leasing contracts as an essential enabler for externalizing economic risks from the OEMs. In a CBM, with kept ownership of the produced products, the increased need for financing functional sales are described as an increased risk of the OEM becoming a “bank”. This is illustrated by a discussion between a manager proposing the idea of a CBM with kept ownership and a manager responsible for business development:

*“But for God’s sake! Today, we try to get rid of our produced cars and get revenue as fast as possible, to get rid of the business risk of owning assets for billions” (Business Developer, 2017)*

As in other manufacturing industries, the large volumes of components being sourced by the OEM result in lower component prices. In a CBM with the basic CE strategies to close, to narrow, and to slow down resource flows, the primary production volume of products will decrease, decreasing the number of new components being sourced from their subcontractors, which is described as a possible risk of increased component prices.

Design is described as being a significant driver in the organization as customers continuously expect new functionality and aesthetics. At the same time, degrees of freedom for the aesthetic is in many parts of the car very restricted. Exterior design is especially dependent on the basic structures of the unibody, e.g., the main pillars are integrating parts in the car’s architecture and provide a structure for crash safety. Thus, the idea to keep a platform for a longer time than what is common today by making it adaptable with new exterior components, was regarded as very complicated

from a crash safety perspective. This possible barrier also raises ethical issues regarding how to handle safety issues if, e.g., crash safety has been improved since an adaptable car first was released although updating these safety features is potentially difficult to meet. Furthermore, the possible customer acceptance for circular value propositions was discussed during the three internal workshops with much uncertainties expressed about how customers would react to use cars that have been refurbished with many components hypothetically being remanufactured as well as hygienic aspects in a refurbished car interior. Today, it is described to be a very different customer acceptance for new versus remanufactured components between different markets, e.g., between the US and Chinese markets. In the Chinese market, attitudes toward remanufactured components are described as being very hesitant due to risks of poor quality and thus could be a hindrance for such circular offerings. In the US market, on the other hand, remanufactured products are described as being more broadly accepted. Emission legislation also prevents upgrades of existing ICEs that often cannot be adapted to meet demands of a new law or customer expectations:

*“Even if I would like to use one of our classic car models from the 1970s from an aesthetical point of view, I am not that sure that I would like it with the same technical content as in 1970!” (Product Developer, 2016).*

Several of activities related to CE principles have for many years been implemented in the OEM such as material recycling, energy, and material efficiency as well as remanufacturing. Here, eco-efficiency is described as being a significant driver for reducing emissions and fuel consumption to meet legislation by reducing weight as a prioritized activity. Most of these activities, however, are described as being isolated in the whole business and design logic without systematically being connected when doing NPD. For example, although remanufacturing of components has been done since the 1940s for many components considered to be both profitable and technically feasible, there are difficulties to gaining acceptance for systematically designing for remanufacturing if such design risks increasing weight and cost. Possible future profits from remanufacturing are often overridden by actual cost for the specific component or the overall vehicle:

*“It is hard to argue for future fictional revenues from remanufacturing, if a component breaks down, compared with the actual costs for producing a component today” (Aftermarket Manager, 2017).*

Keeping up with digitalization is described as an increasing challenge and systems that are exposed to fast technology development such as infotainment systems face the risk to become technical and functionally obsolete soon after launch due to the longer development times for vehicles than for other consumer electronics. However, possibilities of software upgrades in the aftermarket have started to gain momentum but is often done while the car is in the workshop for a yearly inspection and often with minimal possibilities to upgrade the car’s main functionalities due to many electronic subsystems being locked and not possible to upgrade with new software. To allocate space in the cars for possible future upgrades with new hardware is described as being very difficult to predict and plan for in advance as well as adding cost for possible future revenues:

*“There is a battle about every millimetre in the design of a new car model, arguing for allocating extra space for future hypothetical upgrades will be very challenging. However, Tesla is just doing that” (Concept Developer, 2018).*

Regarding the end of life treatment of cars, OEMs are due to the end of life (ELV ) directive to take responsibility of the vehicles’ end of life destiny. In Europe, the ELV directive will require 93% of a car to be recycled. In practice, this means that the metals, being the main material category in cars, are re-melted and circulated into new metal components, while still functioning components are reused as scrapped spare parts. However, the remaining materials, such as plastic and textile components, being too costly to dismantle, are usually incinerated. The recyclability of plastic components was described as being of increased interest by the top management in the OEM in relation to the extensive public debate regarding plastic waste in the oceans.

#### **5.1.4 Main described possibilities for adaptability and circularity**

During interviews and workshops, respondents and participants describe that there could be interest from the OEM to consider a CBM and to embrace CE strategies with adaptable products due to increased economic pressure to keep up with emerging technology trends as electrification, autonomous driving technologies, as well as increased demand for connectivity. These new technologies create a high pressure on the development organization to be many years ahead in choosing the relevant technologies and functionality to add in new cars. This rapid technology development also increases the need for onboard calculations in the vehicles, resulting in ever more embedded computer boxes and longer software code. In a scenario with an adaptable car that would be

used much longer than today, respondents saw a technical possibility that integrated hardware could be made “dumber” with most of the calculations done outside the vehicle by cloud computing and wireless communication. Nevertheless, electrification, connectivity, and AD technologies are described as being especially enabling technologies for scenarios of vehicles designed for hailing services. Reasons for this are that such vehicles have much more intense driving patterns over all hours of the day compared traditional ICE cars. Moreover, with almost no need for service, a well proven and durable technology with no need for manual drivers, these cars could be used at their highest utility and deliver the utmost value over the products use cycles.

During the interviews and workshops, emerging actors providing transportation as a service are described as affecting the OEMs way of considering the customer’s future needs and wishes. For example, users of a carpool or Uber hailing services are described as being less interested in values that the automotive industry traditionally has prioritized, such as exterior styling and driving performance, or the role of the car as a social marker. Instead, customer experiences in the car interior will be much more critical as this will represent most of the customer’s touchpoints with the OEMs products. Actors such as Apple and Tesla are often mentioned as examples where the traditional business and design logic has been put on its head as these companies anticipate what consumer’s will like rather than asking them what they want. This approach has become standard way in NPD in the automotive industry today:

*“When you create your future, you get another drive to come up with innovative solutions” (Product Designer, 2016).*

There is also a trend that one of the most expensive parts of new cars, the platform, in the future risks being redesigned more often than before due to fast changing fashion and technologies trying keep up with customer interest. Such redesign of platforms is a significant undertaking for the OEM with massive development costs and brings a wave of change for components and subsystems that need to be redesigned, often leading to a totally new platform design. Thus, sticking to the same platform for longer is described to be very interesting from a business perspective.

In summary, respondents describe many challenges in approaching a possible CBM, but they also describe that there already exists many examples of well-implemented CE activities such as material recycling and eco-efficiency, sales of used cars, repairs, and remanufacturing. However, these activities are described as fragmented and to a large extent being disconnected from the development organization, having a primary focus

on putting new vehicle models on the market. However, the general view presented during interviews and workshops is that it is not the developing organization that represents the main barriers. Rather, this fine-tuned machinery, with the desired criteria, pours products “upstream” during the development process, which after a couple of years delivers the intended outcome, downstream. That is, the main barrier for a CBM is the existing BM.

## **5.2 Empirical field study A2: The dominant business and design logic in the automotive industry in general**

Based on interviews with experienced designers, engineers, industry experts, and a commercial customer, some general themes that help to establish an overall picture of the incumbent automotive industry have emerged. One theme is that of the business logic of an economy of scale that for a long time has been described as the dominate driver for incumbent automotive OEMs. The design logic is described as supporting this DBL with styling and technical solutions that balance estimated sales prices for the products against the development cost and an optimization for mass production and meeting legislation standards:

*“Due to crash safety legislation, many components in the vehicle are welded and not easily removable. For example, I wanted to repaint my Mini in the same colour for all components, but the workshop couldn’t remove several of the exterior panels as they are welded to the body. That’s how it is today if something fails, then everything is replaced due to the many components being integrated and it is not possible to open up and repair as in the old days.” (Design Manager, 2018)*

Another theme is the balance between product cost and durability, and a common view among the respondents regarding expected life length (lifecycle) of produced cars is that they are designed to last for approximately between 200.000- 300.000 kilometres of driving. In Europe, this is reached after about ten years, based on the assumption that a private car is driven about 20.000 kilometres/year. The expected life length is based on specifications for component testing where main components fulfil required life lengths. However, this testing is mostly done on individual components and with many uncertainties what actually happens in real driving conditions and setting specifications for the durability of components are also described as being affected by the business logic for capturing value from the aftermarket, the most profitable part of the lifecycle:

*“There is an enormous aftermarket and these actors must live as well, and there is a complicated business situation. For example, we want the customer to visit the workshop once a year, even though it is not required from a technical point of view. But if cars don’t need a yearly service, what shall we then live on? “ (Attribute Leader, 2017)*

A further theme is the heavy investments in production tooling for metal forming, described as one of the major costs in car production, where the material value of a produced car body mainly produced in various grades of steel is only some percentage of the total cost compared to vehicles and other components such as the drivetrain. This has been described as a barrier for refurbishing and remanufacturing of complete vehicles due to overall component wear, corrosion, exterior wear, and minor exterior damages, all costly to restore in pristine and faultless body surfaces:

*“There is a huge initial investment cost for the platform for the first model of a car but then you start to reuse platforms and components. Look at, e.g. Volkswagen; they have the same platforms for VW, Audi, Skoda, and Seat, and they have long-range plans for four to eight years. They would not erase and trash all their existing investments they have calculated to get return on their investments from. These big OEMs are like oil tankers, taking forever to turn around.” (Design Manager, 2018)*

*“The material and production cost of a traditional “top hat” of a car is only some percentage of the overall costs of the whole vehicle, and as the design primarily is for cost-efficient production, there are few economic incentives to do exterior facelifts on an already produced car on the aftermarket. That is, it takes a lot more time to disassemble a produced car than to assemble new vehicle in production. It is better to just scrap it and material recycle than to try to do upgrades.” (Attribute Leader, 2017)*

The design logic is described to be dominated by the drive to create distinguishing designs catching the intended customers interest by supporting their tangible and intangible needs for transportation as well as the customer’s self-image, providing the desired story of the customer being associated with a particular car brand:

*“Cars are the caveman jewellery; you are what you drive!” (Automotive Journalist, 2018)*

A former design manager in a large vehicle OEM explained his view about why it is necessary to continuously change aesthetics:

*“A manufacturing company continuously must have something interesting to tell its customers. Just as if you and I meet every day, and what I say starts in the same way, and it’s the same things you say, same food you eat, and the same clothes you wear. In the end, you will start to avoid me. Not because you are unpleasant, but because I’ve become uninteresting for you! You simply know what to expect in the meeting; it’s becoming mentally poor, and this is why companies renew their products! “ (Former Design Manager)*

However, this dominant business and design logic has a coherent view among the respondents: the emerging technology and customer trends such as electrification, connectivity, and autonomous driving technologies will change the industry fundamentally in the coming years, especially if these technologies are applied to transportation services such as Uber. If large transportation providers take increasingly large market shares using autonomous vehicles, these large customers will challenge the existing logic of designing, producing, and owning vehicles, products that require continuous service and expensive consumables. Thus, it will become more desirable to buy vehicles with low lifecycle costs rather than enticing exterior design and other attributes:

*“If I would start an automotive company today, I would design a platform open for various coach builders to make their pods for solving various customer needs of mobility by services [e.g., Uber]. If I as a customer would use such a mobility service, I would foremost be interested in the interior, having the right experience with entertainment, a private silent sphere, etc. and to charge my pads and phones of course. Then the car would become more like an airline company or a bus, and I would definitely be less interested in knowing that leather seats required fifteen bull hides to make or having endless choices of colour and trims alternatives as common today.” (Design Manager, 2018)*

*“Currently, there are more than 200 hundred start-ups globally, developing vehicles based on electrical drive train technologies searching for one billion dollars to start production. These start-ups have a small window of opportunity open, before the incumbent OEMs in a couple of years have turned around and launched EVs at a mass scale.” (Design Manager, 2018)*

A self-employed taxi driver has an interesting view on the coming challenges for the incumbent OEMs sticking with ICE. For a couple of years, the taxi driver had switched from an ICE car to a BEV as he wanted to be ahead of compliance as tougher emission standards will soon be implemented at airports in Sweden. However, having many years of experience driving ICE vehicles, driving about 150.000 Km a year, he described many other benefits when comparing his current Tesla Model S Taxi with ICE taxis he had previously owned:

*“After two years and driving 300.000 Km, this car almost feels like brand new from the factory. There is only small visual wear on the leather seats and some minor exterior cracks on the rear lights. The battery capacity has only decreased a few percent, and there is no need for doing service each quarter as for conventional ICE cars. In a conventional ICE car driven 300.000Km a lot of expensive components in the engine, the exhausts system, and the gearbox usually would have failed by that distance. Also, the business case is extremely good, because of the low cost for electricity and maintenance, even though the purchase price is more than double compared to a conventional ICE taxi.” (Self-employed Taxi Driver, 2017)*

A common opinion among the respondents was that Tesla is the actor that so far has been most successful in challenging the traditional logic of the automotive industry even though Tesla has yet to be profitable:

*“What Elon [Tesla] did was to pull down the pants on the whole south part of the German automotive industry. Most of these premium car OEM’s there had ambitious plans to launch electric supercars, as Tesla managed to do with the Model S, but at a considerably higher sales price. Tesla managed to launch such a supercar at a third of the cost the German actors planned for, and on top of that, he provided the fuel for free! It would be like if Henry Ford*

*would have included a fuel card with free petrol for every sold T-Ford.” (Automotive Journalist, 2018)*

However, the inertia from the economy of scale was often mentioned as an important enabler and advantage for the incumbent OEMs. That is, OEMs source such enormous volumes of components from sub-contractors they create profound economic barriers for start-ups trying to enter the market. The design manager with a recent experience from one of these start-ups illustrated this:

*“When they finally get their venture capital, they must build an assembly factory and quickly get suppliers for the components. However, when they approach the traditional subcontractors that can produce the quality acquired for the automotive industry, the primary question is how many components the start-up have in mind. If the first series only then is estimated to be some thousands of units, the probably answer is no. That is, BMWs product-series of, e.g., a dashboard is 600 thousand units per year. The next question is whether the start-up would like the subcontractor to employ more people for setting up a production line for their components. Moreover, the incumbent OEMs are usually not that happy that their established subcontractors also start to produce for start-ups, which could be competitors after some years. Thus, such an arrangement often makes subcontractors hesitant to start a collaboration with small actors. The big incumbent OEMs also have a strong advantage in negotiating with their established subcontractors, offering them contacts for coming series in advance.” (Design Manager, 2018)*

However, the start-ups aiming at designing EVs also were described as having many benefits in the form of much less complex technologies if designing BEVs than the traditional OEMs and can explore new design and production solutions with more modular platforms that easily could be modified and upgraded after launch both with new functionality via software upgrades and physical exterior components.

### 5.3 Empirical field study A3: New actors disrupting business-as-usual in the automotive industry

The interviews with practitioners in the incumbent OEMs as well as the author’s own search found evidence that there has been a rapid growth of start-up companies developing various vehicles such as cars, two-wheelers, and flying cars with alternative propulsion technologies, mostly electrical. Some of the most discussed companies are Tesla, Faraday Future, Local Motors, and Open Motors. Altogether, there are hundreds of actors globally trying to challenge the traditional business and design logic in the automotive industry by designing vehicles and exploring ways to overcome the enormous entrance costs.

Tesla has however been very assiduous and paved a path for a different business and design logic. This path has changed the view of electric cars as a product mainly appealing to customers driven by environmental concerns to appealing to customers concerned with performance, styling, range, driving experience. Tesla has also decided a different path than the traditional dominant business logic selling cars through dealerships.

In some examples, this new design logic is combined with a new business logic that considers vehicles as a service. Some of these actors already have shown the potential to use assets (cars) at a higher utilization rate by providing mobility services for actors such as Uber. The following section presents a study of two of these start-ups in the US, Local Motors and Open Motors.

#### 5.3.1 Design of future proofing products, enabled by co-creation at Local Motors



Local Motors (LM) is a start-up company founded in 2007 that focuses on “shaping the future for the better” by designing and producing vehicles via open collaboration and co-creation of modular platforms using standard components and 3D printing of production moulds and body parts with the components of the vehicle being produced and assembled on a small scale (micro) production plants. Through these approaches, LM aims to shorten development time and reduce cost by optimising production tools for low volumes, compared to conventional automotive production, which depends on expensive tools for sheet metal stamping or injection moulding of components in large quantities.

Future proofing products are described as a “key thing” for LM. For their autonomous shuttle bus concept Olli, now under development, LM is exploring ways to design a hardware platform that can allow further

upgrades with new functionality without risking the vehicle prematurely becoming “a static collection of nuts and bolts”. Such continuous upgradability is connected to LM’s business model with the intention to provide vehicles via a subscription model where customers receive software and hardware upgrades. LM sees that new functionality can be added either by the vehicle itself. For example, by monitoring and analysing users’ behaviour during autonomous driving it can adapt to the passenger’s reactions to the vehicle’s road behaviour by, e.g., changing the driving style. Also, physical upgrades are accounted for by the possibility to upgrade to a larger battery pack if a longer range is needed or new technology such as supercapacitors is introduced. LM also sees a potential for styling upgrades, inspired by the fashion industry with fast aesthetic changes that could keep a vehicle fleet contemporary.

Local Motors systematically uses co-creation to tackle problems with “static teams” in traditional product design. With their digital platform “Launch Forth,” they can deal with various design challenges open to everyone around the world to contribute to different levels of detail, including a large group of contributors, ranging from thousands in initial phases for

Table 3. Example of products being available from Local Motors and Open Motors

|  |  |
|--|--|
|    |   |
| <p>Local Motors self-driving shuttle bus Olli. Image: Azra Habibovic</p>   | <p>Open Motors, modular EV platform Tabby EVO</p>  |
| <p>Local Motors is a start-up company with the aim to disrupt current ways of designing and producing vehicles. With co-creation, standard components, 3D printing, and small-scale production plants (micro production), Local Motors aims to create alternative vehicles intended for both private use and use in MaaS services.</p> | <p>Open Motors is a start-up company developing a modular, open platform that other actors can develop further into various types of EVs, and also offering a network of suppliers of components. OM has further developed this platform into the EDIT modular vehicle concept, an adaptable vehicle aimed at solving the needs for mobility service provider for flexibility and upgradability.</p> |

general opinions and hundreds for ideation and even fewer for detailed development. This means LM has access to a comprehensive range of competencies even though they are a small company. LM further sees openness as essential for their business and design activities, and everything uploaded on the platform is protected by creative commons license, where contributors retain ownership of their intellectual properties and become intellectual investors. By using their open innovation community, LM sees further possibilities to use this community for testing and development of upgrades during the use phase of the vehicles.

### 5.3.2 Open Motors, modular vehicle platforms for mobility service providers

Open Motors (OM) started in 2013 with an intention to design a modular platform for electric vehicles with a business-to-business focus selling vehicle platforms to mobility providers and entrepreneurs. This approach is intended to enable other entrepreneurs and companies such as large OEMs, mobility service providers, and delivery firms to develop complete electrical vehicles much faster and cheaper than if they were to develop the vehicle platform from scratch as the platform is one of the most expensive parts of the vehicle.

OM sees their platforms as enablers for helping other entrepreneurs realize their visions of electrical vehicles and mobility solutions. This is done by shortening the time to market, reducing the gigantic investments needed to design platforms, customizing for branding, and providing features that minimize business risks associated with using traditional vehicles for mobility services and allowing an open design that can enable cost-effective upgrades with new ICT. OM can also provide their customers with a network of suppliers of components in various volumes and certification as a service, even further lowering the thresholds for small entrepreneurs becoming automotive OEMs. The platform is provided as open source, allowing detailed access of detailed design and allowing for improvements by OM's customers or other contributors via their community.

With their modular and upgradable design, OM sees potential in reducing the risk of vehicles becoming prematurely obsolete, something they claim a traditional ICE car will be facing already after two years – If being used intensively in a hailing service. The Tabby platform, available since 2015, has been used by different entrepreneurs to develop various types of small EVs for different applications. OM develops its products based on insights from customers providing mobility as a service and this has been further developed in the EDIT concept. Edit is a concept for an autonomous EV, intended for use in Mobility-as-a-Service (MaaS) applications. Edit is based

on a modular platform with an adaptable body design. The lifecycle for Edit is intended to be at least 20 years and to change and upgrade over several use cycles, depending on the customers' (e.g., the MaaS providers) changing needs.

OM has different design and business logics. That is, traditional automotive manufacturers design their products to be difficult to replace or repair and encourages customers to buy a new car as soon as expensive parts such as the engine or gearbox become broken or become too costly to repair. The OM design logic keeps some central components in the vehicles that can be refurbished over time, allowing for a longer life cycle of the vehicle. By this approach, OM is similar to OEMs in the airplane and train industries as OM does not intend to change platforms that often and designs for upgradability.

## 5.4 Empirical field study B Firms running a CBM

### 5.4.1 Fairphone

Fairphone is a Dutch company with ambitious goals to change the way smartphones are made throughout the whole value chain by designing long-lasting phones with "fair" and recyclable materials and reasonable working conditions for those working in the value chain. Fairphone started in 2010 with a campaign about conflict minerals. Since then, they have promoted transparency in their operations and marketing. By making their supply chain visible, Fairphone wants to initiate a discussion about where its consumer products come from, what raw materials it uses, and how the phones are made. Fairphone 2, released in 2016, was claimed to be the world's first modular and fair smartphone and has been sold in more than 100.000 copies.



Fairphone 2 is designed with a modular setup where the components of the phone are easy to disassemble with standard tools and customers are encouraged to keep their phones for a long time with incentives for repair by providing spare parts at reasonable prices. Fairphone 2 can be bought as a kit of spare parts for easily assemble by the customer and will cost about 10€ more than buying a complete assembled phone.

The design of Fairphone model 2 should last at least five years, and components are chosen with that time frame in mind even though there are many uncertainties. For example, Fairphone has assumed that a display size of 5 inches with a full HD resolution with 446 PPI would be high enough resolution although some competitors' smartphones already have much higher resolutions. However, Fairphone doubts that the human eye can recognize the difference.



Despite that the components are easy to exchange if damaged, Fairphone has struggled making components upgradeable and has only succeeding with a better camera module so far. The main reason for this is due to the chipset limiting the compatibility with other components in the phone. However, Fairphone added an extra USB port for the possibility to use external hardware modules unknown at first launch and developed by other companies or by Fairphone. For example, a smart case could be designed with an extra battery, wireless charging, new payment methods, or anything inventors and entrepreneurs could come up with. The phone's modules are made with recyclability in mind and are rather easy to separate. Fairphone also launched a recycling program in 2014 where used phones can be sent to their partner for recycling. Fairphone pays for the shipping from most EU countries and takes back other phones brands.

Table 4. Fairphone 2, a modular smartphone designed for longevity.

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|--|--|
|    |   |
| <p>The teardown of Fairphone 2 by iFixit, which gave Fairphone 10 out of 10 points for reparability score (10 is easiest to repair). Image: ifixit.org</p> | <p>The Fairphone 2 is designed for easy repair by the users themselves with markers for screws and easy identification of modules. Image: ifixit.org</p> |

## 5.4.2 LedLease

LED Lease is a Dutch company that since their start in 2010 wants to be seen as a forerunner of a circular economy. LED Lease gives their customers the option to pay per amount of light they use instead of buying and owning lighting fixtures and light sources, which is the most used model in the property business today. LED Lease own their installations and offers lightning contracts for ten years, and their customers primarily see lower costs from energy savings as the main reason to buy LED Lease's services, which can be 50-75% more energy efficient than conventional fluorescent lamps installed, for example, in low utilized parking garages.

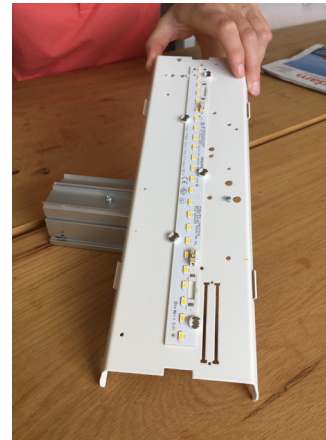
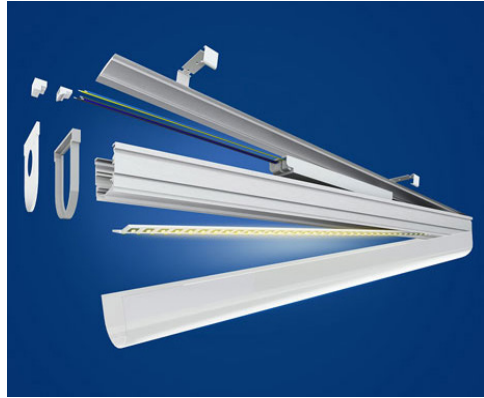
Their reason for starting with functional sales is described to be due to the market barrier with potential customers being hesitant to invest or change to the more expensive LED technology in their commercial buildings. The customers are charged a monthly fee for the light services but pay separately for their usage of electricity for technical and transparency reasons. In addition, this arrangement lowers LED Lease's financial risks.

Service and monitoring of the installations are included in the subscription, and Led Lease monitors their installed lightning facilities to keep it at its highest utility over the usage time and to identify broken or faulty lightning fixtures before their customers do, providing a good uptime. In a situation where the customer does not pay, the lights can be turned off remotely.

Usually, LED Lease's customers do not do lifecycle costing, which makes the comparison with traditional sales difficult. Today, LED Lease only has contracts with private companies as they describe transactions to public actors as difficult due to barriers in public procurement criteria not including functional offerings.

LED Lease has developed their lighting fixtures that are optimized for their circular business model by a design that is modular, scalable, upgradeable, and easily assembled by low skilled installers. The estimated life length of the LED Lease being used is approximately 50 000 hours, which for most applications is about ten years. The fixtures can be upgraded with new drive electronics and light sources for new use cycles. In addition, LED Lease can add new functionality such as photo recognition that can identify free parking spaces in garages.

Table 5. LedLease, selling light as a service



Led Lease is a Dutch start-up that wants to be a forerunner in a circular economy. LED Lease designs and specified their lightning fixtures for as long life as possible and takes care of installation, maintenance, upgradeability, and recycling. Customer pays for the amount of light (Lux) through a monthly subscription. Image: <http://ledlease.com/en/Technology.aspx>

Led lease has designed their lighting fixtures to be modular and upgradable. The image shows the installation of the printed circuit boards with the LED light sources, which are easy to assemble/disassemble using simple fasteners rather than being glued to the cooling plate, the most common fastening technique used in the industry. Image: Thomas Nyström

LED Lease describes its design logic being about maximizing energy efficient use, reuse, easy repair, and material recycling, and it notes they have to push their suppliers to develop more durable LED designs and electronics, but has not fully managed to do so. The suppliers usually respond that “it is only your company that wants this improved life length”. Nevertheless, to maximize the life length, LED Lease has managed to reduce heat in their fixtures using mechanical solutions together with running their installations at 70% of their full effect as high temperatures significantly reduce the life length of LEDs. However, this is described as increasing the initial installation costs due to more LEDs needed in the fixtures.

# 6 Analysis and discussion

This chapter summarizes and discusses the theoretical and empirical results presented in Paper I and II, combined with empirical findings from studies A 1-3 and B, based on the following research questions:

RQ1: What are the challenges and possibilities for an incumbent manufacturing firm to embrace all three business and design strategies for CE (closing, narrowing, and slowing down resource flows)?

RQ 2: What does a change/design manager need to be aware of when proposing an adaptable product to top management in an incumbent OEM?

RQ 2.1: How can OEMs operationalize business and design strategies for CE with the aim of identifying a CBM that combine profitability and low business risks through adaptable design in the early development phases in incumbent OEMs?

## 6.1 Barriers and possibilities for CBMs with future adaptable design in the automotive industry

If considering the radical vision of CE aimed at an ideal closed system (Cullen, 2017), there are still many large barriers remaining for the manufacturing industry. The CE strategies for reducing resource flows are characterized as being the most challenging for the incumbent automotive OEMs as their current business models are based on a continuous flow of virgin resources turned into manufactured products. If then considering that a CBM should be based on the lake principle as proposed by Stahel (2006) where a firm creates, delivers, and captures value through their already produced stock of products, firms voluntarily would increase their secondary production on behalf of their primary production (Zink & Geyer, 2017). Both the automotive industry as well as the manufacturing industry in general are far from being circular today.

However, cars to some extent could be considered as an example of design that slows down resource flows (Bocken et al., 2016). The picture that emerges from the field studies however, points to the fact that these circular activities in the incumbent automotive industry are “detached islands” of practice and knowledge that are not being systematically organized or used in business development and design in NPD.

Findings from this thesis further support this argument of “detached islands” due to primary drivers of traditional automotive OEM’s business

logic to cost-efficiently produce large volumes of vehicles, where practices of customization, standardization, platform design, and modularization primarily are used as means to reduce production costs. A chief enabler in this DBL is to offer a wide variety of models with a wide variety of options for the customers regarding exterior colours, interior trims, and various accessories using the same platform and sharing components from previous models. The OEMs are also very dependent on their subcontractors for development and production of components as they get discounts for buying large quantities of components.

One more significant driver in this DBL is to reduce financial risks by selling produced vehicles as fast as possible and retrieving revenues from the aftermarket for maintenance of ICE cars, where spare part repairs and accessories are an essential part of creating such revenues. Also, the practice of developing new models based on competitors’ models and target price creates a barrier for introducing new technologies and solutions as they raise the sales price.

The primary role of the design logic is to support this DBL through contemporary vehicle design that attracts and keeps customers attracted to the brand and new models. Although design has a significant voice in the decision making of new products regarding aesthetics and user experiences, the existing flow-based business model is taken for granted and with little possibility for negotiation in NPD. Instead, the main focus in the development organization is to get new models on the market and what happens with the products in the aftermarket is less important. This results in a design logic where vehicles are optimized to last for 200-300,000 km, or approximately ten years of usage, are supported with well-developed procedures for quality testing of components based on set specifications.

Furthermore, this design logic supports an efficient and automatized production, primarily considering necessary service points, often resulting in limiting other exchanges, repairs, and upgrade possibilities due to complexity and cost. The result is also a design logic where most ICE cars produced today are not designed for upgrades of major assemblies such as retrofitting the powertrain, exterior body design, or interior design. This is true even though some car models share a common platform with a high degree of modularization used for building several variants of a powertrain for ICEs, PHEVs, and BEVs.

Nevertheless, even if the 10,000 components are initially separate modules, many these are “frozen” into sections in the product architecture at the point of final assembly in the production line. A practical example here is the exterior design of traditional cars that is well integrated into the Unibody.<sup>13</sup> In the overall product architecture, this Unibody provides the physical structure

for the vehicle's exterior panels and interior sub-systems and components as well as providing durability and distributing stresses through deformation zones. Once the multiple sheets of pressed steel are welded together, the Unibody is not easy to modify. It will be extremely difficult to change the height, width, or length of the vehicle as well as the exterior aesthetics by exchange major exterior panels such as the roof or side sections of the car. Also, the visual properties the paint layers are thoughtfully applied to the exterior panels, making it time-consuming and costly to repair, refurbish, or upgrade.

However, based on finding from the pre-study, as presented in Paper II, there are considerable differences in the design logic between cars versus commercial vehicles. This difference is mainly due to the different usage requirements such as load capacity, reliability, and durability, where large fleet-owning customers' main focus is on low lifecycle costs. The result of this is a design logic for heavy vehicles with improved fuel efficiency, flexibility, and durability, where for example a heavy truck is designed to work for one million kilometres or more, many times the expected life of a car. However, the linear flow-based business model dominates the commercial production, even with many existing examples of BMs yield the results of a PSS (Tukker, 2013). Table 6 summarizes the findings of main barriers and enablers for a circular business and design logic derived from interviews and workshops.

Table 6. A summary of main barriers in the incumbent OEM of car for implementing a stock based CBM, based on principles of closing, narrowing and slowing resource flows in the incumbent automotive industry

| Main characteristics for current business logic   | Main characteristics for current design logic  | Main business & design barriers for implementing circular business model   | Enablers for a circular business logic  | Enablers for a Circular design logic  |
|---|--|--|---|---|
| Current business models are based on sales of produced vehicles, which are sold as quickly possible to maximize profit and avoid being a "bank" for a stock of unsold products.<br><br>Financial agreements such as private leasing or subscriptions for speeding up sales. | Primary focus on the point of the first sale by putting the product on the market with desired attributes/price.<br><br>All new technology that has to be added increases the price, so it becomes difficult to sell the car in the end. | A need for financial capital for functional sales (if keeping ownership).<br><br>All costs for the product are charged to each project. Project measured on deliverance within budget. Those who do not stay within budget are removed.    | Selling a more durable product with a higher price could be feasible and cheaper from a life-cycle cost perspective.<br><br>Keeping ownership or control over produced products fosters a logic for keeping products at their highest utility and cost efficient. | Setting a bold goal for CE/CBM can steer the development organization towards a "take & stock" based logic.<br><br>Design for a total cost of ownership by optimizing products for extended life by reuse, reparability, upgrades, remanufacturing. |
| Sell cars and make a profit when they have to be maintained or break down.<br><br>Get the customer into the workshop once a year.   | Add on services developed for existing products such as maintenance.<br><br>Optimized design for an expected life length with regular service intervals  | Most revenues come from the aftermarket, including maintenance, repairs, spare parts, accessories, and financial services.<br><br>Future adaptability will be considered to drive developing costs for uncertain future revenues.          | The emergence of fleet operators such as carpools and hailing services put more focus of total cost of ownership than traditional features such as styling colour and horsepower.   | Service design that continuously develops and tests new service content for existing products that can keep products from becoming prematurely obsolete.  |
| Continuous model changes,<br><br>"We live on making continuous model changes".<br><br>A new product attribute profile "list based on benchmarking of competitors models with a set target price.  | Changing "things" makes life interesting.<br><br>Incremental development based on "follow the leader" logic.<br><br>Safety and styling have a powerful say in decision making.   | Customers expect new functionality and aesthetics of new models. Otherwise, they want to pay less.<br><br>The established business model is not being challenged during design and product development, only the technical specifications. | Design of product life extension can reduce business risk.  | Setting a bold goal for CE/CBM can steer the development organization towards an independent design logic based on a CBM.   |

<sup>13</sup> Accessed, 15 December 2018: <https://www.youtube.com/watch?v=IhbXPzPlzNI>.

Table 6 (continued). A summary of main barriers in the incumbent OEM of car for implementing a stock based CBM, based on principles of closing, narrowing and slowing resource flows in the incumbent automotive industry

| Main characteristics for current business logic  | Main characteristics for current design logic  | Main business & design barriers for implementing circular business model   | Enablers for a circular business logic   | Enablers for a Circular design logic  |
|--|--|--|--|---|
| <p>Cost calculation starts when a physical construction emerges based on set performance.</p> <p>Be number one with new technology, but not alone due to high entrance cost for development and adoption for mass production.</p> <p>Keep up with compliance.</p>  | <p>Propose a set of criteria for components that meet the target price.</p> <p>Components are optimized and tested for 200-300.000km/10 years of usage.</p> <p>Incremental improvements regarding most technologies for emission and fuel efficiency, etc.</p> <p>With exceptions for radical technologies such as autonomous driving deemed necessary.</p>  | <p>With a too low target price, durability will be difficult to achieve and thus risks will increase if the OEM keeps product ownership.</p> <p>Different life lengths between various components and the whole vehicle itself.</p> <p>A circular product risk being considered too expensive by the need for more durability and future revenues by resisting obsolescence.</p> <p>New certifications standards such as WLTP in the European market can hinder future upgrades.</p>   | <p>From the early stages of development, design of the CBM and suitable products jointly balance initial costs with future profitability from an adaptable and durable product.</p>  |   |
| <p>An economy of scale by heavy investments for mass production, dependent on the manufacturing of components being outsourced to subcontractors.</p> <p>Platform design and modularization for providing many model variations at low costs per unit produced</p> | <p>A high degree of modularization and use of standardized components carry over between models and from previous generations based on existing components available at a low cost due to high volumes</p> <p>Platform and components made modular for efficient production, by sub-assemblies for automatic assembly</p> <p>Platform and components made modular for efficient production by sub-assemblies for automatic assembly.</p> | <p>To upgrade major systems such as the drive train on an already sold vehicle on the aftermarket is too costly today due to current design for efficient production.</p> <p>Emission and safety legislation can prevent upgrading of existing ICE powertrains in the aftermarket.</p> <p>Hardware upgrades can be difficult if electrical actuators are locked.</p> <p>The unibody makes exterior components difficult or almost impossible to upgrade as they are integrated into the load-bearing product architecture.</p> | <p>Micro production making today's repair shops tomorrow's "retrofit and upgradability" shops.</p> <p>Planning for tool inserts for upgrades already in the design of tooling for the first model.</p> <p>Fast changing technologies such as ICT &amp; AD can make solutions for a cloud computing system cost effective.</p> <p>Shift to technologies that are less affected by emission legislation.</p> | <p>A modular platform design that is open for several adaptations and upgrades during usage, both regarding the main product architecture as well as hardware and software functionality.</p> <p>As well as for aesthetic upgrades and for user experiences.</p> <p>Active safety upgrades that make an existing car safer.</p> |
| <p>Maintaining an economy of scale by continuously cost reductions</p>   | <p>Low cost materials used in car exterior such as the car body.</p>   | <p>Low material values can make re-manufacturing less profitable due to wear and corrosion.</p>  | <p>Sourcing materials that are possible to circulate cost effective.</p>   | <p>Specifying more durable materials with predictable wear.</p>   |

From a design practitioner's perspective, designing for extended life length through adaptivity can at first glance be considered to be too complicated and too restricted, as illustrated from the interviews with practitioners. For example, even when there is the intent to reuse an old vehicle platform for a new model, the complexity in interfaces between components usually in the end results in a new platform design. Also, the idea of making significant subsystems as the propulsion system upgradable through retrofits is challenging but technically possible today, at least from a production perspective (Hyundai Ionic). Nevertheless, offering the powertrain that can be retrofitted like the ability to change an existing vehicle from ICE, PHEV, to EV could be doable from a technical perspective and be supported through design, but would, however, be a challenge for the aftermarket. Nevertheless, adaptable design can encourage ideation and innovation that considers the total life of a product and many customers and users during multiple use cycles.

## 6.2 Learnings from the Studied OEMs with alternative business and design logic

The four studied start-up companies – Fairphone, LED Lease, Open Motors, and Local Motors – share a common goal to become established OEMs in their industry. These companies have somewhat different approaches that can be used as learnings for incumbent OEMs.

Fairphone shows that it is possible for a firm with small resources to launch a product with circular business and design logic as with the modular Fairphone 2. Fairphone also shows that it is possible to affect the value chain and build an active customer community supporting their way of designing and doing business. However, the phones are sold to customers in a traditional flow-based business model combined with a market communication emphasising the vision of changing the telecom industry, circularity of materials, and offering spare parts at affordable prices, encouraging customers to keep and repair their phones as long as possible. Learnings from Fairphone indicate that it is not necessary for an OEM to keep ownership of their products in a CBM.

However, Fairphone clearly describes that one of their main challenges is due to lack of control as many customers skip software upgrades for their phones, resulting in customers becoming unsatisfied of the performance of their phones. This means these phones could be judged as prematurely obsolete. Also, even if Fairphone does not own their produced product, they face a huge technical problem in being reliant on large subcontractors of electronics and operating systems where the manufacturers of the main chipset and Google (the makes of Android operating system) have critical

roles in setting a death date for the main hardware and whether the existing hardware can support new versions of Android. Furthermore, as there is a rapid technological development of hardware components, they can on short notice from the OEMs cease to be produced, leading to a situation where Fairphone has to buy the available stock of this hardware to keep a stock for remaining production and future spare parts. This situation emphasises the critical role of subcontractors for maintaining a circular system.

LED Lease, on the other hand, did not become circular as the result of sustainability reasons but because it had difficulties getting owners of commercial buildings willing to pay for LED technologies as the upfront costs are more expensive than buying fluorescent lamps. To deal with this fierce resistance from the building sector, where costs for lightning installations and energy use are considered to be a very small portion of the total costs of a commercial building's operating costs. LED Lease approached this barrier by offering services providing uptime with a "no cure, no pay warranty on the cost cuts" to their customers. This approach is very much in line with has been described as a success factor with the Xerox case (Chesbrough & Rosenbloom, 2002) when the at that time more expensive copier technology had problems getting customer acceptance.

Based on their business model with a primary focus on selling services, LED Lease describes a strong internal drive to work with solutions for extending the lifespan of their products by making them reusable, upgradable and recyclable. As well as being easy to assemble and install by low skilled installers to keep the installation costs down and keeping the lightning installations (owned by LED Lease) at its highest utility during the service period of many years. However, as opposed to Fairphone, LED Lease does not see that the "circular button" (as they describe it) as the main reasons for customers buying their services. Instead, they indicate that all components together (energy savings, circularity, and social commitment) create a strong value proposition for their customers. However, LED Lease face the same problem as Fairphone in getting large subcontractors of electronics to provide components for a much longer lifespan than conventional lighting.

The learnings from FairPhone and LED Lease are also applicable in the case of the two studied automotive start-ups, Local Motors and Open Motors. Both these actors are driven by their bold visions of changing the automotive industry by offering new mobility solutions. However, just as with LED Lease, none of these companies implicitly claimed that they are working according to CE principles, even though several of their approaches seem to be well in line with such principles. These principles include solely focusing on electrical drivetrains in their vehicles (narrowing flows by resource efficiency and increasing the usage by mobility services ), longevity through modularity and adaptability (slowing

down resource flows), and design for material recycling (closing loops). Rather, the enormous investments needed to become an automotive OEM in development of platforms and sourcing components have driven these actors towards a business and design logic of modular platforms, use of standard components, low-cost production techniques, and easy assembly. These companies providing mobility services a vehicle designed to be future proof (Local Motors), provide vehicle platforms for other actors to further develop and tailor vehicles (Open Motors). Such open design approaches – enabling future adaptations and upgrades during the vehicle's use phase – differ significantly compared to the incumbent OEMs approach. Designing vehicles with a locked design for the point of the first sale is difficult and costly to adapt after launch.

Table 7 summarises enablers and barriers for circularity and product adaptability from these four start-up companies. Main conclusions from these compilations are that just as in the case with the DBL in the incumbent automotive industry the business logic in these start-up companies supports their design logic to capture value from their specific business models. However, these actors manoeuvre more freely than the incumbents regarding the choice of suppliers for technologies and components and with a much lower organizational complexity. Finally, even if these companies do not have a track record as the incumbents in making profits, development capabilities, and so forth, they are in this thesis being used as promising examples of how approaching a CE could be achieved by setting bold visions and goals, turning those goals into business models and innovative design of products based on this DBL. All together, they form a variety of examples of product designs with a high potential to resist premature obsolescence.

Table 7. An overview of described enablers and barriers for circular business models and designing modular and adaptable vehicles based on interview of four start-ups in empirical studies A3 and B.

| Main enablers for adaptability and circularity   |   | Main described barriers for adaptability and circularity  |  |
|--|---|---|--|
| Business logic   | Design logics   |   |  |
| Main focus is to change the way products are made throughout the whole value-chain (FP, LM, OM).<br>To question where our consumer products come from and how they are made (FP).  | Design of long-lasting products with fair recyclable materials and reasonable working conditions (FP).<br>Future proofed design, keeping products relevant.<br>Designing product for extended life length by modular design made for longevity where components are easy to assemble/disassemble with standard tools by the users themselves (LM, OM, FP, LL).<br>Take back programs for material recycling (FP, LL). | The current design of chipset (the central processor) does not allow upgrade of modules to better performance. Only exchanging modules that meet the processor's original features (FP).<br>Fast fashion changes in smartphone design could make products look outdated (FP).<br>Subcontractors of components halting production due to new technologies, resulting in OEMs needing to buy remaining stocks to manage spare parts (FP). |  |
| Offering multifunctional products.   | Reducing needs for having many products (e.g., slots for two sim cards in a smartphone or different vehicle configurations) (FP, OM).   | Encourage users to use products right realizing the embedded potential for longevity (FP).  |  |
| Being open with IPs, supply chains, and cost for the products. Using open source software and hardware platforms (LM, OM, FP, LL).   | Open design intended for further development by customers and users (OM, LM).   | Finding ways to finance NPD and production (FP, LM, OM).  |  |
| Open innovation and co-creation to find the right competencies without the need for a large development organization (LM).   | Facilitating an open innovation platform with a developer community.<br>Intellectual property investors that want to realize the OEMs products (LM, FP).  | Scale-up of production (LM, OM).<br>Facilitating an open innovation platform with a developer community (LM).   |  |
| Selling products such as a service with a primary logic on reducing the life cycle costs for the customer (OM, LM, LL).<br>A higher price can be covered in a subscription model if reducing life cycle cost for the owner or service provider (OM, LL). | Customers get continuous software upgrades keeping products at its highest utility.<br>Using the most energy efficient technologies as possible for product usage and propulsion (LL, OM, LM).<br>Embedded sensors for monitoring function and maximizing uptime, with a possibility to shut down plants if customers do not pay the monthly fee (LL).  | Financial issues when selling functions (LL).<br>Low energy prices and low relative costs of electricity as part of the total operating budgets (LL).   |  |
| A price policy for spare parts that give users economic incentives to repair themselves instead of buying new (FP).  | Small scale (Micro) production based on standard components.<br>Tool making by additive manufacturing (LM, OM).   | Facilitate the co-creation process in the right direction and maintaining interest in the development community (LM).   |  |
| Open hardware and software protocols (FP, LM, OM).<br>Expansion port intended for development of future applications by third-party actors (FP).   | The possibility to customize modules by personal shape and patterns via 3D printing (LM, FP).   | Being prepared for redundancy if, e.g., Google stops supporting the Android OS, switch to Linux instead (FP).<br>Technical limitations in additive manufacturing technologies (quality, time, costs) (LM).  |  |

FP = Fairphone, LL = Lettlease, LM = Local Motors, OM = Open Motors

### 6.3 Bridging existing islands of theoretical knowledge of CBM and adaptable design

The theory presented in Paper I, II, and in chapter three represents three main fields regarding theories related to logic doing business, the design of physical products and intangible services, and approaches towards eco-sustainability. These three areas of academic knowledge have in this thesis formed a basis for building a theory that can give explicit prescriptions of how circular business and design practices can be improved.

From the field of business logic, the following theoretical knowledge considered useful is the dominant logic: business models, business model innovation, CE, CBM, the logic for effectuation, and lean entrepreneurship. The theory of the dominant logic has been chosen as the main explanatory model of why the current barriers for CBM exist, resulting in a master and slave relationship between business and design logic. Theories in Business Model and BMI have further been used for providing structure and support in practical work of how to develop a CBM. The field of entrepreneurship is considered to be especially relevant for changing from an LBM to an CBM as the top management in incumbent OEMs will face the same challenges as an entrepreneur seeking customers that are willing to pay for a business idea. If the firm lacks prior business cases of a CBM to compare, it can use an effectuation approach to design their desired outcome.

From the field of eco-sustainability, this thesis considers theory from industrial ecology and the circular economy as the main two routes for manufacturing industries to be eco-sustainable. A central differentiator here is the relative versus the absolute goal towards ES (type I-III ecology) being represented by an eco-efficient versus an eco-effective approach. Theory for a circular economy forms a basis for the intended outcome where among the more than hundred definitions of CE (Kircherr et al., 2017), the CE definition being used in this thesis is based on Bocken et al.'s definition. (2016). This is based on the argument that it combines both the eco-efficient and the eco-effective route for achieving radical resource efficiency. The concept of a stock-based business model was chosen as a boundary principle. Furthermore, principles of backcasting give a structure for keeping a focus on the vision for the desired outcome and lower the risks for deviating into BMI moving towards incremental eco-efficient solutions. Knowledge from the field of Products Service Systems (PSS) gives a structure to a systematic co-development of products and services in parallel with evidence of improved resource efficiency. Also, knowledge regarding obsolescence form an essential basis for understanding what factors affect products to become unattractive and considered to have reached the end of their lives.

From the field of design, theories of design, as being a change process form a basis to consider design as both a problem-solving process and a managerial tool for changing existing situations into preferred ones (Section 3.4). This view aligns with the concept of effectuation, design thinking, as well as with suggested roles of top management for radical BMI, suggesting changing from being moderators or sponsors to taking a leading role as architects of the BMI process, considering it as a design challenge (Brown & Martin, 2015 p.59) with wicked problem(s) to be systematically explored and effectuated.

However, the considerable overlap between the fields of design thinking versus entrepreneurship that today have more well-developed structures for practice than design thinking has put more focus on the latter (Sarasvathy, 2001; Blank, 2006; Ries, 2011; Blank and Dorf, 2012). Furthermore, theories of adaptable design and remanufacturing offer a practical base from a

### Bridging existing islands of theoretical knowledge of CBM and adaptable design

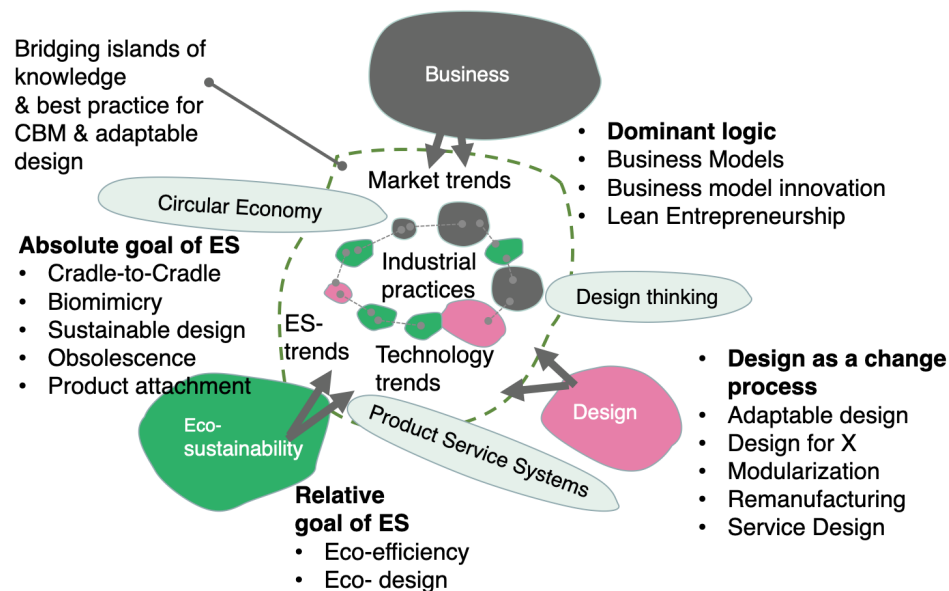


Figure 3: Based on theory from research fields in business, design, and eco-sustainability and empirical findings from industry, this thesis concludes that there today exists an archipelago of detached islands of academic knowledge, best practices, and emerging trends in manufacturing industry; if bridged, these can lead to a potential for radically improved resource productivity with CBMs being combined with adaptable products and services.

These three theoretical fields reviewed in this thesis are to a large extent fragmented from a perspective of how to achieve radical resource productivity in the manufacturing industry. The BM and BMI and entrepreneurship literature primarily has a focus on how to create, capture, and deliver value, often without any explicit consideration regarding eco-sustainability effects of various BMs.

Moreover, even though the vast production of scientific papers and grey reports in recent years regarding the need for and implementation of CE, circular business models and closed-loop supply chains in most cases have been a focus on the business side of the circular economy. The question about how to combine business modelling with a design of suitable products has just started to emerge (Frishammar & Parida, 2018; Moreno et al., 2016; den Hollander et al., 2017; and Linder & Williander, 2015). Also, the question of how to operationalize CE in incumbent organizations is still rather unexplored.

Furthermore, the literature about design for circularity such as cradle-to-cradle places focus on dividing products into technical and biologic materials streams but does not explicitly propose adaptability or longevity as essential prerequisites. Instead, emphasis is on short product lifecycles and relying on closing loop strategy of material recycling powered by renewable energy. Literature focusing more directly on circular design proposes a full shed of approaches to design but without explicitly differentiating between various effects of using different methods from an eco-sustainability perspective.

The specific literature about adaptable design has a primary focus on the benefits of more flexible products that could be upgraded for environmental gains but does not mention how increased cost for making more adaptable products could be managed from a business or customer perspective. However, as Engel et al. (2017) bring forward, even if the future value of making enduring products with prolonged service life increases by making products upgradable and adaptable, it also has a cost and there is a threshold where decisions about how modular and adaptable design should be managed so the costs for interfaces do not become too high as it is possible to be both inappropriately modular as well as too modular in product design. Therefore, seeing future adaptability as an economical option of future value to be used or not will be of high managerial importance by making early cost assessments in the BMI process. So far, the field of PSS seems to be the closest one to combine both business and design logic, fostering modularization, reuse, and remanufacturing with the intention to reduce cost and environmental impact, for example, the often referred to examples from the Imaging industry such Xerox business model that over the years have come to affect the design logic into a design practice for multiple lifecycles (Gray & Charter, 2007).



## 6.4 A window of opportunities for adaptable design in the incumbent automotive industry

Recently, the automotive industry has been affected by global technological trends of digitalization and market trends as the emergence of competitors providing mobility services. These trends, in combination with stricter emission legislations on markets such as China and Europe, are starting to put pressure on the OEMs' business-as-usual approach. According to Roland Berger<sup>14</sup>, the automotive industry is specifically being exposed to four main "mega trends": mobility, autonomous driving (AD), digitalization, and electrification. The mobility trend can be illustrated by the emerging solutions for shared mobility, hailing services, shared parking spaces, and connected mobility services as in the mobility as a service (MaaS) concept.

Furthermore, these ongoing technological trends are also driving costs, making cars more expensive, as well as decreasing the traditional revenues streams from the aftermarket as electric vehicles have less need for regular services and exchange of consumables. On the other hand, EVs reduce mechanical complexity compared to ICE technologies, offering a new freedom for product architecture. From a customer perspective, benefits are also reduced cost for usage and maintenance as well as a potential for significantly improved longevity for central components as the electric motor.

From a customer perspective, mobility services by itself and in combination by AD technologies are predicted to affect private ownership of cars. In addition, the digitalization trend affects the traditional interfaces between the OEMs and their customers regarding sales and connectivity and is disrupting traditional channels of wholesales of cars through dealers as well as providing end consumers easy access to mobility services without owning their own cars. Nevertheless, AD technologies also risk increasing costs for cars, as the high pace of development increases the risks for AD system becoming technically obsolete, based on the current development rate of cars for several years, and has been described as a challenge for the OEMs to sell by their traditional BMs.

The combination of these tech and market trends is risking increasing costs for the OEM when developing new products. In addition, the customer trends risk reducing the OEM's margins due to large fleet owners' main interest of buying vehicles that can provide uptime mobility services with low lifecycle costs. Moreover, even though the automotive industry so far has been very successful in resisting eco-sustainable transitions (Nieuwenhuis, 2014), there will be severe challenges ahead to meet stricter compliance, e.g., with ICE based powertrains on large markets such as China and Europe. The current automotive ecosystems are also significant users of non-renewable resources and global pollution, from production, use, and the

scrapping of cars and vehicles, with much material and resources wasted in the current linear system. Also, in the current automotive system, CE activities today are mainly focused on material recycling and eco-efficiency, and the route for capitalizing on product life extension of already produced stock of products is underexplored and mostly left to aftermarket actors to capture value on, e.g., second-hand sales, repairs, and remanufacturing.

These tech and market trends have been picked up by the many start-ups, making both innovative vehicle products as well as by new business models, with Tesla as a forerunner for a massive change, supported by their challenging visions of changing the world and the automotive industry for the better.

However, the incumbent automotive OEMs are also building capabilities for implementing new technologies for connectivity, electric drive trains, and AD as well as developing new customer offerings such as financial leasing contracts, subscription services, car pools, and deliverance services, or teaming up in various joint ventures with intentions to use existing vehicles in ride hailing services<sup>15</sup> or designing vehicles for use in ride hailing services.<sup>16</sup>

Chesbrough and Rosenbloom, (2002) emphasize that a successful business model connects technical potential with the realization of economic value by unlocking potential value. In a circular business model (CBM), such latent value will be embedded in the firm's know how about their products' functionality and durability and by embedded material values in these products. In a stock based CBM, where an OEM keeps ownership of its products (that they have in-depth knowledge about), there is (in theory) a much better probability for products being continuously monitored and assessed regarding their health. Here, also another tech trend can be an enabler for lowering business risk: the rapid development and implementation of embedded sensors and algorithms that can be based on driving behaviour and road conditions as well as predict the health of components and optimize when to do maintenance or overhaul activities. This logic has started to become established in the heavy vehicles sector, where OEMs can monitor the health of individual components such as a turbo-generator to predict when the component should be remanufactured instead of waiting for a costly breakdown to occur. Here, OEMs can capitalize from the lower maintenance and usage costs if vehicles can be designed to stay at its highest utility over a longer lifecycle than expected today from traditional cars.

All together, these trends with growing business risks of continuing the flow-based linear business-as usual approach can, if turned around, be

<sup>15</sup> See Daimlers Via Van: <https://www.viavan.com/>

<sup>16</sup> See Volkswagens subsidiary Moia <https://www.volkswagenag.com/en/news/stories/2017/12/techcrunch.html>

<sup>14</sup> Roland Berger, AUTOMOTIVE DISRUPTION, Accessed: 26 October, 2018, <https://www.rolandberger.com/sv/Publications/New-mobility-trends-China-is-driving-away-from-the-competition.html>.

considered to constitute a window of opportunities for incumbent OEMs to explore how CBMs can be a route to combine a radically increased resource efficiency with profitability. That is, products designed for extended life can be a route to open this window and to manage the increased business risks if keeping ownership of produced vehicles. Here, the technological and markets trends offer an opportunity to explore CE strategies for product life extension by an increased customer acceptance for buying mobility without owning cars, more reliable technologies through electrification with low usage, and maintenance costs and the possibility to monitor and measure product health by embedded sensors combined with machine-to-machine technologies (Ellen Macarthur Foundation, 2016; Cullinen, & Mahon, 2013).

Not exploring possible new business opportunities with CBMs may also lead to high business risk on a market with fierce competition. Disruptive competitors can take market shares by using the OEM's products in a PSS, thus increasing the risk for reduced sales by buying less vehicles for use in hailing services or car pools, forcing the OEMs to become sub-supplier of embedded technology to another brand owning, the customer relationship.

#### **6.4.1 Suggested Routes toward design for adaptable products in incumbent OEMs**

This section summarized results based on the research question:

RQ 2: What does a change/design manager need to be aware of when proposing an adaptable product to top management in an incumbent OEM?

As Kasarda et al. (2007 p.727) state that "product life ends because a product is unable to adapt to change" adaptable design therefore can be considered a strategy for improving products overall value by allowing products to adapt to meet new customer demands and needs over its service life that depend on design for modularity, upgradability, and durability.

However, designers can only design a potential for extended product lifetime (den Hollander, 2018 p.29). Sooner or later, all products will become obsolete due to the previously described drivers for obsolescence. In reality, these drivers are often intertwined. In many cases it can be difficult to conclude what specific reasons made an owner or user consider a product or service to be obsolete, which may depend on his or her available knowledge, moods, or force of legislation. (Lallmahomed, Rivera 2016 and Diener, 2017)

For example, a skateboard rider considering replacing the skateboard's metal bearings with new ceramics ones. The rider's reasons could be both technical, for example needing or wanting more advanced bearing technology that minimizes friction and promises improved wear-resistance and speed, and for social reasons, such as higher status in a specific subgroup of skateboarders. Further, if used in a commercial context as in a PSS, as a skateboarding pool, the change to ceramic bearings could, even if the ceramic bearings are more expensive initially than the metal bearings, are cheaper in the life cycle costs.

A starting point in designing products for a CBM is therefore to be aware of the reasons why customers and users may start to consider products obsolete due to aesthetic, technical, functional, and social causes that result in a product becoming economical unattractive. These various reasons for premature obsolescence have to be carefully considered in the BMI process. Both as these drivers for obsolescence represent possible business threats, but also can be seen as enablers for delaying obsolescence.

A solid theoretical base has been presented in Paper I, II and in chapter five, regarding business as the dominant logic, business models and business model innovation, CE, CBM, and Lean entrepreneurship as well as adaptable design, remanufacturing, product service systems, service design. In combination with already established practices in industry, see Paper II and chapter five, this has in many cases been described as profitable but to most extents is not being coordinated into NPD in the established OEMs, and has not been coordinated with designing CBMs with product life-extension strategies.

These thoughts-barriers between the business, design and eco-sustainability theories and industrial practice, have resulted in several islands of knowledge available both in literature and in industrial practice. However, for the most part, this literature and practice have a primary focus on designing products for efficient production, and offering a broad palette of product models based on the same platform design with a sharing of components between product models for reduced costs.

## 6.4.2 A conceptual framework for integrating business and design logic for circular business model innovation

This section proposes a route for OEMs to explore and facilitate a circular business model innovation process and a design process for developing future adaptable products that can keep business risks low in the planned CBM. This conceptual framework for facilitating organizational learning for circular business model innovation (CBMI) aims at circulating, reducing, and slowing down material flows by BMI.

The framework builds on lines of thought by scholars, c.f. Simon (1996), Brown and Martin (2015) and Checkland (2011), that see design as a transformational process of changing a current state to a desired one. In this context is the outcome of a CBM being based on an existing stock of products. This normative stance is derived from principles for Backcasting (Broman and Robert, 2017).

A holistic vision of a transformation from an LBM to a CBM by a set of guiding principles are used as boundary conditions for the Business Model to focus on value capturing within. The first principle is the vision of stock or lake based CBM, i.e., that the value creation and delivery shall be based on the existing stock of products. Thus, the aftermarket is a “lake” for capturing value instead of using virgin resources from the earth’s crust and biosphere. Secondly, the three CE strategies for closing, narrowing and slowing down resource flows are further setting the boundaries for running and maintaining the lake-based CBM, (figure 3), as well as creating solutions for reaching the intended vision. The most fundamental one of the three strategies is closing flows by creating a loop, since narrowing and slowing down resource flow does not lead to a circular system.

However, by a combination of all three strategies, with value capturing from the accumulated stock of resources, there is a potential for high resource productivity. Theories that underpin principles used in setting the vision have been adapted from: Lifset and Graedel (2002), Graedel and Allenby (2003), Stahel (2006), Stahel and Clift (2015), Bocken et al. (2016), and den Hollander (2018). However, with the important notion, as Cullen (2017) points out, there will always be leakage in the flows of resources and energy needed for keeping flows circulating, thus acknowledging that the ideal state of absolute circularity is a theoretical vision.

**Strategies for slowing down resource flows**  
(i.e. prolonging the time from extraction (A-B) to a closed loop is achieved (B-A) for the resource used, by reuse, upgrades & remanufacturing)

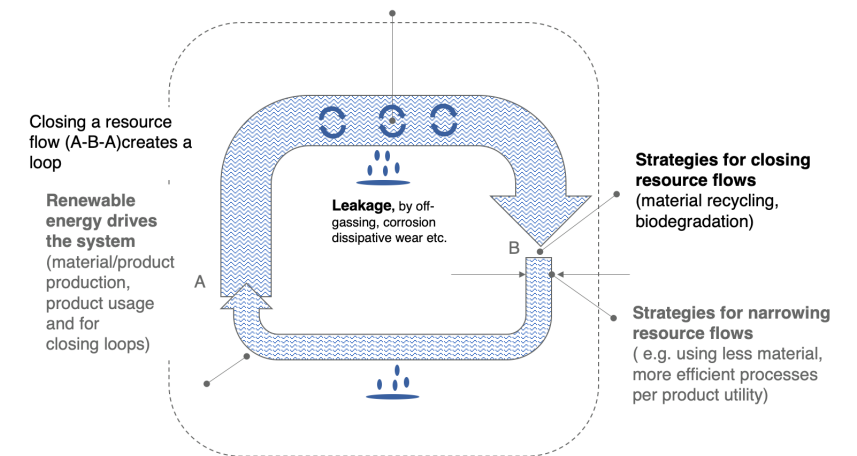


Figure 4. Basic principles for setting a vision in the CBMI framework. These principles are based on the absolute goal of a CE as a (theoretical) vision of an economic system that circulates resource flow and is driven by renewable energy. Each resource flow is represented by a specific resource category. Closure of several resource-flows creates a “lake” that over time builds a stock of resources, where value capturing is based within the economic system. Actuators that can manipulate and steer the resource flows in the system are strategies for closing, narrowing and slowing down flows. These three strategies result in business and design activities with the goal to create, deliver, and capture value from the stock of accumulated resources, and from the products and services being produced and used in the system.

Necessary preparations before starting the CBMI process for those appointed responsibility for it, or even if self-initiative is taken, the role as a “change manager” is to get buy-in from the top management, and a commitment that the top management on a regular basis will take an active role in the BMI process. This should be followed by setting up a separate group, “a dedicated team” consisting of people with necessary competencies and functions from business development and design. This team has and is given the prerequisites to distance themselves from the DBL in the firm’s current operations of the “performance engine” (c.f. Govindarajan and Trimble, 2010). This team can then start to build awareness and understanding about the current (problematic) state embedded in the organization’s DBL and the rest of the value chain.

The interventional approach in the CBMI process is derived from the methodology for lean startup and Customer Development (Ries, 2011; Blank and Dorf, 2012), as radical and architectural BMI will impose

top management to step into unknown territory and with a lack of prior experiences or successful examples to lean on. In the Customer Development process, a dedicated team builds knowledge by doing small-scale and cheap hypothesis testing and iterations, rapidly and in close contact with potential customers, to reveal essential barriers and make failures come at a low cost early in the process, thus preventing more essential expensive failures later on.

However, an essential difference in the CBMI approach, compared with Customer Development, is that the CBMI process aims to remain locked on the desired future state based on the business model principles for circularity. This differs from the traditional Customer Development approach, which allows for significant deviations from the original business model idea (pivoting).

After these preparations, that in a large and incumbent organization could be easier said than done, the process in the CBMI framework starts with step one, setting a vision of a future state of a CBM that covers all three

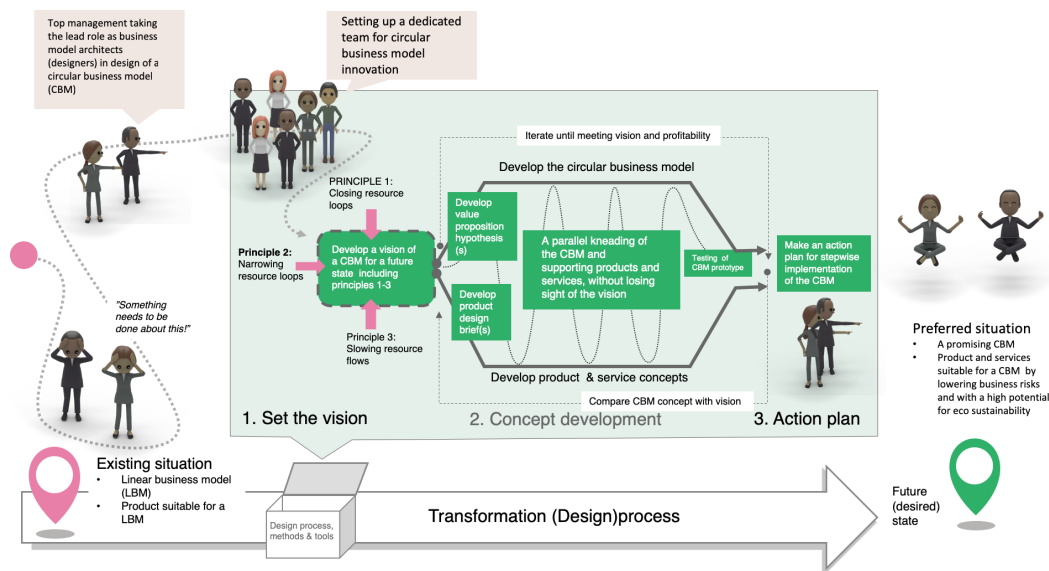


Figure 5: A tentative framework for circular BMI, aiming at slowing down resource flows by design for a CBM via product life extension. The framework a) draws from previously presented concepts of design as a change process (Simon, 1969), b) principles for Backcasting (Holmberg and Robert, 2000), c) customer development (Blank and Dorf, 2012), and d) is combined with various supportive tools for BMI and circular product design when deemed necessary during step 2. Image: © 2018 Thomas Nyström and Einar Dahl

strategies for CE. This vision then forms a platform to start identifying the main gaps compared to the present state. The reason for setting this vision based on a set of principles is to reduce the risk of deviations by the people involved or affected by the proposed CBM from the vision by theoretical and practical problems identified throughout the CBMI process.

Further, inspired from principles of CD and the value proposition designer (Osterwalder and Pigneur, 2010), step two is starting up the concept development phase by producing one (or multiple) value proposition hypotheses based on possible customer segment(s), which is summarized into an initial value proposition or propositions (VPs) that form a basis for the BM development. Hypotheses about suitable customer segments, their needs and functional requirements (pains, gains, and jobs to be done) are then summarized in one (or multiple) design briefs, forming a basis for starting the exploration of a design of a (conceptual) product or products or service(s).

Compared to proposed methods for Customer Development, for circular products, or components with high embedded economical and material values, the CBMI framework recommends working with several VPs aimed at different customer segments that deliberately form a chain of possible customers and users over several use phases. Preserving such embedded values in product categories with fast technological development and fashion changes, will decrease business risks by systematically designing for multiple product usages. To further minimize such risks of physical products becoming obsolete, the next steps in the conceptual design phase start with exploring possibilities for designing for product life extension by making them reusable and adaptable, with upgradability with new functionalities like new service content, better efficiency, or possibility to remanufacture, and materially recycle. This conceptual design is done in close cooperation with the BM development, in an iterative procedure identifying obstacles from too high costs to the need for new partners.

The conceptual BM development and design work in practice can be supported by the already wide variety of supportive methods, such as and that were suggested in the theory section. The approach is to intentionally use supportive methods and tools that are easy to grasp and that align with already established practices and processes in the organization, thus making the threshold low for learning and using the CBMI framework. The third and final step in the CBMI process is then to draw up an action plan for a stepwise implementation of the CBM and the supporting product and services over time, and help the firm to keep the aim locked on the vision.

After completing a CBMI process, the top management (hopefully) will be in a better position than before, to judge what business possibilities, risks, and organizational barriers there might be in their organization and the rest of

the value chain. If successful, the process will add knowledge that can affect the top management “adaptive capacity” (Kor and Mesko, 2013 p.241) and thus affect the system for decision making and resource allocations in the DBL.

The proposed CBMI framework shares an ideology with the framework proposed by Bocken et al. (2016), in considering BM development in conjunction with product design towards a vision. However, the difference is that the CBMI framework puts more emphasis on prerequisites for reaching the highest level of circularity, by a waste hierarchy (c.f. King et al., 2006 p. 258), thus aiming at radically increased resource productivity compared to if the OEM does a little bit of everything at a random priority. The CBMI approach would, in best cases, contribute to manufacturing firms embracing the full potential of a CBM with more predictable and manageable business risks, as well as with its higher potential for eco-sustainability.

## 6.5 Possible implications and consequences from the choice of qualitative methods

Single case studies have often been considered as of less scientific value, especially in the discourse about whether single case studies with mostly “context-dependent” knowledge can be generalizable to provide “content independent” knowledge (Flyvbjerg, 2006). Flyvbjerg (2006), however, argues that predictive theories cannot be found in studies about human affairs and consider context learning through case studies a prerequisite for a learning process, moving from lower levels of rule-based learning with general knowledge to deeper learning and becoming an expert. Flyvbjerg (2006) emphasizes that too much distance, from the object of study might lead to “blind academic alleys” with the unclear use of research outcomes.

To avoid what Eisenhard and Graebner (2007) describe as risks of bias by impression management, or retrospective sensemaking by the respondents, highly knowledgeable respondents with many years of experience from different hierarchical levels, selected and interviewed in the field studies (see Table 2). Flyvbjergs arguments thus underpin the approach in this study using a case study as the essential method for a learning process and to get close contact with the subject studied. Even if this might lead to difficulties to provide generalizable knowledge, and with the researchers, by their intervention, possibly affecting the participants, and vice-versa, with the researcher possibly being affected by the participants. However, as Flyvbjerg (2006 p.9) further argues, formal generalizable understanding is only one of many ways to gain knowledge within a specific field or society

in general, and can be of great scientific value, and has often helped to pave paths for scientific innovation, underpinned by examples from basic research in physics.

In this specific research, a challenge occurred during the action research process. The group of practitioners working with exploration of CBM in the main object of study (the automotive OEM), due to a heavy workload and changed internal directives from the top management, was delayed in their internal explorational work. However, even if this, to some extent, affected the possibilities to develop the proposed framework for BMI in conjunction with the internal group of practitioners, this did not affect the collection of data regarding current barriers in the organization or the collection of data about existing products.

The SSMA process here proved to be a strength in keeping the focus on the collaborative learning process, even if this process, according to Checkland (2006) will be more or less eternal. Also, in relation to this unexpected deviation from the initial project directives, it seems relevant to bear in mind what Checkland (2000 p.33) describes as challenging in doing action research in organizations with unpredictable human behaviors: “we can never know for sure what is going on inside the head of another person; and we cannot assume that their words necessarily reveal it”, illustrating a general problem in doing qualitative research, that there very seldom are exact answers to problems or any patent solutions, if humans are being involved in the studies.

**7**

**Summary  
and  
conclusions**

This thesis, based on theory and empirical findings, has taken the position that an OEM – at least in theory – can maximize resource productivity and reduce business risks in a stock based CBM by using design strategies for prolonging product life. A starting point in designing products for a CBM is to be aware of the reasons why existing products considered usable can become obsolete by aesthetic, technical, functional and social causes. These various drivers for premature obsolescence have to be carefully considered in the BMI process, as they simultaneously represent possible business threats as well as enablers for delaying obsolescence.

However, with hundreds of CE definitions, there is a “methodology soup” that makes it difficult for manufacturing firms to set clear objectives in their approach to a CE, or to know what strategies to use. Without implementing CE principles in a specific hierarchical order, there is a risk for disorganized approaches leading to incremental improvements such as the push for eco-efficiency has been criticized for.

Furthermore, one of the main conclusions is that the main challenges for design and production of adaptable and long-lasting vehicles that could perform better over several use cycles are not primarily design-methods or available technologies. The main barrier is instead embedded in the dominant business logic of the firm, with the design logic mostly being a faithful solution-provider for the DBL. Reasons for this are that the established business logic has proved to be profitable, and will always dominate, as the survival of the firm is invariably the most crucial aim for the top management.

However, as the current business logic in most firms today is taken for granted, and given that there is a lack of a well-organized approach to business model innovation (compared to the well-established structures and practices for product design innovation), making radical real changes to the established Business Model is difficult.

Adaptable design will turn the current design logic on its head by building modular and upgradable designs. Especially with consideration to general adaptability, i.e., to design for future unknown changes, adaptable design will challenge the development of organizations to make on-going assessments between costs and revenues with regard to future proofing products.

Paper I, and section 6.1 illustrates such barriers for adaptable design, by the subordinate role of design being a mere solution provider to the existing BM, as the dominant business logic sets the rules for the design logic in the firm. Any design logic not fitting this business logic faces a considerable risk of being discouraged.

Radical product design changes are thus dependent on being able to make radical changes to the business model, and that will be difficult. Hence, radically changing to design for product life extension requires designers to not only get buy-in from top management but also enroll them as business model architects.

Moreover, even if all CE strategies proposed in this thesis (e.g. reuse through second-hand sales, repairs and remanufacturing of components, and rebuilds of commercial vehicles, as well as experimentation with various mobility services) are already implemented in the incumbent automotive industry by several well established “islands” of practice and knowledge related to CE, and in many cases profitable, these islands are for the most part detached by the DBL in their large organizations and value chains, and not systematically using the full potential of being strategies for resource productivity. However, in theory the technical barriers for attaching these islands in a CBM could be rather straightforward, once a profitable business case for a CBM and adaptable products could be established.

Based on the pre-study in Paper II, and the theory section (3), there are differences in what make private cars, light commercial, and heavy vehicles obsolete. In general, products can become obsolete by aesthetic, functional, technical and social factors making them economic unattractive, but can the obsolescence-designated lifecycle of today’s vehicles be designed the other way around? What if cars intentionally were designed to adapt to perform better over time?

The simple answer to this question is that it would be technically feasible from a durability point of view. Heavy vehicles such as long-haul trucks are already designed to last many times longer than personal cars, due to different user needs. However, from the perspective of improving the vehicles Eco-sustainability performance by upgrades of components such as the drive train or computer system, the design challenges will be more difficult compared to today’s design. Consider however the design of commercial aircraft. They are designed for longevity and in many cases are upgraded with contemporary interiors as well as new engines and functionalities, used for decades, and used in a PSS. As Kasarda et al. (2007 p.727) state: “product life ends because a product is unable to adapt to change”.

Findings from the incumbent OEMs and the studied start-up companies described in Paper I, II and in chapter 5, gives a wide variety of business and design approaches to CE and CBM that are driven by bold visions of changing industries and the world to the better. These actors, by searching

for ways to overcome market barriers and enormous financial and technical challenges to become vehicle OEMs, are using CE strategies in their product design to create longevity and adaptability – even to the point of being somewhat explicitly communicated in their value propositions. These start-up actors, with more innovative technologies, production processes, distributing sales channels, and an alternative DBL, will disrupt traditional OEMs that are locked into a track by massive investments in existing technologies and manufacturing facilities.

Findings from theory and empirical field studies reported in Paper II and chapter 5 propose that the same drivers that today make products prematurely obsolete can be used the other way around, as enablers for designing for future adaptability. The proposed CBMI framework for exploring business and product design opportunities, in parallel with the CBMI framework, can – with manageable business risks and by setting a vision of a stock based CBM and using already existing islands of CE knowledge and practices – explore how a CBM with adaptable products and services can be feasible in their organization.

## 7.1 Industrial and scientific contributions

This thesis has illustrated the role of the dominant business logic and how circular design approaches that challenge the current Business Model will be more difficult to implement. This conclusion moreover challenges the often-made assumption in the field of sustainable design that designers have the most crucial role in the realization of eco-sustainable products. In fact, their power is limited to design proposals that do not challenge the firm's existing DBL too much.

Today there is a growing body of knowledge of CE, along with a vast amount of abstract definitions, frameworks for implementation, methods, and tools for circular design and product development, as well as established practices in the industry. All put together, these conditions can be seen as islands of knowledge and excellence applicable for developing products' suitable for the effectuation of circular business models. However, in most examples and research areas, the main focus has been on approaching CE with an eco-efficiency approach achieved through more efficient production or use, but not from the CE perspective of extending product life.

Available methods and tools for adaptable design also have a theoretical and technical focus, lacking alignment between business and design logic, making them difficult to use for practitioners within business and design. However, even if the idea of a circular economy has become a promising concept for the industry to keep up growth and sale and reduce externalities, a circular economy will not save humanity, but instead may buy us some

time. So here time once again becomes vital, as slowing down resource flows by extending the time of product utility to capture future values latent in (to borrow Stahel's term) the "lake" of already produced products.

## 7.2 Recommendations for further research

To overcome barriers to make incumbent OEMs explore CBMs and adaptable design, require challenging attitudes that exist both within organizations in the form of the dominant management logic (Prahalad & Bettis, 1986), as well as consumers logic for purchasing products and services, where customers and end users do not always make rational decisions based on maximizing product utility. That is, as attitudes, values and behavioural intentions play an important part in daily purchase decisions. Ignoring them can have an adverse effect on the profitability of a CBM and in general customer and end user's acceptance of adaptable vehicles is very much unclear today, and several possible challenges can be further investigated. For example, will customers trust parts of the car being 20 years old, while others are two months old? Or what if some components have been used in several other vehicles, will customers then accept these as long as safety and functionality are met? Further issues could be, for how long time it will be "acceptable or trustable" for a customer to keep a vehicle if it can be upgraded? How often do customers want to change interior details or other components if this was possible? Or to what level of detail upgrades must be visible and predictable to make the transition to this new logic viable?

A further potential problem area is with unwanted customer behaviour during product usage, and how to handle unwanted usage that could increase product wear, and what incentives can spur a desired product usage behaviour? These questions must be better understood. In PSS providing mobility services towards private customers, problems with both product-thefts and careless behaviour resulting in thrown away bicycles has been reported for example in bicycle-pools in China. How to handle unwanted usage could must be better understood.



# **Svensk sammanfattning**

## Adaptiv design för cirkulära affärsmodeller i den tillverkande fordonsindustrin

Visionen om en cirkulär ekonomi (CE) lovar både lönsamhet och miljömässig hållbarhet för tillverkningsindustrin och kan ur ett resursflödesperspektiv drivas genom att kombinera tre affärs- och designstrategier för att sluta, minska och bromsa flödes hastigheten för olika resursflöden. Att sluta resursflöden (genom att bilda en sluten loop) uppnås genom materialåtervinning, att minska mängden av använda resurser i loopen sker genom resurseffektivitet, såsom att använda färre resurser per producerad produkt eller under produktanvändning. Att sänka ner flödes hastigheten uppnås genom att öka användningstiden från "vagga till vagga" i en sekvens genom, återanvändning, uppgradering och återtillverkning av produkter, med syftet att förlänga produktivslängden och att bibehålla den maximala nyttjandegraden för produkterna så länge som det är fysiskt möjligt.

För ett tillverkande företag som vill utforska möjligheterna med en CE är strategier för att sluta och effektivisera resursflöden ett relativt enkelt sätt att minska användningen av jungfruliga material och bidrar till ett mer resurseffektivt samhälle. Ur ett produktdesignperspektiv är det också relativt enkelt genom alla redan tillgängliga metoder och verktyg för cirkulär design som ger stöd i att välja material som kan återvinnas och designa energieffektiva produkter m.m. Ur ett affärsperspektiv däremot, är det inte mindre än en revolution som efterfrågas, eftersom de flesta etablerade tillverkningsföretag (OEMer) över tid har utformat sina organisationer för att primärt fånga värde från att sälja de produkter de producerar i flödesbaserade linjära affärsmodeller. Logiken för att designa produkter är i sådana affärsmodeller väl i linje för att stödja detta värdefångande.

Således är radikal produktdesign, med design för att medvetet sluta, minimera och bromsa resursanvändning, i väletablerade OEMer beroende av motsvarande radikala affärsmodellförändringar, då det annars skapar stora interna konflikter med den befintliga affärsmodellen. Sådana hinder är särskilt svåra att bryta igenom om en OEM överväger att hålla ägandet över sina producerade produkter och istället erbjuda produkternas funktion(er) eller prestationer till sina kunder, istället för att använda de traditionella kanalerna med befintliga återförsäljare. En av de största riskerna med en sådan cirkulär affärsmodell (CBM) är att produkter som ägs av en OEM (och risker som normalt kunderna har i dag genom att produktägandet övertas av OEMen), riskerar att bli för tidigt utdaterade (obsoleta). Dvs kunder och användare bedömer produkterna som för dyra, ofunktionella, icke tidsenliga, farliga eller av andra skäl ointressanta att använda.

Trots en omfattande litteratur under de senaste åren kring affärsmodeller, affärsmodellinnovation, cirkulär ekonomi och design för en cirkulär ekonomi, finns det fortfarande många praktiska hinder i tillverkningsindustrin för en större omställning till cirkulära affärsmodeller med anpassade produkter som kan sänka affärsrisker i sådana CBM. Detta gäller speciellt för att designa produkter som systematiskt inkluderar alla tre av de ovanstående cirkulära affärs- och designstrategierna och där produkter avsiktligt utformats för återanvändning och att kunna förbättras under användningstiden för framtida okända behov och krav även efter att de lämnat produktionsbandet.

Trots dessa hinder är design av sådana framtidsadaptiva produkter (FA) en möjlig väg för ett tillverkningsföretag att både sänka sina affärsrisker i en CBM och samtidigt spara avsevärda mängder material och resurser under hela produktlivscykeln. Det vill säga, leda till ökad resursproduktivitet.

Syftet med denna licentiatavhandling är att bidra till och utöka diskursen om CE som huvudsakligen en gigantisk latent affärsmöjlighet för tillverkningsindustrin att lönsamt bli lite mer miljöbättre utan att göra några större förändringar i sin nuvarande affärs- och designlogik.

Forskningen utgår ifrån tre perspektiv; För det första undersöks och illustreras rollen som design som en leverantör av lösningar för den befintliga affärsmodellen med praktiska exempel ifrån industrin.

För det andra utforskas de utmaningar och möjligheter som finns för tillverkningsföretag att omfamna alla tre strategier för cirkularitet (sluta, minimera och bromsa resursflöden) för att uppnå ekologisk hållbarhet.

För det tredje beskrivs och diskuteras möjliga konsekvenser för utformning av framtidsadaptiva produkter som är lämpliga i "lager-baserade" CBM. Dvs. där produktägandet bibehålls av en tillverkare eller tjänsteleverantör. Slutligen föreslås en väg för vidare implementering av framtids adaptiv design inom den etablerade tillverkningsindustrin. Slutligen föreslås ett område för en framtida fördjupning av forskning kring framtidsadaptiv design.

Dessa ämnen undersöks genom en kombination av empiriska fältstudier baserade på intervjuer och workshops med aktörer inom bilindustrin, samt väletablerade aktörer och uppstarts företag som utmanar den rådande affärs och designlogiken. Slutligen jämförs dessa resultat med resultat ifrån intervjuer med nystartade företag som strävar efter att driva cirkulära affärsmodeller och som har utformar modulära och framtidsadaptiva produkter.

## Bakgrund och introduktion

Mot bakgrund av de globala hållbarhetsutmaningarna från en växande befolkning och ökad levnadsstandard där fler människor ägnar sig åt mer resurskrävande aktiviteter kommer de närmaste 30-40 åren att vara en kritisk tid att inte överskrida de planetära gränserna - särskilt med tanke på att de exakta gränserna för jordens övergripande ekosystem är oklara (Rockström et al., 2009). Inom tillverkningsindustrin anser många företag att det är avgörande att utforska vägar för hur de öka sin resursproduktiviteten och därigenom bli mer miljömässigt hållbara (Upward & Jones, 2016). I de bästa av världar uppstår en sådan hög resursproduktivitet när naturresurserna används så energi och material effektivt och ekonomiskt som möjligt (OECD, 2008) och detta ligger väl i linje med en traditionell industriell logik hos företag att vilja minimera sina kostnader och maximera sina vinster. För tillverkningsföretag som har linjära affärsmodeller (LBM) uppkommer sådana vinster från marginalerna som finns mellan försäljningspriset för en produkt och kostnaderna för material, utveckling, produktion och försäljning av dessa produkter.

Den dominerande affärslogiken (DBL) idag för att åstadkomma sådana vinster inom tillverkningsindustrin är att producera produkter baserat på massiv användning av jungfruliga material och resurser (ofta icke förnyelsebara), maximera tillverkningsvolymerna, minimera kostnaderna och med en produktdesign som gör gamla produkter föråldrade efter en "lämplig" användning tid, för att kunna upprätthålla försäljningen av nya produktmodeller. Modeller som kontinuerligt utvecklas och lanseras på dagens (mestadels), mättade och starkt konkurrensutsatta marknader.

I motsats till en sådan linjär affärslogik har visionen för en cirkulär ekonomi (CE) föreslagits som en gigantisk affärsmöjlighet för tillverkningsindustrin att lönsam bli "grön" utan gränser för fortsatt ekonomisk tillväxt (Ellen Mac Arthur Foundation, 2012,2015). Vid första anblicken kan CE visionen tyckas vara ett mycket lovande koncept, men genomförandet av en CE, kommer för företag som driver en LBM vara något radikalt utmanande. En väldigt förenklad vision för ett CE-system kan definieras som ett ekonomiskt system som inte genererar avfall och som drivs av förnybar energi, och där ekonomiska och materialmässiga värdet av de produkter, material som finns i omlopp i systemet bibehålls så länge som möjligt. I ett sådant cirkulärt system fångar företag ekonomiska värden ifrån lager av redan tillverkade och sålda produkter ackumulerade i lager (stocks) av resurser. Dagens linjära system kan beskrivas som ett kontinuerligt flöde (river) där en CE syftar till att vända dagens "flödesbaserade ekonomi" till en "lake"- och "loop" ekonomi" (Stahel, 2006).

Ur ett resurseffektivitetsperspektiv är CE-konceptet ett relativt enkelt sätt för tillverkningsindustrier att radikalt minska användningen av jungfruliga material genom att tillämpa affärs- och designstrategier för att sluta, effektivisera och bromsa ner material och resursflödena (Bocken et al., 2016). Ur ett produktdesignperspektiv är det också relativt enkelt genom att tillämpa redan tillgängliga designverktyg för till exempel cirkulär design eller metoder inom Design for X-paraplyet (Gatenby, & Foo, 1990, Ellen Mac Arthur Foundation & IDEO, 2017 ) som ökar medvetenheten och erbjuder praktiskt stöd till designers genom riktlinjer för att designa produkter för önskade egenskaper.

I en teoretisk vision för ett CE-system skapas det incitament att designa produkter som är anpassade för en optimerad resurseffektivitet. Detta kan ske genom att tillämpa affärs- och designstrategier för att även sänka flödes hastigheten av material och resurser (Bocken et al., 2016), genom en produktdesign som systematiskt kan förlänga produktlivet så att produkterna som används i CE-systemet (i en sekvens) för (1) återanvändning, (2) uppgradering och återtillverkning. Endast som en sista utväg skall sådana cirkulära produkter materialåtervinnas och cirkuleras tillbaka för att ingå till nya produkter.

Om man vidare lägger till ett affärsperspektiv kan sådana cirkulära och anpassningsbara produkter erbjudas genom värdeerbjudanden, där kunderna betalar för produktens funktioner eller prestanda, och där tillverkare eller tjänsteleverantörerna bibehåller produktägandet och kontrollen över sina produkter för att maximera produkternas nyttjandegrad i ett så kallat produkttjänstesystem (PSS) (Sakao et al., 2009). Inom PSS-forskningsfältet (Nasr & Thurston, 2006, Pearce, 2009; Tukker, 2004, 2013) har flera studier visat på en lovande potential för att lönsamt kunna minska resursförbrukningen i sådana PSS avsevärt.

Så här långt verkar det vara helt möjligt att ställa om till en CE, men jämfört med dagens linjära system kommer affärsriskerna vid en sådan förändring att bli mycket stora för att ett tillverkande företag om produktägandet och kontrollen över produkter bibehålls. Detta då produkterna har utformats för att säljas till återförsäljare som i sin tur säljer vidare till slutkunderna, och som utformats för att i många fall bli föråldrade av snabba mode, tekniska och funktionella förändringar. Att då anta ifrån att den högsta ledningen i ett väletablerat tillverkningsföretag (OEM ) plötsligt skulle överge sina befintliga eller planerade investeringar i produkter, för ny teknikutveckling och produktionsanläggningar etc., är osannolikt då det skulle innebära en smärre intern revolution i företaget. Särskilt eftersom de flesta väl-etablerade OEMer har haft mycket gott om tid på sig att optimera sina organisationer för att fånga ekonomiska värden ifrån att sälja varor i dessa finjusterade flödesbaserade affärsmodeller.

En försvårande omständighet för att kunna ändra dessa befintliga affärsmodeller (BM) är att det vanligtvis inte finns någon del av företaget som har det specifika ansvaret för den etablerade affärsmodellen, och som har mandatet att kunna genomföra radikala förändringar av den.

I stället är BM inbäddad i och drivs av företagets organisation som helhet och där endast Vd eller styrelsen kan besluta om radikala förändringar av den etablerade BM. Dvs det saknas en organisationsstruktur för affärsmodellinnovation (BMI), som vanligtvis finns för de flesta centrala områden i tillverkningsindustrin som tex. ny produktdesign eller teknisk innovation. Strukturer som i större OEMer ofta finns representerad i den högsta företagsledningen, och där det sker ett kontinuerligt och ofta systematiskt innovationsarbete.

Rollen av design som en process för förändring, eller rollen som designers som förändringsagenter för att påverka produktens övergripande livscykelegenskaper har diskuterats flitigt under många åren inom forskning och praktik inom eko-design, design för hållbarhet, cirkulär design och design-tänkande etc. Men i de flesta befintliga OEMer begränsas designers praktiska möjligheter att tillämpa sina färdigheter för cirkulär design i stor utsträckning av den dominerande affärslogiken (DBL). Frågan blir då, utifrån dessa organisatoriska utmaningar med stora affärsrisker och påverkan ifrån den nuvarande affärsmodellen för att kunna designa cirkulära produkter, var förändringsagenter i väletablerade OEMer skall börja för att ställa om organisationen mot cirkularitet?

## Syfte, forskningsfrågor och resultat

Denna avhandling presenterar och diskuterar hur tillverkningsindustrin teoretiskt kan optimera sin resursproduktivitet och minska affärsriskerna i en lagerbaserad CBM. Tonvikten kommer att ligga på cirkulära affärs- och designstrategier för att sänka flödes hastigheten av material och resursflöden, genom att förlänga livet på de produkter som tillverkas.

Detta kan ske genom design av produkter som kan anpassa sig till framtida förändringar (framtidadaptiva (FA)) och som då får en potential att radikalt kunna minska miljöpåverkan. Samtidigt som de bibehåller eller ökar de ekonomiska värden som finns inbäddade i dessa produkter när de används effektivt i ett PSS.

För att utforska hur sådana FA produkter kan designas i etablerade organisationer har följande forskningsfrågor formulerats:

RQ1: Vad kan vara utmaningar och möjligheter för ett etablerat tillverkningsföretag att omfamna alla tre affärs- och designstrategier för CE (sluta, effektivisera och bromsa material och resursflöden)?

RQ 2: Vad behöver en förändrings agent/design manager vara medveten om, om man skall föreslå en framtidadaptiv produkt till företagsledningen hos en befintlig OEM?

För att ta itu med dessa breda frågeställningar har två undersökande delfrågor formulerats:

RQ 1.2 Vilka drivkrafter finns för att olika typer av fordon blir utdaterade i förtid idag (premature obsolete)?

RQ 2.1 Vilka vägar är lämpliga för att operationalisera affärs- och designstrategier för CE, med målet att identifiera en CBM som kombinerar en potential för både lönsamhet och låga affärsrisker genom FA design, i tidiga utvecklingsfaser hos befintliga OEM-företag?

Ovanstående frågor har undersökts med hjälp av intervjuer och workshops med aktörer inom bilindustrin, i kombination med intervjuer med två små och medelstora företag som driver cirkulära affärsmodeller

De viktigaste resultaten från dessa studier är att CE-strategier för att sluta minska och bromsa ner resursflöden har funnits under lång tid inom bilindustrin, i form av materialåtervinning, (skrotning av gamla fordon) resurseffektivitet (material och bränsleeffektivitet) och återtillverkning. Dessa metoder resulterar emellertid i mycket låg resursproduktivitet. Det vill säga att väsentliga ekonomiska och materiella värden försvinner på grund av de dominerande affärs- och designlogikerna för att bibehålla resursflöden, som genererar intäkter genom stora volymer av producerade och sålda produkter.

De främsta utmaningarna för befintliga OEM-företag att genomföra en CBM är att hantera både en process för cirkulär affärsmodellinnovation och en designprocess för framtida anpassningsbara produkter parallellt. För att en OEM ska ha en chans att lyckas med den här tvådelade utmaningen måste ledande befattningshavare i befintliga OEM-företag ta rollen som BM-arkitekter/designers om den cirkulära affärsmodellen skall ha en chans att framgångsrikt kunna implementeras i en väletablerad OEMs organisation.

## Framtida forskningsfrågor

För att övervinna hinder som gör att befintliga OEM-företag kan utforska möjligheter med CBM och framtidsadaptiv design kräver en djupare förståelse för de logiker, attityder och beteenden som finns både inom organisationer i form av den dominerande managementlogiken (Prahalad & Bettis, 1986), som i denna avhandling beskrivits som den dominerande affärslogiken (DBL). Samt kunder och användares logik för inköp av produkter och tjänster, där kunder och slutanvändare inte alltid tar rationella beslut baserade på maximering av produktutnyttjande. Här spelar attityder och värderingar som resulterar i praktiska beteenden en central roll i dagliga köpbeslut. Att inte förstå eller ignorera sådana logiker kan ha en mycket negativ inverkan på lönsamheten hos en CBM. I dagsläget är kunders och slutanvändares acceptans av FA fordon mycket oklar idag och flera möjliga utmaningar finns som är kan vara lämpliga för fördjupade studier. Till exempel; kommer kunderna att lita på ett fordon där delar av bilen är tex. 20 år gamla, medans andra bara är några månader gamla?

Eller om några centrala komponenter har använts i flera andra fordon, kommer kunderna acceptera dem så länge som säkerhetskrav och funktionalitet uppfylls? Ytterligare problem kan vara hur lång tid det kommer att vara "acceptabelt" för en kund att behålla ett befintligt fordon om det kan uppgraderas med nya estetiska attribut och teknologier mm? Eller hur ofta skulle kunderna vilja ändra utseendemässiga detaljer eller funktionella komponenter om det skulle vara möjligt? Eller till vilken grad måste detaljuppdateringar vara synliga och förutsägbara för att göra övergången till en ny designlogik möjlig?

Ytterligare ett potentiellt problemområde är kring oönskade kundbeteenden vid produktanvändning och hur sådan oönskad användning kan öka produktslitaget och vilka incitament kan sporra till ett önskat produktanvändningsbeteende? I PSS som tex. tillhandahåller mobilitetstjänster genom cykelpooler mot privatkunder, har problem med både stöld av produkter och slarvigt beteende beskrivits till exempel i cykelpooler i Kina. Generellt behöver kunskapen kring sådana beskrivna kund- och brukarrelaterade utmaningar fördjupas för att bättre kunna designa framtidsadaptiva produkter som kan realisera potentialen för ökad resursproduktivitet inom tillverkningsindustrin.

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# Appended publications

## Aiming for circularity by product life extension, a radical activity requiring top managers to become business model designers

### Abstract

The idea of product life extension is one important principle for a circular economy and there is a growing toolbox for product designers to make it happen. However, due to the intertwined relationship between business and design logic, product life extension is not just a product design activity. This conceptual paper illustrates how product design is subordinate to and is a mere solution provider to the existing business model. It is the dominant business logic of a manufacturing firm (derived from its business model) that sets the rules for the design logic and any design logic not fitting the business logic will be discouraged. Radical product design changes are dependent on being able to make radical changes to the business model. Because the business model is implicit, not explicit like product design, changing it can be practically difficult. For example, often, there is no one part of the organization that has responsibility for the business model. It is owned and operated by the firm as a whole and often by top management. Hence, radically changing to a design for product life extension requires designers to not only get buy-in from top management but also enroll them as business model designers.

*Keywords:* Circular business models, Product Service System, Business and design logic, Circular Economy, Design for Circular Business Models

### Introduction

In a world with increasing ecological stress and resource challenges, the concept of a circular economy has been proposed as a promising route for manufacturing companies to do business that could achieve both profitability and eco-sustainability.<sup>1</sup> From a resource flow perspective, a circular economy can be defined by three simple principles: closing, narrowing and

<sup>1</sup> Ellen MacArthur Foundation, EMF. "Circular Economy Report - Towards the Circular Economy Vol. 1," 2012. Accessed September 13, 2018, <https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition>. 15  
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The Circle Economy, IMSA AMSTERDAM. Report by IMSA Amsterdam for Circle Economy April 2, 2013, "Unleashing the Power of the Circular Economy," 2013, accessed September 13, 2018, [https://mvonederland.nl/system/files/media/unleashing\\_the\\_power\\_of\\_the\\_circular\\_economy-circle\\_economy.pdf](https://mvonederland.nl/system/files/media/unleashing_the_power_of_the_circular_economy-circle_economy.pdf)

slowing resource loops,<sup>2</sup> i.e. with the aim of intentionally creating circular material flows in industrial systems. According to these principles, closing loops are achieved by material recycling and narrowing loops by resource efficiency, such as using fewer resources per product produced, or during usage. Slowing loops can be achieved by reuse and remanufacturing, extending product life to keep products at their highest utility for as long as physically possible. Seen from a resource perspective, this is a straightforward way for a manufacturing industry to radically reduce their use of virgin materials and enabling a significant, more resource efficient society.

From a product design perspective, slowing resource use is a relatively straightforward and already available through design tools, such as the DfX-methods,<sup>3</sup> focused on easy disassembly, recycling, modularity remanufacturing, upgradability etc. These tools offer support to designers with practical guidelines for designing products for desired characteristics. Thus, changing design logic for slowing resource use (e.g. product longevity) is well supported by previous work and could be seen as a doable engineering activity. Products can technically be designed for longer life. On the other hand, this may not be in agreement with the business logic of the firm. Most incumbent organizations have, over many years, optimized their organizations for capturing value from selling goods in a flow-based linear business model. As such, actually slowing resource use depends not just on product design, but on changing business logic and the organizations that use them.

Needless to say, there are still many barriers for a widespread adoption of circular economy principles in industry.<sup>4</sup> What these barriers are and how to overcome them is not yet well documented. There is a vast body of literature in recent years on business models and business model innovation, including from the organizational perspective c.f.<sup>5</sup> and in the circular economy<sup>6</sup> context, but research on business innovation for a circular economy is arguably in its infancy. This conceptual paper aims to contribute to this research space.

<sup>2</sup> Bocken, Nancy M. P., Ingrid de Pauw, Conny Bakker, and Bram van der Grinten. "Product Design and Business Model Strategies for a Circular Economy." *Journal of Industrial and Production Engineering* 33, no. 5 (July 3, 2016): 308–20. 309 doi:10.1080/21681015.2016.1172124.

<sup>3</sup> Gatenby, David A., and George Foo. "Design for X (DFX): Key to Competitive, Profitable Products." *AT&T Technical Journal* 69, no. 3 (1990): 2–13. doi:10.1002/j.1538-7305.1990.tb00332.x.

<sup>4</sup> Rizos, Vasileios, Arno Behrens, Wytze van der Gaast, Erwin Hofman, Anastasia Ioannou, Terri Kafyeke, Alexandros Flamos, et al. "Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers." *Sustainability* 8, no. 11 (November 23, 2016): 3. doi:10.3390/su8111212.

<sup>5</sup> Foss, Nicolai J. & Saebi. *Business Model Innovation, the Organizational Dimension*. Oxford University Press, (2015).

Teece, David J. "Business Models, Business Strategy and Innovation." *Long Range Planning* 43, no. 2–3 (April 2010): 191. doi:10.1016/j.lrp.2009.07.003.

Zott, Christoph, and Raphael Amit. "Business Model Design: An Activity System Perspective." *Long Range Planning* 43, no. 2–3 (2010): 216–26.

The paper's purpose is twofold. Firstly, it shows the role of design as a solution provider for the existing business model, illustrated by examples from industry. Secondly, it discusses the challenges and possibilities for a manufacturing firm to make the transformation by embracing all three strategies for circularity (closing, narrowing and slowing down resource loops) to achieve radical eco-sustainability<sup>7</sup> from extended product life with the help of literature from business, design and eco-sustainability fields of research.

## Theory

### ***The dominant business logic in large incumbent OEMs; the linear business model***

The business model of a firm is seen -by several scholars- as an image or a blueprint of the "core" logic of doing business. It reflects the management's hypothesis about value creation, by solving potential customers wants and needs, and identifying how to organise, get paid, and make a profit for delivering such values c.f.<sup>8</sup> Alternatively, the business model is considered as being a mediating device for capturing latent value(s) from technical innovations, as e.g. illustrated by Chesbrough & Rosenbloom,<sup>9</sup> in which a new business model helped the innovative, but at that time expensive, photocopier technology to diffuse in society. Henry Sloan, the CEO of GM between 1923 and 1946, suggested that: "*The business of business is business*"<sup>10</sup>, probably with the assumption that the main reason for companies to do business is to earn money and make a profit, and in the process, staying alive on the market.

Capturing value, along with competencies and technologies the firm should use and develop, and how to sell to which markets, are a few of the key

<sup>6</sup> Kirchherr, Julian, Denise Reike, and Marko Hekkert. "Conceptualizing the Circular Economy : An Analysis of 114 definitions." *Resources , Conservation & Recycling* 127, no. April (2017): 221–32. doi:10.1016/j.resconrec.2017.09.005.

<sup>7</sup> Radical eco-sustainability is defined as business models that has a logic that aim at what den Hollander refers to as a type III circularity, described in, den Hollander, M.C. "Design for Managing Obsolescence: A Design Methodology for Preserving Product Integrity in a Circular Economy," 2018.5. doi:10.4233/UUID:3F2B2C52-7774-4384-A2FD-7201688237AF.

<sup>8</sup> Foss, Nicolai J. & Saebi. *Business Model Innovation, the Organizational Dimension*. Oxford University Press, (2015).

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Teece, David J. "Business Models, Business Strategy and Innovation." *Long Range Planning* 43, no. 2–3 (April 2010): 191. doi:10.1016/j.lrp.2009.07.003.

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<sup>9</sup> Chesbrough, H., and Richard S. Rosenbloom. "The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-off Companies." *Industrial and Corporate Change* 11, no. 3 (June 1, 2002): 529–55. doi:10.1093/icc

<sup>10</sup> Merrifield, Ric. *Leadership Lessons: Henry Ford, Reed Hastings, Alfred Sloan, Sam Walton, Oprah Winfrey*. New Word City, Inc., 2018. Accessed September 19, 2018, <https://books.google.com/>

<sup>11</sup> Prahalad, C K, and Richard A Bettis. "The Dominant Logic: A New Linkage between Diversity and Performance." *Strategic Management Journal* 7, no. 6 (November 1986): 485–501. doi:10.1002/smj.4250070602.

components in what Prahalad & Bettis describe as the "*dominant general management logic*" of a firm.<sup>11</sup> Prahalad & Bettis first saw this dominant logic as a "*knowledge structure and a set of elicited management processes*"<sup>12</sup> for how managers (in a firm) conceptualize their business and make critical resource allocations decisions. This view was further evolved into viewing the dominant logic as an information filter,<sup>13</sup> where the managers only filter such data that they see as relevant, and ignore others. Relevant, data are then incorporated into the organization's strategy, values, systems, and routines etc. The result is a resource and capability infrastructure that will influence the firm's further search for growth, diversification and strategic experimentation.

Kor & Mesko, consider the dominant logic a central part in understanding dynamic managerial capabilities,<sup>14</sup> where managers, by their "*human capital, social capital, and cognition*", can orchestrate a renewal of a firm for evolutionary fit.<sup>15</sup> The concept of the dominant management logic and the interplay with dynamic managerial capabilities offers an explanation model for what forms a firm's decision making in their ongoing operations, as well as why changing their existing business model is often difficult to achieve.

In most established manufacturing companies, the dominant business logic,<sup>16</sup> has been- and still is – to pack intellectual and technological properties into physical products or bundles of products, and then sell them to customers in exchange for money in as large quantities as possible. In this transactional based model, the legal rights over a product are transferred at the point of sale from the seller to the buyer, who also inherits all responsibility for operations and product disposal.<sup>17</sup> This responsibility (and burden) includes future risks such as potential premature obsolescence. From a resource perspective, the throughput from most OEM's business models in the machine manufacturing sector is based on extracting and using virgin resources, which are digested in a linear cradle-to-grave manufacturing flow-based system of take, make, use and lose<sup>18</sup> without the OEM taking direct responsibility for the post-production destiny and various externalities from the life-cycle stages of their products

<sup>12</sup> Prahalad, C K, and Richard A Bettis. "The Dominant Logic: A New Linkage between Diversity and Performance." *Strategic Management Journal* 7, no. 6 (November 1986): 490.

<sup>13</sup> Bettis, Richard A., and C. K. Prahalad. "The Dominant Logic: Retrospective and Extension." *Strategic Management Journal* 16, no. 1 (1995):7. doi:10.1002/smj.4250160104.

<sup>14</sup> Adner, Ron, and Constance E. Helfat. "Corporate Effects and Dynamic Managerial Capabilities." *Strategic Management Journal* 24, no. 10 (October 2003): 1011–25. doi:10.1002/smj.331.

<sup>15</sup> Kor, Yasemin Y., and Andrea Mesko. "Dynamic Managerial Capabilities: Configuration and Orchestration of Top Executives' Capabilities and the Firm's Dominant Logic." *Strategic Management Journal* 34, no. 2 (February 2013): 233–44. doi:10.1002/smj.2000.

<sup>16</sup> As a direct analogy to the Dominant Management Logic, the concept of the Dominant Business Logic are introduced and will further in this paper be used as describing the current logic in a manufacturing company for capture and deliver value.

<sup>17</sup> Stahel, Walter R., and Roland Clift. "Stocks and Flows in the Performance Economy." In *Taking Stock of Industrial Ecology*, 137–58. Cham: Springer International Publishing, 2016. 140. doi:10.1007/978-3-319-20571-7\_7.

<sup>18</sup> Raworth, Kate, and Kate Raworth. *Doughnut Economics: Seven Ways to Think like a 21st-Century Economist*. Chelsea Green Publishing Company, 2017.212.

produced. Success, in this dominant business logic, is usually measured by the amount of value-added via sales, and by effect, the throughput of resources. This linear business model has for a long time been heavily criticized for creating most of mankind's negative environmental impacts, from overconsumption, premature product obsolescence,<sup>19</sup> creating low economic incentives and barriers for product recovery and accelerate waste generation etc..<sup>20</sup>

### Changing the dominant linear business logic with business model innovation

Although all firms, either articulated or not, employ a specific business model,<sup>21</sup> it is often taken for granted and seen as implicit in the organization. As an effect, business model innovation<sup>22</sup> in incumbent firms is rarely objectified, and responsibility is rarely appointed for in the same structured way as other innovation and product development activities (Figure 1). In large OEMs, this way of organizing has been described as “*machine bureaucracies*”, that has become “*fine-tuned to run as integrated, regulated machines*”<sup>23</sup>, performing repetitively standardized operating tasks like designing, producing and selling physical products. Design and product development activities in these organizations are often run as a recurring and cyclical process that uses a natural science-based approach of experimentation and testing that is owned by individuals and departments set-up specifically for these tasks. This process is carried out in detailed stages. From the very early stages of conceptual design coordinated by advanced engineering and design departments, to industrialization by product development and production departments. These activities are combined with, often deeply-rooted structures for aftermarket operations as resellers of products, spare parts and service etc..

As these machine bureaucracies are designed and optimized for specific purposes, they are also extremely difficult to reorganize and change when conditions change. According to Mintzberg,<sup>25</sup> organizational charts like the

one in Figure 1. can be used to reveal current positions and functions in a firm and how these positions are grouped into unit/departments, as well as illustrating flows of formal authority between them.

Without a formalized authority for business model innovation, as often is the case in incumbent firms in early development phases, any change to the business model (depending on how much a new business model will challenge the dominant business logic) has to be referred back up to the top management. This can result in a delay even when more radical business model innovation is warranted, for example when disruptive competitors, changing customer demands or, as this paper addresses, when implementation towards circular economy principles is initiated.

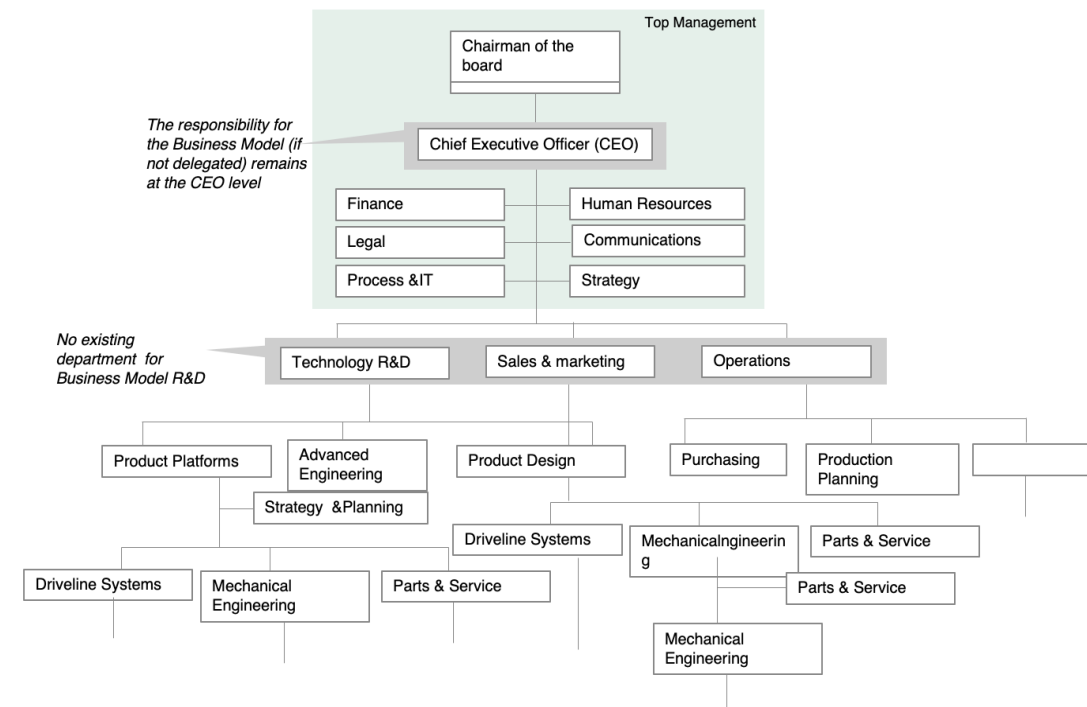


Figure 1. A generic organizational structure illustrating a mass production firm organized as a “*machine bureaucracy*”, adapted from Mintzberg,<sup>24</sup> combined with a contemporary manufacturing firm’s generic structure. Based on such a view, the responsibility for developing new business models can only be, if not having an own department, assumed to be watched over and gated by top management. The top management is not only the gatekeepers of the current business model but also for all major business model changes.

<sup>19</sup> Cooper, Tim. “Inadequate Life? Evidence of Consumer Attitudes to Product Obsolescence.” *Journal of Consumer Policy* 27, no. 4 (December 2004): 423. doi:10.1007/s10603-004-2284-6.

<sup>20</sup> See reference nr 1 for an overview over described problems with the linear economic model, e.g. in Ellen Macarthur's reports, or for waste generation e.g. King, Andrew M, and Stuart C Burgess. “The Development of a Remanufacturing Platform Design.” *Proceedings of the Institution of Mechanical Engineers*. 219:8 (2005): 623.

<sup>21</sup> Teece, David J. “Business Models, Business Strategy and Innovation.” *Long Range Planning* 43, no. 2–3 (April 2010): 191. doi:10.1016/j.lrp.2009.07.003.

<sup>22</sup> For an overview of some selected business model innovation definitions see e.g. Fallahi, Sara. “A Process View of Business Model Innovation.” Chalmers University of Technology, 2017.16. <https://research.chalmers.se/publication/253166>.

<sup>23</sup> Mintzberg, Henry. *THE STRUCTURING OF ORGANIZATIONS*. Prentice-Hall, 1979. 315. Accessed September 13, 2018, <https://www.nrc.gov/docs/ML0907/ML090710600.pdf>.

<sup>24</sup> Mintzberg, Henry. *THE STRUCTURING OF ORGANIZATIONS*. Prentice-Hall, 1979. 37. Accessed September 13, 2018, <https://www.nrc.gov/docs/ML0907/ML090710600.pdf>.

<sup>25</sup> Mintzberg, Henry. *THE STRUCTURING OF ORGANIZATIONS*. Prentice-Hall, 1979. 37. Accessed September 13, 2018, <https://www.nrc.gov/docs/ML0907/ML090710600.pdf>.

Regardless of who is responsible for the business model innovation process, it can be , according to Osterwalder & Pigneur’s popular Business Model Canvas<sup>26</sup> viewed as a “kneading” - within and/or between one or several of the “building blocks” in the business model.

According to Birkinshaw & Shazansari,<sup>27</sup> there are three main challenges for business model innovation: (1) The inertia caused by the existing business model , (2) the complexity of complementary elements and (3) how to establish and maintain coherence among business model elements. They exemplify these challenges by a framework (Table 1) dimensionalizing business model changes according to a depth dimension with incremental to radical changes and a breath dimension, wherein business model innovation can be *modular*, when some of the building blocks in the business model are changed) or *architectural*,when most of the building blocks are changed).

*Modular and incremental* changes in this model are described as small adjustments to the firms existing business model, such as adding new offerings to the firm’s existing products. This can be exemplified by an automotive OEM introducing a new financial leasing offering for cars. *Modular and radical business model changes*, on the other hand, would be if the OEM would add new services to their existing products, e.g. launching a subscription service of a car and thus creating several business models that must be managed in parallel or “ambidextrous”<sup>28</sup>, by both selling cars and selling subscriptions.

*Incremental and architectural changes* could be exemplified by the OEM designing a service that enables deliverance of groceries in the trunk of a car in the parking lot while the owner is at work.<sup>29</sup>

*Architectural and radical changes* represent the most extreme category as they demand fundamental change to the current business logic. This category could be exemplified by an OEM selling uptime instead of selling products, keeping ownership of produced products in a product service system (PSS) and keeping responsibility for operations, a responsibility that is currently held by their customers.

Table 1. Dimensions of different types of business model innovation, with the suggested role of top management for the various business model changes. Adapted from <sup>a</sup>

|  |  |  |
|--|--|--|
| → Depth of business model changes      | Incremental  | Radical  |
| ↓ Breath of business model changes     |  |  |
| Modular                                | Continuous innovation<br>E.g. financial leasing of cars          | Ambidextrous<br>E.g. a car as a service  |
| The suggested role for top management  | Only monitoring  | Sponsors   |
| Architectural                          | Evolutionary<br>E.g. a remote deliverance service to parked cars | Revolutionary<br>E.g. providing performance in a product-service system with kept ownership of produced products |
| The suggested role for top management: | Moderating   | business model architects  |

<sup>a</sup> Stieglitz & Foss in Foss, Nicolai J.&Saebi, and T. Saebi. Business Model Innovation: The Organizational Dimension. Oxford University Press USA, 2015.113.

Drawing from the model above, the various dimensions of changes in a business model innovation process pose different challenges to a firm’s top management. For small incremental changes with small adjustments of only some of the existing building blocks, there is no challenge to the dominant business logic, and the result of the business model innovation process may be aligned with the existing business logic. The top managements role is here only to monitor the progress and prevent business model innovation that risk to challenge the current business logic. For business model innovation with modular changes, top managements role is to sponsor and usually separate the new business model in a separate organizational unit. Radical changes, on the other hand, including changes that are evolutionary and especially architectural, pose a much bigger threat to the existing business model. Such changes suggest that most business model building blocks be modified, generating substantial organizational change and risks to the whole organization. Such business model innovation processes have to be rooted and aligned in the top management, needing them to be deeply involved in the everyday experimentation and strategic decision making.

<sup>26</sup> Osterwalder, Alexander, Pigneur, Yves. Business Model Generation: A Handbook for Visionaries, Game Changers and Challengers. John Wiley & Sons, 2010.

<sup>27</sup> Birkinshaw & Shazansari in Foss, Nicolai J.&Saebi, and T. Saebi. Business Model Innovation: The Organizational Dimension. Oxford University Press USA, 2015.114.

<sup>28</sup> Pal, Rudrajeet, and Arun Pal Aneja. “Ambidexterity Drivers of Value-Creation and Appropriation in Business Models An Explorative Study from DuPont.” Research Journal of Textile and Apparel 21, no. 1 (2017): 2–26. doi:10.1108/RJTA-09-2016-0021.

<sup>29</sup> Volvo Cars, In-car delivery, Accessed, September 20, 2018, <https://incardelivery.volvocars.com/#/>



## Design: a solution provider for the dominant business logic

From a perspective of an incumbent manufacturing firm, the traditional logic of using design since the late 1800's has been as an enabler for the success of the firm's dominant business logic. It has mostly been associated with decoration (styling) of the mass-produced artifacts' aesthetic properties, as e.g. shape and color etc. The potential of design as a solution provider for the dominant business logic became very clear during the 1930's when the US automotive industry by GM introduced annual model changes. With intense marketing, GM was able to differentiate themselves in a fierce recession-era business environment. They also started to build what has become a very established consumer culture around individual ownership of cars, where the metric of success for this design-logic has been its contribution to the earning of money.

The status quo in this dominant business logic is a design logic that provides solutions "in harmony" with the dominant business logic. Disharmony could, of course, occur when definitions of good work differ between competencies in the organization.<sup>30</sup> A product design could fail by reasons of too little effort spent on aesthetics, wrong aesthetics or functionality, insufficient durability, or a price that's too high resulting in insufficient sales. But the real clashes occur when the design logic starts to challenge the dominant business logic. As an illustration of design as a solution provider for the dominant business logic, Table 2. compares business and design logic of two startup companies, both selling consumer electronics: smartphones versus tracking devices for personal belongings. Even if these firms operate on the same consumer electronics market, they have different business models, which affects their approach to product design from a circular economy perspective quite a lot.

These examples illustrate two different approaches in which the product design provides a solution for the existing dominant business logic/ business model. In the case of Fairphone model 2, it has a design for an estimated life-length of five years, by easily exchangeable modules and with the intention that end-customers themselves could disassemble and exchange modules that are broken. This modularity and design for repair are supported by a business logic that encourages customers to repair by-offer spare parts at a low cost. Such a long-planned life expectancy is considerably longer than for the average usage time of smartphones today,<sup>31</sup> which can have a significant eco-sustainability potential depending on the energy usage during the use phase.<sup>32</sup> Of course, actual consumer behavior, such as the consumer's willingness to upgrade the operating

<sup>30</sup>Koppman, Sharon. "Making Art Work: Creative Assessment as Boundary Work." *Poetics* 46 (2014): 1–21. doi:10.1016/j.poetic.2014.09.001.

<sup>31</sup>Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann, P. "The Global E-Waste Monitor." Bonn/Geneva/Vienna., 2017.21. <https://www.itu.int/en/ITU-D/Climate-Change/Pages/Global-E-waste-Monitor-2017.aspx#ExecutiveSummary>.

<sup>32</sup>Bakker, Conny, Feng Wang, Jaco Huisman, and Marcel Den Hollander. "Products That Go Round: Exploring Product Life Extension through Design." *Journal of Cleaner Production* 69 (2014):13. 10–16. doi:10.1016/j.jclepro.2014.01.028.

Table 2. Comparing a circular with a linear business model regarding design being a solution provider for the existing business model

### Example A: FairPhone Model 2, a modular smartphone



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Fairphone offers customers a smartphone designed for longevity. Fairphone has ambitious goals to change the way smartphones are made throughout the whole value-chain by designing long-lasting (and for some components upgradable) phones with recyclable materials.

Left: A Fairphone Model 2, with its components being removed by use of simple tools and instructions printed on the modules.

| Business logic   | Design logic  |
|--|---|
| Buy and use the phone for as long as possible.                                       | Fairphone 2 is designed with a modular setup where the phone's components are easy to disassemble with standard tools or by hand by the users themselves.                                 |
| Software upgrades for improving battery life.  | The camera can be upgraded to improved image quality.   |
| Spare parts sold at a low price, giving economic incentives for customers to repair. | Ifixit, an NGO that publishes repair instructions of consumer electronics, ranked Fairphone 2 as the easiest to repair of all major smartphones models on the market in 2015 <sup>c</sup> |
| Suppliers of spare parts are contracted for three years after the last day of sales. |   |
| Own take-back system for already sold phones.  |   |

**Example B:** Tile, a Bluetooth tracker for personal belongings



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Tile offers location tabs that help customers locate their personal belongings. The tabs can be placed on keys etc. and located/managed by a smartphone app. Each tile has a sealed design and an internal battery, that has a (by Tile) guaranteed life-length of one year.

Right; A sawn apart and disassembled Tile, revealing the printed circuit board (PCB) with a standard battery, being soldered to the PCB.

| Business logic  | Design logic  |
|---|---|
| <p>An economy of scale, buy a new Tile that is guaranteed to function for one year.</p> <p>After a one-year customer gets a message in the app that there is time for replacement, offering a discount price if buying a new one.</p> <p>No take back system available.</p> | <p>A sealed design without possibility to change the battery by the end customer, unless he/she mechanically breaks the casing and desolders the battery.<sup>b</sup></p> <p>However, the design of the Tile, with a split line, indicates that it should be possible to open the housing for battery replacements.</p> <p>After one year, the app indicates that the tag needs to be replaced, and eventually, the old Tile stops working.</p> |

<sup>a</sup>Fairphone 2 modular design, last modified August 30, 2018, <https://screenshots.firefox.com/zkUAnEpVXS47viQj/www.flickr.com>

<sup>b</sup>Several repair videos for Tile battery replacements are available on youtube: Accessed September 2, 2018, <https://www.youtube.com/watch?v=-TwBraUQJIA>

<sup>c</sup>Ifixit, Smartphone Repairability Scores, last modified October 10, 2018, <https://www.ifixit.com/smartphone-repairability?sort=>

system, and the mere availability of what is required to do an upgrade, such as the support from Google of old Android operating systems, affects the actual life-length in the end. In order to address this, Fairphone is exploring possibilities to develop their business model even further, providing the phones as a service and retain ownership. This strategy would then enable Fairphone to control both the hardware and software upgrades on the stock of phones being in use, and thus minimize the risks of customers not upgrading their phones as needed and then deeming their phones to be obsolete prematurely. By doing these activities Fairphone illustrates a dominant business logic that embraces all three circular strategies, for closing, narrowing and slowing down resource loops.

The TILE tracker, on the other hand, is designed for a fixed life-length of one year. Even if it would be technically feasible to use Tiles for additional use cycles, they have due to safety, environmental, reliability concerns and to keep up with fast changes in new technology (according to Tile)<sup>33</sup>, a sealed design. This disallows simple battery change runs counter to many other small consumer electronics (many watches, music devices, lighting etc) that allow customers or other actors access to change batteries and make other small repairs. The result of such a design for premature product obsolescence <sup>34</sup> is the generation of a lot of electronic-waste, as TILE themselves claim to have sold more than 10 million products and has no take-back system for used Tiles. Instead, customers are encouraged to send their technological obsolete Tiles for “proper recycling”, that in practice will result in various types of recycling depending on the geographical market. The design logic described here exemplifies a linear business and design logic that is common for many other consumer electronic products, increasing the growing global E-waste stream of small electronic equipment.<sup>35</sup>

Despite the potentially great difference in resource outcome, the design logic is in harmony with the dominant business logic and business model for both described examples, In the case of Fairphone, customers are given economic incentives to keep and repair their phones with cheap spare parts and repair themselves, with software updates intended to prolong battery life, something not always being the case for other smartphone manufacturers.<sup>36</sup> In the Tile case, it is the opposite as the existing product

<sup>33</sup>reTile replacement program, Accessed 19 September, 2018, <https://support.thetileapp.com/hc/en-us/articles/200550678-What-is-reTile->

<sup>34</sup>Rivera, Julio L., and Amrine Lallmahomed. “Environmental Implications of Planned Obsolescence and Product Lifetime: A Literature Review.” *International Journal of Sustainable Engineering* 9, no. 2 (March 3, 2016): 119–29. doi:10.1080/19397038.2015.1099757.

<sup>35</sup>Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann, P. “The Global E-Waste Monitor.” Bonn/Geneva/Vienna., 2017.40. <https://www.itu.int/en/ITU-D/Climate-Change/Pages/Global-E-waste-Monitor-2017.aspx#ExecutiveSummary>.

<sup>36</sup>See for instance the lawsuit against Apple for slowing down older iPhones due to battery issues. Accessed September 15.

<https://appleinsider.com/articles/17/12/20/apple-responds-to-reports-of-worn-battery-forcing-iphone-cpu-slowdown>

Accessed September 15. <https://appleinsider.com/articles/17/12/28/criminal-lawsuit-over-iphone-battery-slowdowns-filed-in-france-where-planned-obsolescence-is-illegal>

becomes premature obsolete after one year, by the software App in the user's smartphone, and customers are encouraged to buy a new Tile at a discount price.

## Circular economy and circular business model innovation

The concept of a circular economy has in recent years attracted extensive interest from business, policy-making and research communities and can be seen as an umbrella of ideas that include, as a base, resource life-extending strategies that can: “*extend the productive life of resources as a means to create value and reduce value destruction*”<sup>37</sup>. Circular economy has offered a discursive space and structure for debate. The rapid growth in the number of academic publications and consultant reports has so far resulted in more than hundreds of definitions, varying in their focus and suggested endstate, whether circular economy is a means of minimizing waste, of boosting economic growth or for increasing eco-sustainability.<sup>39</sup>

Business model innovation, for its part, has by several scholars been pointed out as a strong enabler for a transition towards a circular economy cf.<sup>40</sup> by opening up businesses to design and implementation of circular business models. Such a business model relies on a set of circular economy principles<sup>41</sup> with the core in the business logic being to assign responsibility for the product value and its lifecycle to a manufacturer or service provider. As e.g. illustrated by Linder et al., in defining a circular business model as: “*a business model in which the conceptual logic for value creation is based on utilizing economic value, retained in products after use in the production of new offerings*”. However, as den Hollander points out, such definitions do not take into account the major differences in the intended outcomes between the “relative” approaches in eco-design, e.g. the assumption that a product inevitably will become waste at some point versus the “absolute” end goal of circularity in design for a circular economy.<sup>42</sup> Stated simply, den

<sup>37</sup> Blomsma, Fenna, and Geraldine Brennan. “The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity.” *Journal of Industrial Ecology* 21, no. 3 (June 2017):605. doi:10.1111/jiec.12603.

<sup>38</sup> Kirchherr, Julian, Denise Reike, and Marko Hekkert. “Conceptualizing the Circular Economy : An Analysis of 114 Definitions.” *Resources , Conservation & Recycling* 127, no. April (2017): 221–32. doi:10.1016/j.resconrec.2017.09.005

<sup>39</sup> Zink, Trevor, and Roland Geyer. “Circular Economy Rebound.” *Journal of Industrial Ecology* 21, no. 3 (2017): 593–602. doi:10.1111/jiec.12545.

<sup>40</sup> Lewandowski, Mateusz, and Mateusz. “Designing the Business Models for Circular Economy—Towards the Conceptual Framework.” *Sustainability* 8, no. 43 (January 18, 2016). doi:10.3390/su8010043.

Linder, Marcus, and Mats Williander. “Circular Business Model Innovation: Inherent Uncertainties.” *Business Strategy and the Environment* 26, no. 2 (February 2015): 1-16. doi:10.1002/bse.1906. Sarasini, Steven, and Marcus Linder. “Integrating a Business Model Perspective into Transition Theory: The Example of New Mobility Services.” *Environmental Innovation and Societal Transitions*, no. September (2017): 0–1. doi:10.1016/j.eist.2017.09.004.

<sup>41</sup> For an overview of circular economy principles see page 605 in Blomsma, Fenna, and Geraldine Brennan. “The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity.” *Journal of Industrial Ecology* 21, no. 3 (June 2017)

<sup>42</sup> den Hollander, M.C. “Design for Managing Obsolescence: A Design Methodology for Preserving Product Integrity in a Circular Economy,” 2018.26. doi:10.4233/UUID:3F2B2C52-7774-4384-A2FD-7201688237AF.

Hollander suggests then that a true circular business model, i.e. one that fits the circular economy concept, not only focuses on value after use possibly making small improvements, but will seek the maximum circularity possible. “*A circular business model describes how an organisation creates, delivers and captures value in a circular economic system, whereby the business rationale is designed in such a way that it preserves product integrity to a maximum extent, minimizes leakage and resorts to the use of resources in the process of creating, delivering and capturing value only when the options for using resources have been exhausted, in order to achieve the most complete cycling of materials within the larger economic system possible.*”<sup>43</sup>.

By this wide variety of approaches towards a circular economy and circular business models, but with a lack of clear definitions, approaching a circular economy offers a vast palette of business possibilities from a management perspective in a manufacturing firm as well as potentially huge business risks and challenges from an eco-sustainability perspective.<sup>44</sup>

As a way to explore such challenges, three basic circular economy principles,<sup>45</sup> closing, narrowing and slowing down resource loops (as illustrated in the introduction section) will further be used in this paper to explore business and design strategies for circular economy. Using these principles (or strategies) will, based on the firm's current dominant business and design logic, result in more or less business and design challenges and more or less, eco-sustainability potential, as illustrated in Table 3.

<sup>43</sup> den Hollander, M.C. “Design for Managing Obsolescence: A Design Methodology for Preserving Product Integrity in a Circular Economy,” 2018. 83. doi:10.4233/UUID:3F2B2C52-7774-4384-A2FD-7201688237AF.

<sup>44</sup> Korhonen, Jouni, Antero Honkasalo, Jyri Seppälä, Antero Honkasalo, and Jyri Seppälä. “Circular Economy: The Concept and Its Limitations.” *Ecological Economics* 143 (January 2018):41.. doi:10.1016/j.ecolecon.2017.06.041.

<sup>45</sup> Bocken, Nancy M. P., Ingrid de Pauw, Conny Bakker, and Bram van der Grinten. “Product Design and Business Model Strategies for a Circular Economy.” *Journal of Industrial and Production Engineering* 33, no. 5 (July 3, 2016): 308–20. doi:10.1080/21681015.2016.1172124.

<sup>46</sup> Govindarajan, Vijay, Chris Trimble, Books24x7 (e-book collection), and Inc Books24x7. *The Other Side of Innovation: Solving the Execution Challenge*. Boston, Mass: Harvard Business School Pub, 2010.

<sup>47</sup> Guiltinan, Joseph. “Creative Destruction and Destructive Creations: Environmental Ethics and Planned Obsolescence.” *Journal of Business Ethics* 89, no. S1 (August 26, 2008): 19–28. doi:10.1007/s10551-008-9907-9.

Tukker, Arnold. “Product Services for a Resource-Efficient and Circular Economy - a Review.” *Journal of Cleaner Production*, 2013. doi:10.1016/j.jclepro.2013.11.049.

<sup>48</sup> Nyström, Thomas, Lisbeth Svengren Holm, and Patricia Van Loon. “Future-Adaptability for Energy and Resource Efficient Vehicles.” In *Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 5: Design for X, Design to X*, Vancouver, Canada, 21-25.08.2017, 5:269–77, 2017.

Williander, Mats Linder, Marcus, and Thomas Nyström. “THE ORGANIZATIONAL IMPACTS OF A PRODUCT-SERVICE BASED business model INNOVATION PROCESS IN AN INCUMBENT MANUFACTURING FIRM.” *Proceedings of the 22nd Innovation & Product Development Management Conference IPEDM 2015*,

Nyström, Thomas, and Mats Williander. “THE business model , THE SILENT RULER OF DESIGN LOGIC.” In *The 6th International Conference on Life Cycle Management in Gothenburg 2013*, 1–4, 2013. <http://conferences.chalmers.se/index.php/LCM/LCM2013/paper/view/508/109>.

<sup>49</sup> King, Andrew M, and Stuart C Burgess. “The Development of a Remanufacturing Platform Design.” *Proceedings of the Institution of Mechanical Engineers*. 219:8 (2005): 623–31.

Bakker, Conny, Feng Wang, Jaco Huisman, and Marcel Den Hollander. “Products That Go Round: Exploring Product Life Extension through Design.” *Journal of Cleaner Production* 69 (2014): 10–16. doi:10.1016/j.jclepro.2014.01.028.

Tukker, Arnold. “Eight Types of Product – Service System : Eight Ways To Sustainability ?” *Business Strategy and the Environment* 260 (2004): 246–60. doi:10.1002/bse.414.

Table 3. Based on the three principles for a circular economy: closing, narrowing and slowing down resource flows, a firm running a linear business model and exploring possible circular economy strategies, will face various challenges from the existing business model and the firm's "performance engine" c.f.<sup>46</sup>. Strategies for material recycling (1) will pose fewer challenges, than aiming for a strategy for product life extension (3), that will affect most of the firms existing business model components, as well as (theoretically) enable the highest eco-sustainability potential. If (3) is combined with (1&2).

| Category-<br>tion of cir-<br>cular econ-<br>omy<br>strategies <sup>a</sup> | Business strat-<br>egies<br>Capturing value<br>from ...   | Design strat-<br>egies<br>Creating and<br>delivering<br>value from....   | Dimensions<br>of business<br>model<br>change <sup>b</sup> | Challenges for manu-<br>facturing firms running a<br>linear business model <sup>c</sup>   | The potential for<br>Eco-sustainability<br>by the degree of<br>circularity <sup>d</sup> |
|--|---|--|---|---|---|
| <b>1: Closing<br/>resource<br/>loops</b>                                   | Sourcing recy-<br>cled materials<br><br>Recycling from<br>own production<br><br>Eco-labeled<br>products                                   | Design for<br>material<br>recycling  | Modular/<br>Incremental                                   | <b>LOW</b><br><br>Externalise cost for<br>recycling<br><br>Handling quality issues,<br>as fast wear out, risks of<br>toxic substance content<br>etc.  | <b>LOW</b>  |
| <b>2: Narrowing<br/>resource<br/>loops</b>                                 | Reducing the<br>cost of mate-<br>rials used in<br>production.<br><br>Fuel efficiency<br>Lightweight,<br>eco-efficient &<br>green products | Design for<br>material<br>efficiency by<br>Eco-design  | Architectural/<br>Incremental                             | <b>MEDIUM</b><br><br>Handling quality issues<br>as fast wear out from<br>lightweight design etc.<br><br>Risks of not meeting<br>compliance<br><br>Cost for avoiding com-<br>pliance as e.g. "Diesel<br>gate"  | <b>MEDIUM</b>   |
| <b>3: Slowing<br/>resource<br/>flows</b>                                   | A circular busi-<br>ness model,<br>offering:<br><br>Function or per-<br>formance in a<br>product service<br>system(PSS)                   | Design for<br>product life-<br>extension by:<br><br>Durability<br>Upgradability,<br>Remanu-fac-<br>turing<br>Servitization | Architectural/<br>Radical                                 | <b>HIGH</b><br><br>How to keep up sales<br>from longer lasting<br>products?<br><br>How to balance cost for<br>product-longevity/pro-<br>duction?<br><br>How to innovate new<br>service content?<br><br>How to get customer<br>acceptance for intangi-<br>ble values in a PSS<br><br>How to avoid cannibal-<br>ization | <b>HIGH</b>   |

<sup>a</sup> Adapted from Bocken et al.<sup>2</sup> and seen as three possible design and business strategies for approaching the Circular Economy

<sup>b</sup> Adapted from Birkinshaw & Shazansari's<sup>25</sup> dimensions of business model changes (Table 1.)<sup>c</sup> Based on cf.<sup>47</sup> and the author's own research about implementing circular business models and PSS in manufacturing companies<sup>48</sup>

<sup>d</sup> Based on research from cf.<sup>1,2,29,30,49,56</sup>

Applying all three principles/ strategies illustrated in Table 3. is considered to have the highest potential for eco-sustainability by prolonging product life and continuously looping product's back into the system for extended use phases and finally closing the material loops by recycling, at the final end of product life. The Narrowing loop strategy could increase the eco-sustainability potential even more if renewable energy is used for production and during the product's use phase. This is especially relevant for energy demanding products. However, even if approaching all three strategies for a circular economy has the highest eco-sustainability potential, it will also pose most challenges on the existing linear business model. Compared if the firm only focuses on e.g. closing the loop activities as making their products easier for recycling. Or saving energy or materials in production, by the narrowing loops strategy, that rather support the already established industrial logic of reducing costs.

In comparison with the two product examples in Table 2., applying the first strategy of closing loops, are well in line with Tile's current approach while Fairphone's approach can be considered to be in line with all three strategies.

### The role of design as a solution provider for a circular business model

Based on the previous lines of thoughts of design being a solution provider for the existing dominant business logic, the following section elaborates routes to follow towards a circular design logic. Fuad-Luke<sup>50</sup>, points out that designers with their catalytic power shape the world and has more potential to slow environmental degradation than politicians, economists, businesses and environmentalists. Guiltinan further argues that significant progress has been made in creating a strong culture for sustainable design among product designers.<sup>51</sup> However, designers don't work in isolation and can rarely act as free agents, being under the scrutiny of the current production and marketing system<sup>52</sup> and from the dominant business logic of the firm, they are working for. The dominant business logic, will then inevitably give input to the design process that sets limitations for the outcome, forcing the design logic to support the existing business model. E.g. with a prescribed target price, a minimum annual sales volume, a specific production-technique, or the use of certain materials etc.. Joore, illustrates this dilemma by citing Tukker et al., regarding conflicts in approaches to design for sustainability as: "Designers, who are action-oriented, simply

<sup>50</sup> Fuad-Luke, Alastair. The Eco-Design Handbook : A Complete Sourcebook for the Home and Office. Thames & Hudson, 2002.15.

<sup>51</sup> Guiltinan, Joseph. "Creative Destruction and Destructive Creations: Environmental Ethics and Planned Obsolescence." Journal of Business Ethics 89, no. S1 (August 26, 2008): 23. doi:10.1007/s10551-008-9907-9.

<sup>52</sup> Nieuwenhuis, Paul. Sustainable Automobility: Understanding the Car as a Natural System. Edward Elgar Publishing Inc., 2014.

start with all their great creativity to work on new sustainable solutions, only to be caught by the unpleasant surprise that the world for some reason does not implement many of their beautiful ideas”.<sup>53</sup> Nevertheless, there could, of course, be exceptions as e.g. Fallahi points out. Some business model innovation activities start “unintentionally” as “skunk works”, from the bottom up innovation activities<sup>54</sup> by engaged individuals such as designers in the organization, and can slowly rise to the top management and be implemented. Such unintentionally business model innovation can be of great importance but will be difficult to implement as soon as the current dominant business logic is challenged. To “intentionally” manage circular product designs, it then becomes crucial to set the “right” input criteria’s from the business model, into the product design process. Today, there is a large body of available knowledge, giving designers a wide range of frameworks, processes, and tools that can give structure and support for circular product design. E.g. standards for eco-design<sup>55</sup>, supported with a wide variety of tools<sup>56</sup>, e.g. in the DFX umbrella, with Design for Remanufacturing, Upgradability, Design for Product Service Systems.<sup>57</sup> Or, more specific methods for Circular design<sup>58</sup>, Cradle to Cradle<sup>59</sup> and Biomimicry<sup>60</sup> etc.

Over the years, the view of design has also slowly started to change, from being an obedient servant for the dominant business logic, emerging into one considering design as a tool for problem-solving as well as a strategic tool in management<sup>61</sup>, such as suggested by the concept of design thinking in 2000s cf.<sup>62</sup>. This view of design both as a problem-solving process and as a managerial tool for change aligns with top management roles for radical business model innovation suggested by Stieglitz & Foss. Namely, it is suggested that they should change from being moderators and sponsors to taking a lead role as architects (or designers) of the process. Hence, given the broad palette of available methods and tools in combination with the previously described approaches to circular design, and circular business

<sup>53</sup> Joore, Peter. “New to Improve – The Mutual Influence between New Products and Societal Change Processes.” Delft University of Technology, Delft, The Netherlands, 2010.6.

<sup>54</sup> Fallahi, Sara. “A Process View of Business Model Innovation.” Chalmers University of Technology, 2017. 37. <https://research.chalmers.se/publication/253166>.

<sup>55</sup> ISO 14006:2011, Environmental management systems -- Guidelines for incorporating eco-design, Accessed September 17, 2018, <https://www.iso.org/standard/43241.html>

<sup>56</sup> Marta Rossi, a, \*, Michele Germani, a, Marta Rossi, a, et al. “Review of Ecodesign Methods and Tools. Barriers and Strategies for an Effective Implementation in Industrial Companies.” *Journal of Cleaner Production* 129 (2016) (2016): 361–73.

<sup>57</sup> Vasantha, Gokula Vijaykumar Annamalai, Rajkumar Roy, Alan Lelah, and Daniel Brissaud. “A Review of Product–Service Systems Design Methodologies.” *Journal of Engineering Design* 23, no. 9 (September 2012): 635–59. doi:10.1080/09544828.2011.639712.

<sup>58</sup> See for instance: Ellen MacArthur Foundation & IDEO, *The Circular Design Guide* (2018), Accessed September 17, 2018, <https://www.circulardesignguide.com/>

<sup>59</sup> Braungart, Michael, William McDonough, and Andrew Bollinger. “Cradle-to-Cradle Design: Creating Healthy Emissions – a Strategy for Eco-Effective Product and System Design.” *Journal of Cleaner Production* 15, no. 13–14 (September 2007): 1337–48. doi:10.1016/j.jclepro.2006.08.003.

<sup>60</sup> Benyus, Janine M. *Biomimicry : Innovation Inspired by Nature*. New York: New York : Perennial, 2002.

<sup>61</sup> Brown, Tim, Martin, Roger. “Design for Action How to Use Design Thinking to Make Great Things Actually Happen.” *Harvard Business Review*, no. September (2015): 1–10. doi:<https://doi.org/10.1016/B978-0-08-022245-5.50032-3>.

<sup>62</sup> Martin, Roger. “Design Thinking: Achieving Insights via the ‘Knowledge Funnel.’” *Strategy & Leadership* 38, no. 2 (March 9, 2010): 37–41. doi:10.1108/10878571011029046.

models, it seems far-sighted to say that there is the lack of supportive tools and methods for circular product design and that this lack constitutes the main barrier for development and implementation of circular business models. Rather, it is more likely the fact that incumbent ss mostly are designed for ongoing operations with the dominant business logic setting the scope and limitations for product design, making conflicts between the established business model and circular design proposals that challenge it inevitable.<sup>63</sup> Thus, a possible route forward is to align business and design logic in early phases of business model innovation and in parallel “knead” the business model and develop circular design proposals that can be in harmony with a circular business logic. Such an approach could as Brown and Martin point out be seen as two parallel design challenges: Namely: Design of, both the artifact itself and the “intervention that brings it to life”.<sup>64</sup>

## Discussion and conclusions

By embracing all three strategies for a circular economy, closing, narrowing and slowing down resource loops there is an increased potential for a manufacturing firm to increase both resource efficiency and profitability. This complete approach can be compared with only focusing on how to make resource flows closed by material recycling, or narrower by implementing eco-efficiency in production, or by incremental product improvements. If circular economy is to be a concept and set of tools for incrementally saving resources and reducing waste and minimizing environmental impact, it is already aligned with a traditional industrial logic of saving costs. But if circular economy is to be a concept suggesting systemic change, it will undoubtedly be more challenging to a firm’s current business logic of keeping up a continuously high flow of products produced and sold, as both the existing logic for earning money and delivering value to customers will be challenged. This challenge could be especially difficult for large OEMs, organized as “machine bureaucracies”. A change to a circular business model<sup>65</sup>, providing functional sales or performances in a product service system<sup>66</sup>, requires both top managements direct and dedicated engagement for a significant period of time. If the responsibility for business model innovation is not delegated down, it will not become operationalized in the organization, and the initiative is likely to fail.

<sup>63</sup> Govindarajan, Vijay., and Chris. Trimble. *The Other Side of Innovation : Solving the Execution Challenge*. Harvard Business School Pub, 2010. 11.

<sup>64</sup> Martin, Roger. “Design Thinking: Achieving Insights via the ‘Knowledge Funnel.’” *Strategy & Leadership* 38, no. 2 (March 9, 2010):59. doi:10.1108/10878571011029046.

<sup>65</sup> Linder, Marcus, and Mats Williander. “Circular Business Model Innovation: Inherent Uncertainties.” *Business Strategy and the Environment* 26, no. 2 (February 2015): 182–96. doi:10.1002/bse.1906.

<sup>66</sup> Beuren, Fernanda Hänsch, Marcelo Gitirana Gomes Ferreira, and Paulo A. Cauchick Miguel. “Product-Service Systems: A Literature Review on Integrated Products and Services.” *Journal of Cleaner Production* 47 (May 2013): 222–31. doi:10.1016/j.jclepro.2012.12.028.

However, as the dominant business logic in most firms today is taken for granted, and in this paper assumed to dominate over the design logic, it drives firms to focus on core activities that support their existing logic, such as capturing value and keeping their shareholders happy, since the survival of the firm and profitability are crucial, and always must be handled by the top management. Thus, even if product design is considered to be a key activity, the design logic must support the existing business model, either being linear, circular or of any other kind. Circular product design beyond closing (material recycling) and narrowing resource loops (eco-efficiency, such as product life extension), will be of no exception as new product designs will always be filtered by the dominant business logic and with the interplay of the top management's dynamic managerial capabilities. Thus, embracing principles for a circular economy without the top management acting as business model designers will then be very challenging, or even pointless.

The aim of this paper has been to nuance the discourse about how to implement a circular economy in manufacturing firms. It illustrates that the primary challenge for incumbent OEMs to design and implement a circular business model with a design for product life extension is not related to technology or design abilities to create such products, but in fact related to organizational capabilities such as managerial capabilities in top management and business model innovation.

Moreover, considering the power of the dominant business logic in determining the ultimate success of circular design proposals, it is critical that design or “change” managers with ambitions to propose circular design to top management be aware of possible challenges. Ultimately, top management will have to be convinced and/or join in the business model design process. One final conclusion is that more attention in research should be given to today’s lack of a well-organized approach to business model innovation in most manufacturing firms.

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## FUTURE-ADAPTABILITY FOR ENERGY AND RESOURCE EFFICIENT VEHICLES

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### Abstract

In contrast to linear business models, circular business models (CBMs) assign the product value and its lifecycle responsibility to a manufacturer or service provider where customers get access to functionality and performance during multiple use cycles. A CBM requires (due to the increased business risk for product obsolescence) suitable products designed for long service life, changes in service content, repair, upgrades and remanufacturing. This paper illustrates drivers that can make three categories of vehicles obsolete in a circular business model. We propose a conceptual framework where drivers for obsolescence are used as enablers for future adaptable design, exemplified with industry cases. Future adaptable vehicles have the potential to be both profitable and energy and resource efficient during use and in end of life in a CBM. However, it will challenge today's business models with a design logic that rewards longer and more flexible product life. Current barriers are legislation, standards and certification, and consumer acceptance. Besides organizations barriers and a general reluctance to changes.

*Keywords:* Adaptable design, Business models and considerations, Product-Service Systems (PSS), Conceptual design

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## 1 INTRODUCTION

Humanity has always faced challenges to adapt in order to find food, shelter, and make tools to solve various problems (Darwin, 1859 in Hekkert et al., 2008) with limited resources. During industrial development, thriftiness was both necessary and considered as financially sound (Lovins, et al., 2007) but also to stay competitive with continuous and increased product sales, that today has created a path dependency towards faster replacement cycles to retain sales volumes as markets become saturated. In a business logic where continuous new products and a short lifespan is rewarded and integrated into manufacturing companies' business models, design and marketing play a central role as both the engine of continuous product innovation, new value propositions, as well as a tool for a "planned obsolescence" (Slade, 2006). As the current business model affect the existing design and decision logic quite effectively, it has to be addressed first in manufacturing companies that want to make significant ecosustainability improvements (Nyström and Williander, 2013). In a circular economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized" (European Union, 2015) there will be increased incentives to design products with controllable and longer lifespans that systematically can be reused, upgraded, remanufactured, and as a last resort be recycled. Especially for companies aiming at develop and implement a CBM, and considering to keep ownership over their products, and sell functions or performances in a product service system (PSS), where service content may have to be changed occasionally. The current rapid rate of technology changes for example in autonomous drive, collision protection systems, electrification etc. will probably increase the pace at which on board vehicle systems will become obsolete in the years to come. However, vehicles produced and sold today rarely perform better than initially rated for and when introduced on the market, but why cannot a vehicle perform better the older it gets? This research aims to combine the business and design perspectives to answer the question; how can adaptable design help OEMs in the transition towards a circular economy? Narrowed down to the questions of: (1) What factors drive obsolescence of different types of vehicles today? (2) What are prerequisites for design of future-adaptable vehicles that could perform better over time? (3) What are examples of adaptable design that can lower business risks in a circular business model?

## 2 THEORY

### 2.1 What is a circular business model?

A circular business model assigns the responsibility over the product value and its lifecycle to a manufacturer or service provider and is here defined as

"a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings" (Linder and Williander, 2015). Circular business models rely on a set of circular economy principles where products systematically should be designed to fit biological and technical material cycles (Braungart et al., 2007). Where waste becomes "food" in a preferred sequence of reuse, remanufacturing and material recycling (Stahel, 2013). The literature on CBMs, also called closed-loop business models, is large but fragmented. It covers areas like product service systems (Tukker, 2004), industrial symbiosis (Chertow, 2007), and remanufacturing, reverse and closed-loop supply chains (Guide and Van Wassenhove, 2001).

### 2.2 What is adaptable design?

Adaptable products could, according to Gu and Hashemian (2004) be divided into specific and general adaptable products, indicating different degrees of complexity. The specific adaptable product allows potential applications that are foreseen at the time when the product is initially designed, for example the possibility to upgrade a product with a certain amount/type of memory. This is somewhat less complex compared to the general adaptable product, which can be described as a product designed to adapt to future unknown needs and requirements that are unforeseen at the point of design, for example prepare the product for different types of future memory upgradability. Adaptable products and adaptable design build on existing design methods, including modular design, platform design, and mass customization (Li et al., 2008). Other aspects that are discussed are durability and upgradeability (Li et al., 2008), reliability and robustness (Uckun et al., 2014; Willems et al., 2003); product attachment (Hekkert, 2008), and the possibility to extend functions, either obtained within the existing parts or due to replacement of components (Li et al., 2008). A further aspect is strategies to control product wear and history for preventive maintenance (Cullinen, 2013). Gu et al. (2004) and Zhang et al. (2015) differentiate between design adaptability and product adaptability. Design adaptability means that the design process can be adapted to generate variations of a product. Zhang et al. (2015) defined this as "an approach to design adaptable products" that can be changed/adapted, such as reconfigured and upgraded, during a product operation stage to satisfy different requirements of customers".

### 2.3 Drivers for product obsolescence?

According to Chapman (2005) and Cooper (2004), product durability, (technical lifetime), is often not the main reason for discarding the product as the actual product lifetime largely depends on the user, his or her

behaviour, and socio-cultural influences. Rai and Terpenney (2008) define obsolescence, from a product design perspective, as “a measure of a product’s loss in value resulting from a reduction in the utility of the product relative to consumer expectations”. Cooper (2010) identified four modes of obsolescence (aesthetic, social, technological, and economic). A fifth dimension (functional) is defined by Caccavelli and Gugerli (2002) as “the lack of ability to provide sufficient level of services to the users with regard to their needs and expectations”. Aesthetic obsolescence occurs according to Cooper (2010) when a customer discards a product no longer considered fashionable, or perceived to be worn out. Technical obsolescence occurs when new technology due to innovation replaces a product (Rai and Terpenney, 2008). Changes in social norms and behavior, laws, voluntary standards etc. can reduce or eliminate the need for certain products, making them social obsolete, driven both from societal changes in preferred aesthetics (Teo and Lin, 2010; 2012), as well as in technical changes. Or forced by physical obsolescence (Guiltinan, 2009) for example by “death dating”, where a product will be worn out, or completely stop working after a specific time of usage (Slade, 2006). Economic obsolescence can according to Cooper (2004) occur due to depreciation, high cost of repair or maintenance relative to replacement, or due to low performance / cost ratio of the product.

## **2.4 The time factor**

Time influences all artefacts that humans create and all that we do (Thompson et al., 2011). Sooner or later all human artefacts will start to degrade and decrease in human value due to a specific or combination of the above obsolescence drivers. Since the fifties, the dominated trend has been an increased speed in most humans’ activities, such as personal traveling, communications and time-saving in product development and production is seen as crucial. For example, the fashion brand Zara requires only approximately 15 days, to get from design-concept to a product in store<sup>1</sup>, while the average time to market is 6 months. Also the pace of new technology introduced vary significantly between different product categories, while data processing and storage capacity in information and communication technology (ICT) has a fast development rate, for example in on-board vehicle-systems as infotainment and navigation systems, mechanical components or accessories could take much longer time before becoming obsolete. The effects of increased pace in product renewal and shorter product lifetimes, is increased resource consumption (Krausmann et al., 2009), and waste from obsolete products, which seriously affects planetary boundaries (Rockström et al., 2009).

## **3 METHOD**

The research follows an inductive approach to develop the basis for further research. The knowledge has been built upon a literature review, personal in depth interviews and focus groups with OEMs and exemplary cases from industry. We employed an abductive approach based on systematic combining (Dubois and Gadde, 2002). Initially we reviewed previous literature and compiled a list of tentative challenges in current business and design logic that formed a questionnaire used.

### **3.1 Data collection**

Four companies within the automotive sector participated in the research study. Three of them are manufacturing passenger vehicles and vehicles’ components, construction equipment, and service vehicle interiors. The fourth company is a large fleet owner of heavy vehicles and machinery. In-depth interviews with several participants at each company were held to understand their current business and design logic. Participants of the interviews included at least one person responsible for design, one for business strategy, and one for marketing or customer relationships. The same set of questions were asked to all persons, regardless of their background, to understand the relationship between design and business. After the one-on-one interviews, (company internal) workshops were conducted where a scenario for a CBM and a conceptual framework with a set of enablers for future adaptability were presented (Table 1). A following discussion highlighted opportunities and barriers towards such a scenario based on historical and existing company activities, as well as implications between current product design and business development. Based on the proposed set of enablers a search and collection of industrial examples was made to exemplify how these enablers can be visible in industry today. The examples chosen were based on a combination of personal interviews, study visits and public company information.

### **3.2 Data analysis**

Based on company-interviews, workshops and the literature study, four levels of adaptability were identified and categorized as follows; 1: Adaptable infrastructure: A supportive infrastructure that can provide different types of fuels and energy and that can be adapted to changing needs of volumes and sizes. 2: Adaptable fleet: A flexible fleet of vehicles that can fulfil the changing requirements of mobility. 3: Adaptable vehicles: Customer products that are adaptable to the changing requirements of the

users. 4: Adaptable components: Sub systems or components that are used by the end-consumer as part of a larger product. For example, an electronic controller in a vehicle that can be upgraded with more processing capacity or software. Due to a further research focus on product level, we will only discuss enabling factors and industrial examples on product level (adaptable products).

## 4 RESULTS

During the interviews with participating and inspirational example companies, the main drivers for traditional automotive OEMs in B2C were described as primarily designing vehicles for cost-efficient production, with continuous investments in facelifts, new design and technology that can attract new customers, while keeping brand loyalty to existing customers. There is no explicit intention to keep products as long as possible on the market, by making them more adaptable, even though aftermarket services were described as a very profitable business activity today (compared to the profit on vehicle sales). For products with high material and component values as for construction equipment, aviation and space industry products, very long usage times, remanufacturing and rebuilding operations have become business as usual, but limited to remanufactured components like alternators, generators etc. in the B2C segment. However, remanufacturing and rebuilding of heavy vehicles also has limitations from a technical, economic and social (legislative) perspective. For example, can the life time of special retrofitted accessories (common on refuse vehicles), be much longer than the lifetime of the carrying vehicle, and reusing old accessories on new vehicles can be very difficult and costly. Social reasons as improved emission legislation, or a higher focus on ergonomics, can also lead to certain vehicles being banned or being less attractive, influenced by political pressure as procurement criteria. Or due to personal motivations from customers. Both in B2B and B2C markets, today's rapid ICT development rate is described as drivers for obsolescence, as vehicles may not be able to be upgraded to autonomous drive, automatic brake functionality, electric drivetrains, etc. without changing the overall product architecture. A practical example is the "in-car delivery"<sup>2</sup> service that is dependent on the fact that the cars' hardware can provide delivery companies one-time access to the car boot. Aesthetical aspects are described as a stronger driver for obsolescence in the B2C market than in B2B, although regular aesthetical upgrades are made in B2B vehicles to build a visual identity for heavy vehicles. B2B customers also expect different looks from previous models or expecting a lower price if no updates are made since. Among B2C customers and large fleet owners there is a rising trend to lease instead of owning a personal car, or to buy mobility, a specific functionality or a performance, for example a certain amount of material per hour.

### 4.1 Designing for adaptability

Design for future adaptable products will most certainly challenge designers, engineers and business developers, not only to identify today's users' needs, but also to broader imagination about future needs that can make the product obsolete and thus increase business risks for the product owner in a circular business model. Designing for adaptability will need a different approach regarding those factors that today drive products to be obsolete as previously been discussed, and the same driver that makes a product obsolete can theoretically be used to prevent obsolescence, if taken into account in the business development and design process for adaptability. Below we propose a conceptual framework with enablers that can be prerequisites for designing future adaptable products. These enablers could be used alone or in combination to optimize the design. Under each main enabler we propose tentative subenablers that can help in the detailed design work.

Table 1. A conceptual framework with main and sub "enablers" for design of future adaptable vehicles<sup>3</sup>

| Aesthetical enablers   | Functional enablers  | Technical enablers  | Social enablers   | Economical enablers  |
|--|--|---|---|--|
| <b>Emotional attachments</b><br>(keeping product contemporary over time)<br><b>Product history</b><br>(provenance) | <b>Modularity</b><br><b>Platform-design</b><br><b>Open architecture</b><br><b>Upgradeability</b><br><b>Standardisation</b> | <b>Durability</b><br><b>Serviceability</b><br><b>Controllable wear</b><br><b>Upgradeability</b><br><b>Remanufacturing</b><br><b>Recyclability</b> | <b>Access and transparency</b><br>(open design)<br><b>Co &amp; user-driven innovation</b> | <b>Value recovery</b><br><b>Traceability</b> (position, behaviour, history)<br>Off book solutions (enabler for PSS)<br><b>Responsibility</b> (e.g. retained ownership from an OEM or service provider) |

### 4.2 Examples of enablers for adaptable design in industry today

The examples in Tables 2,3,4,5 and 6 illustrate how different enablers for product adaptability can be used in practice as steps towards product adaptability. The examples are based on a combination of personal interviews, study visits and company information. The examples are mainly

from the automotive sector, with two exceptions from the telecom industry illustrating better the current trend towards modularity and reparability, and the increasingly used ICT in vehicles, for example by autonomous drive. Besides, actors outside the automotive industry developing their own autonomous vehicles.<sup>4</sup>

Table 2. **Aesthetical enablers:** Keeping products contemporary over time


|   |   |  |
|---|---|--|
| <p><b>Example:</b> The Mini<br/>www.mini.com</p>  | <p><b>Enablers for adaptability:</b></p>  |  |
| <p>The Mini, launched in 1959 has become an iconic product sign for small cars. The current design still bears traces of the original mini character from the 50-ies, even with significant updates in the exterior design.</p> | <ul style="list-style-type: none"> <li>- A human inspired exterior design with a personal character</li> <li>- A balance between novelty and typicality, where the original product sign still can be recognised in current models</li> </ul> | <p>Image: Thomas Nyström</p>   |

Table 3. **Functional enablers:** Modularity & Platform design


|   |  |  |
|---|--|--|
| <p><b>Example:</b> Modular smartphones<br/>https://atap.google.com/ara/</p>   | <p><b>Enablers for adaptability:</b></p>   |                                    |
| <p>Several actors in the telecom industry as LG, Motorola and Google has developed modular smartphones with upgradeable modules. Even if add-on modularity has been available for long time for accessories, this trend is more advanced. And, in some cases (Fairphone, Google ARA) also based on different business models.</p> | <ul style="list-style-type: none"> <li>-A modular design made for exchangeable modules</li> <li>-Open hardware and software protocols</li> <li>-An intention to build a community of developers</li> <li>-A possibility to customise modules by personal shape, colours and patterns by 3D printing</li> </ul> | <p>A prototype of the Google project ARAs "endoskeleton" with exchangeable hardware modules. Image: Maurizio Pesce</p> |

Table 4. **Technical enablers:** service and reparability

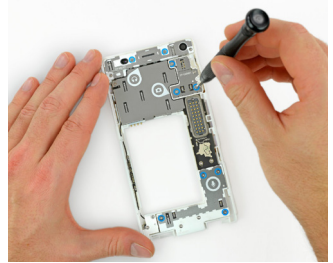


|  |   |   |
|--|---|---|
| <p><b>Example:</b> Fairphone<br/>www.fairphone.com</p>   | <p><b>Enablers for adaptability:</b></p>  |    |
| <p>Fairphone tries to change the way smartphones are made throughout the whole value chain via design for long usage time, recyclable materials and fair working conditions. Fairphone 2 is designed with a modular setup where components are easy to disassemble and repair with standartools by the users themselves.</p> | <ul style="list-style-type: none"> <li>-Design for longevity and repair</li> <li>-Low margins on spare parts</li> <li>-Supply of spare parts after last day of sales.</li> <li>-Open software</li> <li>-Robust cover to prevent screen damage</li> <li>-Expandable memory and two sim cards, reduces the need for an extra phone.</li> <li>-Expansion port for future applications</li> </ul> | <p>The mainframe in Fairphone 2, designed for easy repair. Visual indications show functions of the modules (white rings), and fastening point for screws (blue rings). Image: Ifixit.org</p> |

Table 5. **Social enablers:** Co creation and micro production

|   |   |   |
|---|---|---|
| <p><b>Example:</b> Local Motors<br/>https://localmotors.com/</p>  | <p><b>Enablers for adaptability:</b></p>  |  |
| <p>Local Motors is a start-up company with the aim to disrupt current ways of designing and producing vehicles, with cocreation, standard components, 3D printing and "micro" production plants. By this Local Motors claim to have shorten development time, reduced cost in product development, and produced several vehicles for both private use and for mobility as a service (MAAS).</p> | <ul style="list-style-type: none"> <li>-Open hardware and software protocols.</li> <li>-A large co-creation community</li> <li>-A community that can be engaged both as users and paying customers</li> <li>-Intellectual property investors that want to realize products.</li> <li>-Flexible production of vehicles and spare parts.</li> </ul> | <p>Local Motor's autonomous shuttle "Olli". Image: Azra Habibovic</p>                 |

<sup>4</sup>For example Googles self-driving car; https://waymo.com/journey/

Table 6. **Economical enablers:** value recovery

|  |  |   |
|--|--|---|
| <p><b>Example:</b><br/>Remanufacturing and rebuild of construction equipment <a href="http://www.remanufacturing.eu">www.remanufacturing.eu</a></p>  | <p><b>Enablers for adaptability:</b></p>   |  <p>Image: <a href="http://www.pixabay.com">www.pixabay.com</a></p> |
| <p>Remanufacturing (REMAN) of components and rebuild of entire construction machines is well established at most construction equipment manufacturers. Machines that have been in heavy use can usually be rebuilt several times, before material recycled. By reusing old engines, up to 66% of the energy consumed in the production stage can be saved.</p> | <ul style="list-style-type: none"> <li>-Customers want to use their machines as cost effective as possible.</li> <li>-A possibility to rebuild machines to original specifications for at least two life cycles.</li> <li>- Some vehicle components can be upgraded, if changes occur in production</li> <li>-The used parts (cores) have a value which reduces the price of REMAN components</li> </ul> |   |

All the previously described enablers for product adaptability can be used by business developers and designers. Used one by one, they can be tools for ideation of incremental steps towards circularity. Used as a whole palette, it can be useful for developing circular business models with a combination of products and services that can lower business risks and increase energy and resource efficiency. By using parts of the vehicle longer and thereby reducing the negative environmental impacts from mining and production, while simultaneously upgrading energy consuming parts with new technology that leads to improved energy efficiency and lower emissions during the use phase, we anticipate massive environmental improvements in the vehicle fleet. In the next phase of our research, we will test this hypothesis. In addition, other barriers and enablers for adaptable design will be further assessed and design methods for adaptability will be established. For example, adaptable design might meet organizational barriers, since it most likely increases development cost in business development and early design phases, which require taking a calculated risk. Other aspects that need further investigation are e.g. deeper understanding of product users and products attachments over longer periods of usage time than today, legislation and certification issues that might limit the reuse potential of products, for example when upgrading a diesel engine to better emission standards than original. Or if material ingredients, allowed at first market introduction, has been restricted at the point of resell or remanufacture years later.

## 5 DISCUSSION AND CONCLUSIONS

Today, islands of knowledge and excellence applicable for developing adaptable products exist, in the automotive industry as well as in research fields such as product modularity, mass customization, design for X, predictive maintenance, and product attachments etc. Multiple lifecycle strategies have also been extensively researched, including reuse, refurbishment, remanufacturing, and recycling. However, in most examples and research areas, the main focus has been on a more efficient production, and not on making products more adaptable during its use phase. And where available methods and tools for adaptable design have a theoretical and technical focus, not aligned with business and design logics, making them difficult to use for practitioners within business and design. We therefore see a need to bridge and combine existing knowledge of adaptable design with business model innovation, to be able to handle the complexity in the transformation from a linear to a circular business model.

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## Appendix A: Interview guide used in the pre-study and the empirical studies A1 and A2

### Background:

The question - how vehicles can be designed for value preservation, longer life and a radically reduced energy consumption? is central in the transition towards a circular economy. Especially for manufacturers who want to offer products, features or performances through service-based business models.

The increased business risk for vehicle manufacturers that vehicle remains attractive and functional over time can be managed by making vehicles more future-adaptive.(FA)

The pre-study identifies obstacles and opportunities related to design of hardware (physical products) in relation to service content (soft products) for a service based business model.

### *Understanding business as usual – status quo.*

#### **Use phase and product characteristics**

How does an average product lifespan look like for your products? (the period from product acquisition to discarding of the product by the final owner)

What products (models) are most sensitive to wear out (do you know why)?

What products (models) are most durable in your range (do you know why)?

What are main drivers / reasons:

Social (e.g new legislation, new ways of doing things)

Technological/functional (e.g new technology /functions are more efficient)

Economic (fuel cost, maintenance costs, personal cost e.g poor ergonomics)

Aesthetical (old machines is seen as less valuable than new models)

What product category has most values embedded (material values, immaterial IPR, knowledge etc.)?

What products/systems/components are most sensitive for changes? (due to technological, functional, economic reasons)?

Is there some machine(s) in your range that are optimized for preserving value by reuse and remanufacturing?

#### **Designing new products:**

What are the main drivers that initiate a new design?

What aspects are taken into account when developing a new product concept?

When will you discuss the new design with other departments?

Do you consider changes in the business model as potential consequence of the new design, or the other way around?

#### **Business logic:**

What department(s) will set the requirements for a new product?

How do you ensure that the design will fit the customers' requirements, needs and wishes?

How often do you reconsider your business model?

How do you ensure that the business offer (i.e. sales / service offer) fit your customers' needs and wishes?

Could you describe a little about the business "landscape"? What central business issues are on the agenda at the moment? What issues are up and coming in a near future?

When developing services (soft products) have you experienced any limitations in the physical product (developments) that make the planned change in service difficult or very costly?

What do you see as the biggest risks in the current linear business?

#### **Scenario Function: circular products and closed-loop business models**

[concept description to put interviewees in right setting]

Imagine that you would keep ownership over your products and offer functions /sell performance to your customers instead of transferring ownership to your customers.

How would that affect how you....

#### **Designing new products:**

How would a circular product in your industry look like?

Do you see possibilities to make the product more flexible or adaptable to the changing needs of different customers?

Will the product change if the company retains the ownership of the product?

#### **Design methods and tools:**

What design tools would you need to design circular products?

At what stage would you need design tools?

Are you aware of any useful tools?

#### **Business logic:**

When moving towards a circular economy, how would your customers' needs and wishes change?

How will this affect your current sales/service offer?

What will be the benefits of such offer?

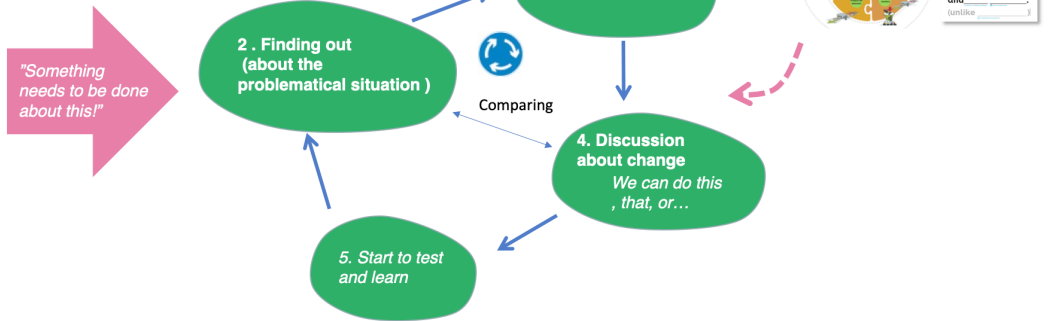
What risks do you see with such circular offer?  
 Can a change in product design help lowering these risks?  
 Do you think these new offers will contribute to a sustainable society?

## Appendix B:

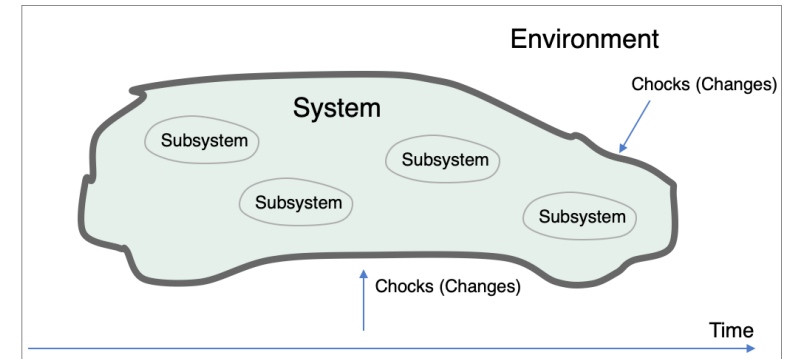
Illustration of the facilitation method (SSMA) being used during the three workshops in empirical field study A2. In step 3 of the learning process, the Business Model canvas, and the Value Proposition Designer was being used together with principles for CE and adaptable design for exploration of barriers and possibilities for various vehicle systems and components. Due to non-disclosure agreements, no further visual materials from these workshops can be presented.

### A structure for learning about change

1 A perceived real-world problematic situation



### The adaptable system



*"An adaptable "whole" (a system) that can survive through time by adapting to changes in it's environment"*

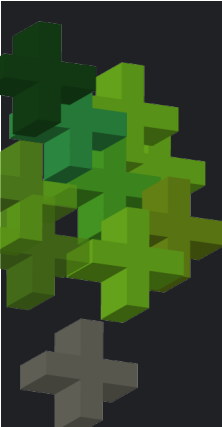
- Communication process (to know what is going on)
- Control process (to respond to chocks)
- Structure in layers
- Emergent properties of the system as a whole (the correct assembled vehicle being meaningful)

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## Adaptive Design for Circular Business Models in the Automotive Manufacturing Industry

The vision of a circular economy (CE) promises both profitability and eco-sustainability to industries, and can, from a material and energy resource flow perspective, be operationalized by combining three business and design strategies: closing loops; narrowing and slowing down resource flows by material recycling, improving resource efficiency; and by extending product life by reuse, upgrades and remanufacturing.

These three strategies are straightforward ways for industries to radically reduce their use of virgin resources. From a product design perspective, it is doable. However, from a business perspective, it is no less than a revolution that is asked for, as most Original Equipment Manufacturers (OEMs) have, over time, designed their organizations for capturing value from selling goods in linear, flow-based business models.

This thesis aims to contribute to the discourse about CE by exploring practical routes for operationalizing circular product design in a “stock-based” circular business model (CBM). The approach is three-fold. Firstly, the role of design as a solution provider for existing business models is explored and illustrated by case studies and interviews from the automotive industry. Secondly, challenges and possibilities for manufacturing firms to embrace all three strategies for circularity are explored. Thirdly, implications for designing products suitable to stock-based CBMs are discussed.

In spite of the vast interest in business model innovation, a circular economy, and how to design for a circular economy, there are still many practical, real-life barriers preventing adoption. This is especially true for designing products that combine all three of the circular strategies, and with regard to the risk of premature obsolescence of products owned by an OEM in a stock-based business model. Nevertheless, if products are designed to adapt to future needs and wants, business risks could be reduced.

The main findings are that CE practices already have been implemented in some respects in the automotive industry, but those practices result in very low resource productivity. Substantial economic and material values are being lost due to the dominant business and design logic of keeping up resource flows into products sold. The primary challenge for incumbent OEMs is to manage, in parallel, both a process for circular business model innovation and a design process for future adaptable products.

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