Business model configurations for rapid production in the consumer products and retail sector

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Exploratory empirical research into the identification of common characteristics in Business Model configurations for Rapid Production in the CPR sector

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Abstract

Additive Manufacturing, which is the process of joining materials on the basis of 3D model data, has commonly been used by companies for Rapid Prototyping purposes. Scholars have argued that the use of Additive Manufacturing for production purposes - i.e. Rapid Production - bears numerous opportunities for business model innovation. However, there is a lack of empirical research into Business Models for Rapid Production. Since companies have recently started to apply Additive Manufacturing for Rapid Production purposes, thereby exploring new Business Models, an opportunity existed to identify the characteristics of these Business Model instances. Using the Business Model Canvas as the underlying framework, this thesis explores the common characteristics of Business Models for Rapid Production based on empirical data in the Consumer Products and Retail sector. Using a sequential research approach, the most important elements within Business Models for Rapid Production are identified and captured using a configurational 'heat map'. The research results highlight the importance of the Business Model elements of 'Customization' and 'Design' (Value Proposition), 'Niche Markets' (Customer Segments), 'Digital' (Key Resources) and 'Buyer-Supplier relationships', particularly those with 'Additive Manufacturing Production Partners' (Key Partners). The main theoretical implications of the research are discussed. Furthermore, the results lead to several managerial implications and an interactive tool for Capgemini as the commissioner of the research.

Preface

With this thesis I conclude my studies at Eindhoven University of Technology (TU/e). The university has been an amazing place to learn and meet new friends. I am very thankful that the TU/e has given me every opportunity to further develop myself, including the possibility to study abroad at UC Berkeley which was (in true American fashion) a dream come true!

I started preparing for this thesis after coming back from my semester abroad. After some back-and-forth with Capgemini on technologies I was interested in, they offered me the opportunity to write my thesis on the subject of Additive Manufacturing. Therefore, I would like to thank Capgemini and in particular Hans Scholten and Peter-Paul Tonen for offering the internship position. The AIE is an extraordinary initiative for a large company such as Capgemini and it is great that Capgemini is thinking about the applications of numerous different technologies. The Co-Zone in Utrecht was the perfect environment to work on an explorative research project within a corporate setting. Furthermore, I would like to thank all the colleagues at Capgemini and the participating external experts for their time and effort during several interviews and many occasional talks. While working at Capgemini, I was supervised by Yvonne Kolen whom I would like to specifically thank for her efforts. Your feedback at important milestones was very valuable and your support when selecting an appropriate research question that would align with both Capgemini's needs and the TU/e's requirements was much appreciated.

Of course I am thankful for the support of Thijs Peeters, who has been my mentor during the Master and helped me in selecting the research topic and performing the research. I think it is quite inspiring that you can combine a full-time job with the preparations for full length triathlons, not to mention actually completing them. Now that you are a father and may have fewer hours to spend on sports, I would like to recommend picking up golf. However, you may find that it still takes a relatively long time to complete (only) 7 kilometers and it can also be quite addicting. I would also like to thank my second supervisor Annelies Bobelyn for her input into my research. Especially your proposal of using the fsQCA analysis was interesting and a nice addition to the research I believe.

I would like to thank Saskia for our long evenings spent together in the library and your patience with me during stressful times. Finally, I would like to specifically thank my parents for their support throughout my studies. I am lucky to have been allowed to take a little bit more time for my studies than we probably expected several years ago. This was only made possible because of you both.

Jelle Zaanen, Utrecht 2017

Executive Summary

Additive Manufacturing (AM) is the process of joining materials, usually in a layer by layer fashion, on the basis of 3D model data. AM presents a radical shift from traditional subtractive manufacturing methods. Especially when used for direct production purposes (i.e. Rapid Production) its unique key characteristics due to a relative lack of tooling constraints allow for the creation of new product offerings and restructured supply chains. Since this implies that companies have the possibility to find new ways of creating, delivering and capturing value, AM in the context of Rapid Production bears numerous opportunities for Business Model innovation. Companies in the Consumer Products and Retail (CPR) sector have recently taken notice of the potential of Rapid Production and some have started applying the technology to offer products on the market. This also means that new Business Models are being explored by these companies. Since there exists a gap in empirically based literature on the subject of Business Models for AM, particularly when used for Rapid Production purposes, this research explores the common characteristics of Business Models for Rapid Production in the CPR sector based on empirical data.

A sequential mixed-method research approach was applied that consisted of three phases:

1. Qualitative data about Business Model instances in the CPR sector was gathered through interviews with experts that had experience with Rapid Production. The Business Model Canvas was used to capture the results and extended where necessary to facilitate categorization of the findings. It consists of nine components which each feature elements that can be used to describe Business Model instances or conceptually explore Business Models. The results show that 'Customization' is the central value proposition that is offered in the Business Model instances. Furthermore there is a focus on niche markets, a high dependence on digital and intellectual resources, and a high level of collaboration with Key Partners that specialize in AM.
2. In the second phase, data was collected from general experts in the CPR sector using an online survey. This resulted in quantitative data regarding the expected likelihood of Business Model elements being offered in a Business Model for Rapid production. A Mean comparison analysis per Business Model component resulted in a ranking of elements per component and the identification of those elements that are significantly more or less likely expected to be offered than others. Furthermore, fsQCA analysis was conducted which lead to the identification of core and peripheral elements and configurations of these elements for the value propositions that are most likely to be offered.
3. In phase three, interviews were held with CPR experts at Capgemini, which is the commissioner of this research. This resulted in qualitative data regarding the possible implications of AM for large established firms in the CPR sector, the identification of possible business opportunities for Capgemini and input for a tool to be used by Capgemini.

The results are integrated into a configurational 'heat map', which represents the main findings of this thesis (figure S1). This can be considered a Sub-(Meta)-Model and shows the common characteristics of Business Model configurations for Rapid Production in the CPR sector.

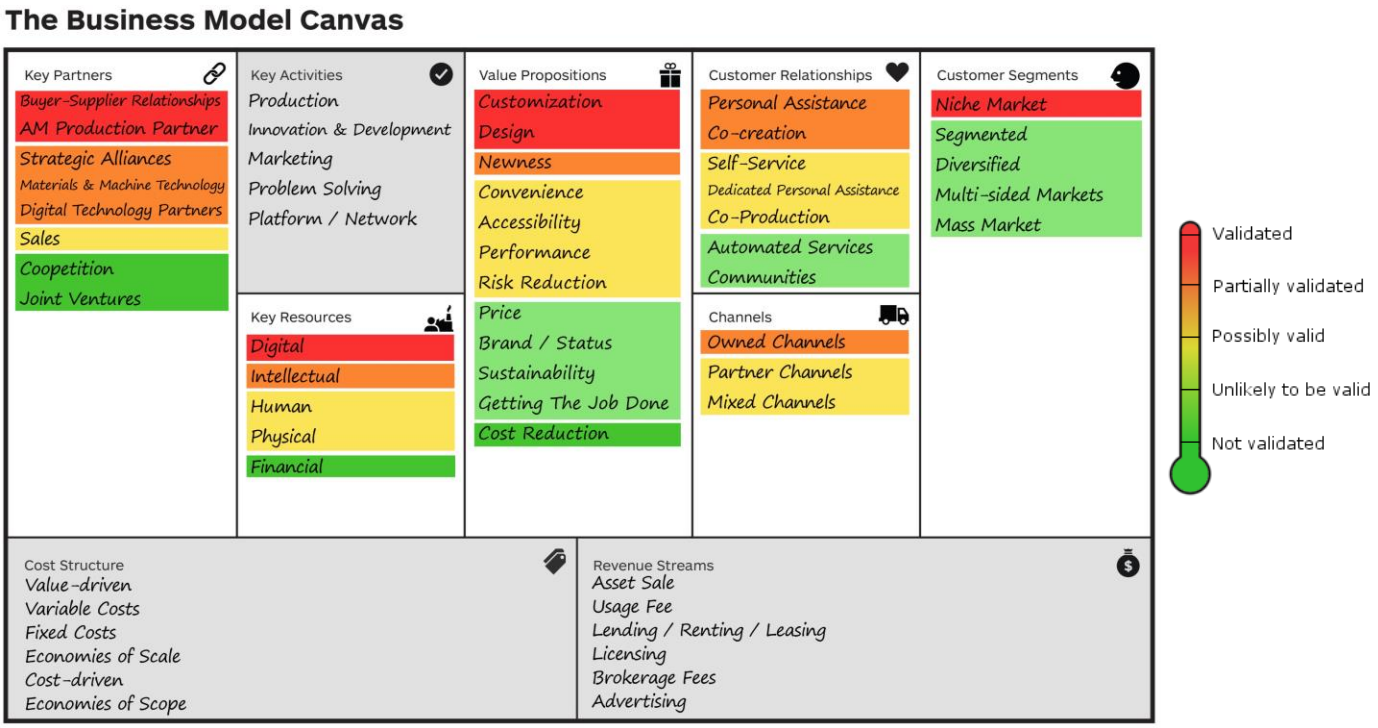

Figure S1: *Configurational heat map of Business Models for Rapid Production in CPR*

The configurational heat map shows that Business Models for Rapid Production revolve around the value propositions of 'Customization' and 'Design', with products targeted at niche markets. Furthermore, digital resources such as digital design files, front-end and back-end systems for webshop integration and in-house developed automation software are key. 'Buyer-Supplier relationships', particularly those with (often local) 'AM Production Partners' are important elements. When offering the 'Customization' value proposition, core elements that should be considered in particular for Business Model configurations are 'Newness', 'Co-Creation' and the use of 'AM Production Partners'. When offering the 'Design' value proposition, the absence of the 'Co-Creation' element and making use of 'Digital Technology Partners' are core conditions that should be considered in particular.

The findings of this research can be used by practitioners to focus their future efforts on the elements which are considered relatively most important and it may direct them in exploring Business Models. Companies in CPR may be able to use AM to differentiate their product offering from competitors with new, innovative niche products aimed at higher-price segments, featuring unique service and experiences surrounding the customization value proposition. The traditional mass-manufacturing based Business Model does not necessarily have to be replaced, but can instead be complemented by the Business Model for Rapid Production for those products produced using AM. Furthermore, such an approach would especially allow larger, established companies such as Capgemini's clients to explore the value propositions and corresponding Business Model configurations that can be offered with AM.

When clients adopt AM technology, the primary future role that was identified for Capgemini in the context of AM should be that of a system integrator, in which it can help companies to integrate and support new order management processes into current legacy systems or built new IT environments altogether. It is further recommended that

Capgemini starts establishing relationships with specialist and local partners. The identified importance on digital key resources is an opportunity for Capgemini as a digital transformation leader to help their clients further in their efforts to become digital leaders. By doing so, these companies are well prepared to offer services and experiences involving Rapid Production in the future. It is further recommended that Capgemini initiates a conversation about the prospects on AM with their clients. The tool that is provided with this research may help Capgemini in doing so.

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1. Introduction

Companies in the Consumer Products and Retail (CPR) sector are operating in a constantly evolving, turbulent environment. Consumers are becoming more empowered and quickly change their behaviour and preferences (Westerman et. al, 2014). Not only are companies facing change on the consumer side, but the internet has also accelerated innovative competition which has led established technology firms and an army of start-ups to move rapidly in consumer markets without following established go-to-market-patterns (Capgemini, 2015). Combined with rapidly evolving technologies that open up disruptive ways of creating value for the consumer and the business itself, these trends have the potential to disrupt traditional value chains and may render traditional Business Models in this sector obsolete (Christensen, 1997).

One of the rapidly evolving technologies that is particularly suspect to be disruptive in the CPR sector is Additive Manufacturing (AM) technology, commonly referred to as 3D printing (1.1). Recent developments in the CPR sector show that companies are considering the use of AM not just for prototyping but also for production purposes (1.2). As argued by Weller et. al (2015) the opportunity to use AM for manufacturing is the reason for the hype surrounding the technology. Furthermore, Weller et. al (2015) note that AM's promise to replace conventional production technologies for serial manufacturing of components or products (i.e. Rapid Production) bears numerous opportunities for business model innovation. Although the use of AM for production purposes is expected to result in new Business Models, there exists a lack of theoretical and practical knowledge on the subject of Business Models for AM (1.3). This problem leads to the formulation of the research goal (1.4). Based on the problem statement and the research goal, the main question and sub-questions are formulated that will be answered with this research (1.5). In order to prevent casting too wide a net during the research, several limitations apply that scope the research (1.6). Finally, the outline of the thesis is presented (1.7).

1.1 Additive Manufacturing technology

AM is the "*process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies*" (ISO/ASTM, 2015). With AM, a three-dimensional digital CAD file is sent to the point of manufacturing, where it is sliced into two-dimensional layers based on the properties of the so-called "printer" that is used. The product is then built up layer by layer by the printer. As such, the AM process represents a radical shift from traditional subtractive methods of creating physical objects such as CNC milling or injection molding. Its additive nature results in several distinctive benefits over the traditional subtractive methods that are unique to AM. This includes the removal of traditional tooling constraints, which allows for the digitally empowered creation of complex assemblies and organically shaped products. Because of this lack of tooling constraints, a single printer can produce an unlimited amount of distinct designs giving rise to new opportunities such as cost-effective mass customization, which is the low-cost, high-volume, efficient production of individually customized offerings (Pine, 1993). Furthermore, the digital CAD files can easily be distributed and duplicated over the internet. When combined with increased access to a network of printers, this opens up the possibility of decentralized production and effectively lowers the barrier to entry for manufacturing in general. Finally, the additive nature of AM leads to less waste of material during production (Lipson & Kurman, 2013).

Although these benefits show the potential disruptive power of AM technology, a nuanced view applies since the technology still needs to overcome several major challenges related to the prime production metrics of production speed, quality of the product and limited availability of (certified) materials (Berman, 2012; Hague et al, 2003). The implications of these aspects on cost of production have led to the technology commonly being used for Rapid Prototyping purposes as opposed to production purposes, also called Rapid Production (Ruffo et. al, 2006; Hopkinson & Dickens, 2003; Bak, 2003; Cozmei & Caloian, 2012). However, rapid developments in AM technology make Rapid Production increasingly viable as a production method and has led some to identify AM as an enabler of the "next industrial revolution" (Economist, 2012) or the "next trillion dollar industry" (Gobry, 2011). Such claims have raised significant interest into AM from the general public and professionals across industries alike. Although the hype surrounding AM technology has increasingly been justified by applications of the technology in the automotive, aerospace and healthcare industries, application of AM in the CPR sector has remained mostly limited to prototyping purposes thus far.

1.2 Application of Additive Manufacturing in Consumer Products and Retail

Recently, progressive companies in the CPR sector have started to realize the potential value of AM and are looking past the prototyping stereotypes. A report by Cohen et. al (2014) stated that in 2011 only about 25% of the AM market involved the production of end products. However, at a 60% annual growth rate, this was identified as the industry's fastest growing segment. Since the inherent value of an innovation remains latent until it is commercialized in some way, pioneers have realized that in order to benefit from AM technology, they have to develop manufacturing strategies utilizing AM equipment, processes, and materials for commercial purposes (Chesbrough & Rosenbloom, 2002; Beyer, 2014). Besides a significant number of startups and entrepreneurs that are attempting to benefit from being first-movers into a new market, large companies in the CPR sector have taken note as well. Examples of pioneers in the industry include major sporting goods companies[1,2] that have promoted running shoes produced with AM, multinational retailers such as Hema that launched a "3D printed" jewelry service[3] and the major consumer electronics manufacturer Philips that brought a male grooming product with an AM produced skin to market[4].

By taking AM technology to the market commercially, these pioneers are essentially exploring what new consumer products they can create, how they can distribute these products and how to capture the value that is created with AM technology. This business logic is described by the Business Model concept. Since these companies are often creating a new product with a different value proposition for the consumer, the traditional Business Model that the company employs may not fit the circumstances of the technological or market opportunity. Academics have shown that in such cases, technology managers must expand their perspectives, to find the right Business Model or create an entirely new Business Model in order to capture value from the technology. The importance of finding the right Business Models is evident since failure to do so will cause technologies to yield less value to the company than they might otherwise. It

[1] http://www.adidas.com/us/futurecraft
[2] https://www.underarmour.com/en-us/3d-architech
[3] http://3d-print.hema.nl/
[4] http://www.3dshaver.com/

may even cause a company to reduce or withdraw from its commitment to exploring and creating new technology in the first place (Chesbrough & Rosenbloom, 2002).

1.3 Problem description

Unfortunately for practitioners, there is little scientific research into the specific ways in which AM technologies are integrated into specific market offers as well as into the potential Business Models that could help in delivering the corresponding value propositions (Hahn et. al, 2014). Although the technological benefits of AM technology are well-documented and consultancy reports do focus on the possible future implications of AM, these publications lack the methodological depth and predictive power of scientific research studies (Hahn et. al, 2014). Since AM is expected to stimulate the emergence of alternative Business Models that allow companies to fully exploit the tactical benefits of the technology, the need for more research into Business Models for AM has been identified in recent publications by multiple scholars (e.g. Hahn et al, 2014; Garret, 2014; Bogers et. al, 2016; Rayna & Striukova, 2016; Beyer, 2014; Weller et. al, 2015).

This need for more research into Business Models for AM is also identified by the commissioner of this research, Capgemini's Applied Innovation Exchange (AIE). The AIE aims to help companies by providing a transformative environment for the exploration, testing and application of innovations (Capgemini, 2016). In order to do so, Capgemini has developed a framework that illustrates the process that the AIE facilitates (figure 1).

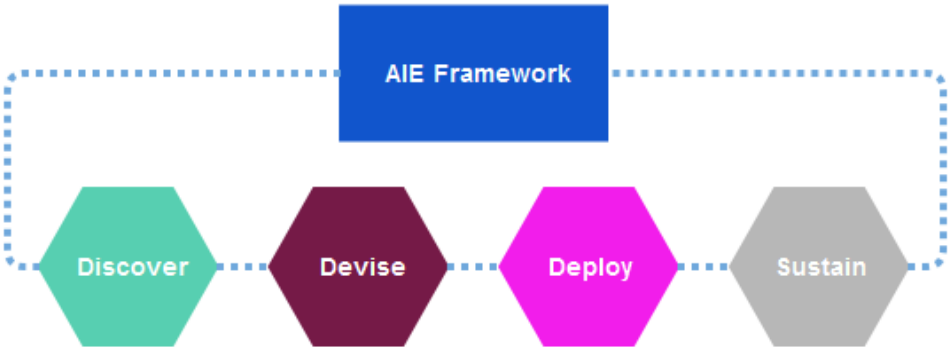

Figure 1: *Capgemini Applied Innovation Framework (adapted from Capgemini, 2016)*

As can be seen in figure 1, there are four stages: Discover, Devise, Deploy and Sustain. The problem that is presented particularly relates to the stages of Discover and Devise. With regards to Discover, AM has been identified as an emerging technology. However, it remains largely unclear what the implications of this technology are for clients of Capgemini because it is unclear how exactly companies are or will be applying the technology. Arguably, this is due to the fact that AM can be seen as an opportunity that has yet to be capitalized upon. In order to fully capitalize upon an opportunity such as AM, alternative Business Models are needed, which is what Capgemini aims to facilitate in the Devise stage. The problem that can be identified on the subject of AM from both a scientific and Capgemini's perspective is therefore:

"There exists a lack of knowledge on the subject of Business Models for Rapid Production and subsequently the business model implications that companies have to consider."

1.4 Research goal

The primary goal of this research is to make a contribution to the academic literature by exploring Business Model configurations for Rapid Production purposes. Qualitative and quantitative insights from practitioners and general experts in the CPR sector on the Business Model level shed more light onto the possible Business Model configurations and the implications that companies in the CPR sector may consider in adopting AM for Rapid Production.

Since the research is commissioned by Capgemini, a complementary goal of this research is to take a first step in identifying the opportunities for Capgemini to support companies in applying AM technology with its core strengths in IT technology, outsourcing and consulting. Because of the design oriented nature of the Master's study Innovation Management, a final goal for this research is to deliver a tool in which the scientific findings on the Business Model configurations for Rapid Production can be used by Capgemini to engage in a conversation with their clients.

1.5 Research questions

In order to achieve the primary goal of the research, the following main question needs to be answered:

"What possible Business Model configurations and implications should companies in the Consumer Products and Retail sector consider when applying Additive Manufacturing for Rapid Production?"

Since the supporting knowledge to answer this research question needs to be gained, the following sub-questions are formulated:

- SQ1: Which configurations have experts that are applying AM technology for Rapid Production in the CPR sector applied in their Business Models?
- SQ2: On which Business Model components and elements do these experts anticipate a strategic shift based on their understanding of and experience with AM technology?
- SQ3: Which elements are most likely to be offered when AM is applied for Rapid Production by companies in CPR according to general experts in the sector?
- SQ4: Which possible business model implications for Capgemini's clients and what opportunities exist for Capgemini?

Based on the integration of the answers to the questions above, the main research question can be answered. The answering of this question will result in yet unexplored insights into how current Business Models for Rapid Production in the CPR sector are configured and what business model implications are expected when AM is further adopted.

1.6 Research scope

Before going into the theoretical background and methodological details of this research, it is important to specify exactly how the research is scoped. This prevents casting too wide a net during the research. Most notably, this research focuses specifically on the CPR sector. This choice was based upon the fact that the Consumer Products/electronics sector is relatively one of the largest sectors for which AM is currently used (Wohlers, 2014). This increases the chances of finding suitable use cases for data collection. At the same time, the CPR sector is also one of the most prominent

sectors for Capgemini Netherlands, which increases the relevance of this research for Capgemini. The motivation to focus specifically on the CPR sector is described in detail in Appendix I.

By focusing on a single sector, it is expected that there will be less variability during data collection on the configuration of Business Models. This is likely to increase the validity of the findings, making the outcome of the study more applicable for practitioners. In making the choice to focus on the CPR sector, the following conditions also apply:

- **Consumer products**: Only consumer products that are produced using AM, or feature a major AM produced component, will be considered.
- **Rapid Production**: The biggest impact on Business Models may be expected when AM is used for Rapid Production purposes versus using the technology for models and prototypes for which the technology is already commonly used. Therefore, the focus of the research will be on Business Models that use AM for Rapid Production purposes only.
- **Consumer products focal companies**: The Business Model configurations are considered from the consumer product focal company perspective. The focal company is defined as the decision making authority in supply chain networks, coordinating the other members in order to realize its strategic objectives (Hanf & Dautzenberg 2006). Furthermore, the focal company is identified by the consumer as being responsible for the end product (Hanf & Pall, 2009). The research excludes the Business Models for those companies that focus primarily on offering AM production services but also sell designs by users such as i.Materialise and Shapeways. However, companies that make use of such services are not excluded.
- **Product level Business Models**: Large established companies in the CPR sector are still in a stage of experimentation with AM for Rapid Production and may have only experimented with the possible Business Model configurations that allow them to capitalize on AM. Although their overall Business Model may not be affected, the insights that these companies may have based on their smaller scale experiments should not be excluded since they can provide excellent insight into the Business Models that they are considering for larger scale Rapid Production. Therefore, the Business Models are isolated on a product level.

1.7 Outline of the thesis

The remainder of this thesis starts with a comprehensive theoretical background in Chapter 2 that introduces the Business Model concept as the primary unit of analysis. Furthermore, the connection between Business Model literature and AM is made by identifying the theorized implications of AM on Business Models from literature. In Chapter 3, the methodology that was applied for this research is explained, which includes research design and methods for data collection and analysis. In Chapter 4, the analyses and results from the collection of data are presented. In Chapter 5, the research questions are answered and the results from the research are integrated to answer the main research question. Chapter 6 concludes the research by discussing the theoretical and practical implications of the research, as well as its limitations and future research opportunities.

2. Theoretical background

From a technological perspective, AM can simply be considered an additional mechanical tool in the existing toolbox of available manufacturing technologies for a company. However, the radically different nature of AM compared to traditional manufacturing methods uniquely positions AM as an enabler to fundamentally change the rules for production. This change may in turn affect how companies create, deliver and capture value. The Business Model concept describes this logic for a company and is introduced as a unit of analysis (2.1). To further clarify the Business Model construct at the conceptual level, models and ontologies have been proposed that describe which components can be used to describe a business model, which in turn have led to frameworks that create a common language for discussing a business model (2.2). The relevance of Business Model design regarding new technologies in particular is presented (2.3). Although the lack of research into Business Models for AM is frequently cited, some scholars have theorized specifically about the Business Model implications that AM will have (2.4). Finally, the literature on Business Models and the theorized implications of AM on Business Models lead to the detailed identification of the research gap that this research explores (2.5).

2.1 The Business Model concept

The Business Model concept emerged in academic literature in the mid-1990's at a time of rapidly growing e-businesses and rapid growth in emerging markets (Zott et. al, 2010). With declining computing and communication costs, companies were able to fundamentally change the way they organize and engage in economic exchanges, both internally as well as externally with suppliers and customers (Zott et. al, 2010; Mendelson, 2000; Brynjolfsson & Hitt, 2004). The Business Model concept was introduced to describe the way in which these companies organized and engaged in their activities.

Although this description may imply that the Business Model concept is generally applicable and simple to understand, its widespread application and deliberate function as an abstraction of reality also represents a source of confusion (Stähler, 2002). The Business Model concept is often confused with the more evolved field of research of strategy. Both strategy and Business Models seem to overlap in describing how a firm operates. Where strategy can be conceptualized as the high-level choices that a firm makes, a Business Model can be thought of as the specific configuration of interrelated activities that a firm puts together to translate its strategy into action (Markides, 2015). Furthermore, where strategy simply focuses on what activities to perform, the Business Model describes how activities fit together in a well-balanced system that relates what the environment wants to what the company does (Markides, 2015). As Casadesus-Masanell and Ricart (2009) note, strategy refers to the choice of Business Model through which the firm will compete in the marketplace. Strategy is more closely related to execution and implementation versus how a business works as a system (Osterwalder et. al, 2005).

Furthermore, there is no definitional clarity regarding the Business Model concept. A complete stream of literature is dedicated to the further clarification of the concept. From a study of academic literature Osterwalder et. al (2005) found that literature on Business Models can be divided into three different categories and make a distinction between the conceptual levels (2.1.1) and the instance level (2.1.2).

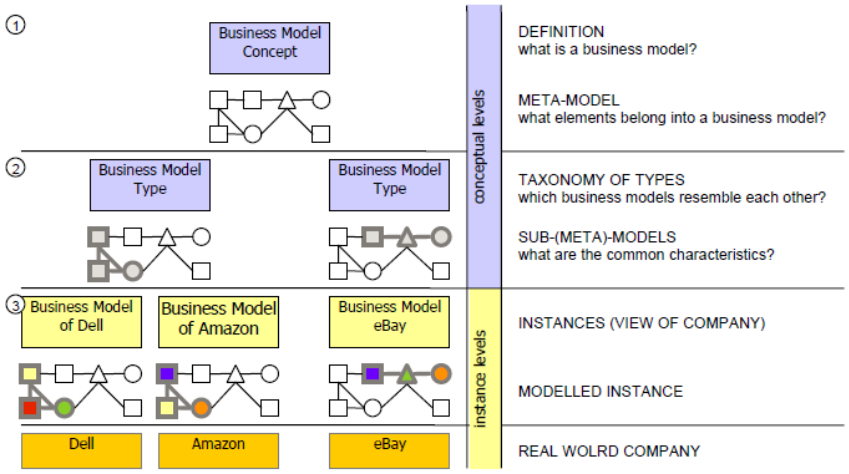

Figure 2: *Business Model concept hierarchy (Osterwalder et. al, 2005)*

2.1.1 The Business Model: conceptual levels

As can be seen in figure 2, on the conceptual levels, a considerable body of literature is concerned with the further clarification of the Business Model definition and what exactly constitutes a Business Model. Although the Business Model concept has quickly gained popularity amongst academics it suffers from a lack of definitional clarity and is often confused with the more established intellectual territory of strategy (Zott et. al, 2010). Definitions of the concept over time are shown in table 1.

Table 1: Examples of definitions of the Business Model concept over time (Source: Zott et. al, 2010)

Author:	**Definition:**
Timmers, 1998	"A*n architecture of the product, service and information flows, including a description of the various business actors and their roles; a description of the potential benefits for the various business actors; a description of the sources of revenues*" (p.2)
Chesbrough & Rosenbloom, 2002	"*The heuristic logic that connects technical potential with the realization of economic value*" (p. 529)
Teece, 2010	*A Business Model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value*" (p.179)

When summarizing the findings of a literature review by Zott et. al (2010) on the definition of the Business Model concept, it can be concluded that Business Models emphasize a system-level holistic approach, in which organizational activities play an important role, towards explaining how firms do business and describing how both value is created and captured.

Conceptual literature has led to meta-models that are concerned with the identification of Business Model components regarding the concepts of value, monetary aspects and network architectures. Components include 'value stream', 'value proposition', 'revenue streams', 'cost structures', 'delivery channels' and 'network relationships' which can each be further broken down into elements. In order to describe the combined set of components Business Model Ontologies (BMOs) have been proposed. These BMO's conceptualize and formalize the essential components of a Business Model into elements, relationships, vocabulary and semantics (Zott et. al, 2010). Based on literature by others, Osterwalder and Pigneur (2004) introduced an extensive ontology (Appendix II) featuring nine components and described the relationships between them (table 2).

Table 2: Business Model Ontology (Source: Osterwalder & Pigneur, 2004)

Pillar:	**Business Model Component:**	**Description:**
Product	Value Proposition	Gives an overall view of a company's bundle of products and services.
Customer Interface	Target Customer	Describes the segments of customers a company wants to offer value to.
	Distribution Channel	Describes the various means of the company to get in touch with its customers.
	Relationship	Explains the kind of links a company establishes between itself and its different customer segments.
Infrastructure Management	Value Configuration	Describes the arrangement of activities and resources.
	Core Competency	Outlines the competencies necessary to execute the company's business model.
	Partner Network	Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value.
Financial Aspects	Cost Structure	Sums up the monetary consequences of the means employed in the business model.
	Revenue Model	Describes the way a company makes money through a variety of revenue flows.

Although each of the components could constitute part of a generic Business Model and can be used to differentiate between Business Models, none of the components in isolation can capture a Business Model as a whole. The Business Model describes all of these components together and the relationships between them (Zott et. al, 2010).

Furthermore, taxonomies of types have been created to classify Business Models within a certain number of common characteristics in a set of different categories (Osterwalder, 2005). Timmers (1998) is known for introducing the classification scheme and definition of electronic Business Models resulting in taxonomies such as "e-Shops", "e-Procurement" and "Third-party Marketplaces" amongst others. Other general taxonomies not limited to e-businesses include "Merchant Model", "Manufacturer Model" and "Subscription Model" (Zott. et. al, 2010). These taxonomies may be applied to categorize Sub-(Meta)-Models, which are Business Models that resemble each other across the various components when Business Models are analyzed at the instance level.

2.1.2: The Business Model: instance levels

The instance level consists of literature that applies the Business Model concept on a more practical level. Literature in this category is more concerned with Business Model design and identification of existing designs. Because the current research explores the configuration of Business Models for AM based on data from pioneers in the CPR sector using AM for Rapid Production purposes, the research falls in this category of literature. As can be seen in figure 2, the instance represents a view of a particular company. As Osterwalder et. al (2005) summarize, authors have described the Business Models of companies such as Xerox (Chesbrough and Rosenbloom 2002), Dell (Kraemer, Dedrick et al. 2000), General Motors' OnStar project (Barabba, Huber et al. 2002), specific online supermarkets (Yousept and Li 2004) and online media companies (Krueger, van der Beek et al. 2004). In order to describe Business Models at the instance level, scholars make use of the meta-models and taxonomies proposed at the conceptual levels. Osterwalder et. al (2005) further identify five main functions of the use of the Business Model at the instance levels. These are:

- **Understanding and sharing:** The Business Model helps scholars and practitioners to capture, visualize, understand and communicate their Business Model in a clear way. This is especially of concern with increasingly complex Business Models for which a shared understanding must be created between stakeholders with different backgrounds.
- **Analyzing:** When a captured Business Model results in a common understanding, the Business Model becomes a unit of analysis (Stähler, 2002) that can be measured, used to track and observe changes and can be compared to Business Models of competitors or even companies in other industries. This may lead to new insights and foster innovation.
- **Managing:** Through the understanding and analysis of Business Models, the business logic of the firm can be managed better. This includes improved change capabilities and increasing reaction capacities in uncertain and rapidly changing competitive landscapes such as CPR.
- **Prospects:** The Business Model concept may not only improve change and reaction capacities, but can also be considered a locus of innovation (Amit & Zott, 2001). By using the components and elements of the conceptual models as building blocks, new Business Models can be constructed. Furthermore, companies can maintain a portfolio of Business Models in the face of environmental change and simulate and test possible Business Models through low-risk experiments.
- **Patenting of Business Models:** Finally, processes or technology that constitutes a fundamental part of a business may be patented, especially in e-businesses, which essentially results in a unique Business Model that cannot be duplicated by a competitor.

Although these functions are all relevant at the instance level, the interpretation of the Business Model is dependent on the conceptualization and representation that is used.

2.2 Business Model representations

Possibly, the main area of contribution of the Business Model concept can be found in the creation of such concepts and tools that help managers to capture, understand, communicate, design, analyze, and change the business logic of their company. Generic and shared concepts for describing Business Models are necessary since they can be understood as a

common language between stakeholders to formulate Business Models in a way that everybody understands (Osterwalder et. al, 2005). Essentially, these tools bridge the conceptual level and the instance level.

The ontology originally proposed by Osterwalder and Pigneur (2004) (table 2) would form the basis of the Business Model Canvas (BMC), which was introduced by Osterwalder and Pigneur in 2010. The BMC is a framework that has the potential to provide both scholars and practitioners with common ground to understand, communicate, analyze, manage and design Business Models. The BMC consists of nine components (figure 3) and features elements within these components that can be used to describe a Business Model at the instance level (Appendix III).

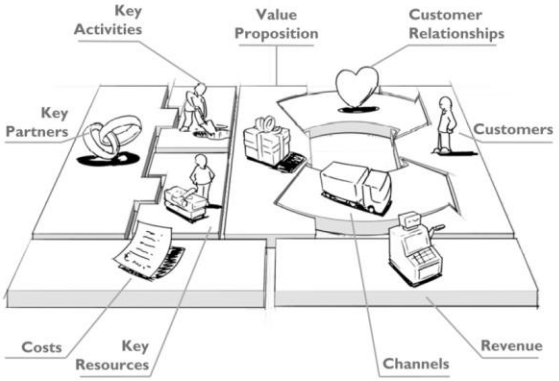

Figure 3: *The nine components of the Business Model Canvas* (Osterwalder & Pigneur, 2010)

Since the value that is offered by the company is central to the Business Model concept, the value proposition is positioned in the middle of the BMC. This is the central pillar of the Business Model that is related to the product or service that is offered. All other components surround the value proposition and are grouped such that one can clearly identify the customer interface, infrastructure management and financial aspects pillar that were shown in table 2 (Osterwalder et. al, 2005). Importantly, the structure of the BMC provides a holistic overview of a conceptual Business Model or realized Business Model.

The BMC has seen a high level of adoption by practitioners to be used for conceptualization and representation of Business Model instances. The visualization of the components allows users of the framework to easily interpret their company's Business Model visually, enhancing understanding (Rode, 2000; Gordijn & Akkermans, 2003). Furthermore, the BMC is particularly useful to sketch-out and thereby conceptually generate adapted or new Business Models. Because of its popularity amongst both scholars and practitioners, the holistic definition for the Business Model concept as proposed by Osterwalder and Pigneur (2010) applies when further referring to the Business Model concept in this research:

"A Business Model describes the rationale of how an organization creates, delivers, and captures value"
(Osterwalder & Pigneur, 2010, p. 14)

2.3 Business Model design

By defining the Business Model concept as a unit of analysis that goes beyond the understanding of the monetization mechanisms that firms use to capture value, as it also translates how value is created and delivered, academics have enriched their understanding of how new technology affects Business Model design and vice versa (Markides, 2015). New technology such as AM increases the range of imaginable Business Model designs (Lechner & Hummel, 2002). It is in the area of Business Model design that the relevance of the Business Model concept at the instance level is found regarding the recent experimentation and adoption of AM technology for Rapid Production purposes in CPR.

As is shown by Osterwalder and Pigneur's (2010) particular focus on Business Model generation with the BMC and the functions of "manage" and "prospects" by Osterwalder et. al (2005), the Business Model does not necessarily serve solely as a static reflection of how a company creates, delivers and captures value. Instead, the Business Model is both a calculative and a narrative device. It allows entrepreneurs and large companies alike to explore a market and bring their innovation into existence through experimentation with reconfigured Business Models (Doganova & Eyquem-Renault, 2009). In a scenario where change is considered, the Business Model concept is particularly useful since it highlights the conflicts that may arise, or the trade-offs that must be made between different possible Business Models (Markides, 2015). This represents a transformational approach, where the BM is considered a concept or a tool to address change and focus on innovation (Demil & Lecocq, 2010).

Christensen (2006) expanded its original theory that focused on disruptive technological innovation to include Business Model innovation, arguing that disruptive innovations can only come about if there is a "supportive" Business Model (Vriens & Søilen, 2014). Business Model change becomes particularly visible when an innovation emerges that potentially changes the value proposition offered by a company. In applying the innovation, a company is forced to change the value proposition that it offers to the customer, which forces re-alignment, or an entirely new configuration of the Business Model to support the innovation. Since new technologies do not have intrinsic value for a company by itself, companies are challenged to find these supportive Business Models by applying the transformational approach (Teece, 2010).

However, especially for established companies, such as the clients of Capgemini, it is often difficult to apply a transformational approach. This is due to the existence of conflicts between traditional and disruptive business models as discussed by numerous authors (e.g. Christensen, 1997; Charitou & Markides, 2003; Markides, 2006). Creating a radically new Business Model is highly risky since the probability of getting it right is known to be low (Kalakota & Robinson, 2001). Furthermore, Chesbrough (2007) identifies a "Business Model innovation leadership gap", explaining that people in organizations lack the responsibility and capability to innovate their Business Models. Incentives are often misaligned for Business Model innovation to occur since managers want to hold on to their existing, market-proven Business Models that may not align with new Business Models that maximize value in the long run. However, not changing a Business Model in a changing environment might even result in completely missing out on the opportunity, which can lead to loss of competitive advantage or even worse.

Chesbrough (2010) argues that a company has at least as much value to gain from developing an innovative new Business Model as from developing an innovative new technology. In the case of AM it is therefore important for companies not only to consider the application of the technology, but also spend significant effort into finding or designing the corresponding Business Model that aligns with the new value proposition. This further highlights the relevance of identifying Business Model instances that have been created for Rapid Production in CPR.

2.4 Business Model implications of Additive Manufacturing

In order to use the Business Model as a unit of analysis for AM, it is important to first understand the possible practical implications of AM (2.4.1). From the academic literature on the subject of Business Models and AM, theorized implications of the application of AM on Business Models can be identified (2.4.2). The theoretical implications are relevant since they provide possible insights that can later be verified or expanded upon through a discussion of the results of this research.

2.4.1 Practical implications of Additive Manufacturing

From reports and literature on the subject of AM, two axes can be identified along which AM can impact companies. The key principles of AM (Appendix IV) presents companies with the opportunity to reconfigure the supply chain or make product changes that can lead to improved or even new-to-the-world product innovations. In moving from Rapid Prototyping to Rapid Production, companies can make changes along one or potentially both of these axes. This is graphically summarized in figure 4 (Cotteleer & Joyce, 2014).

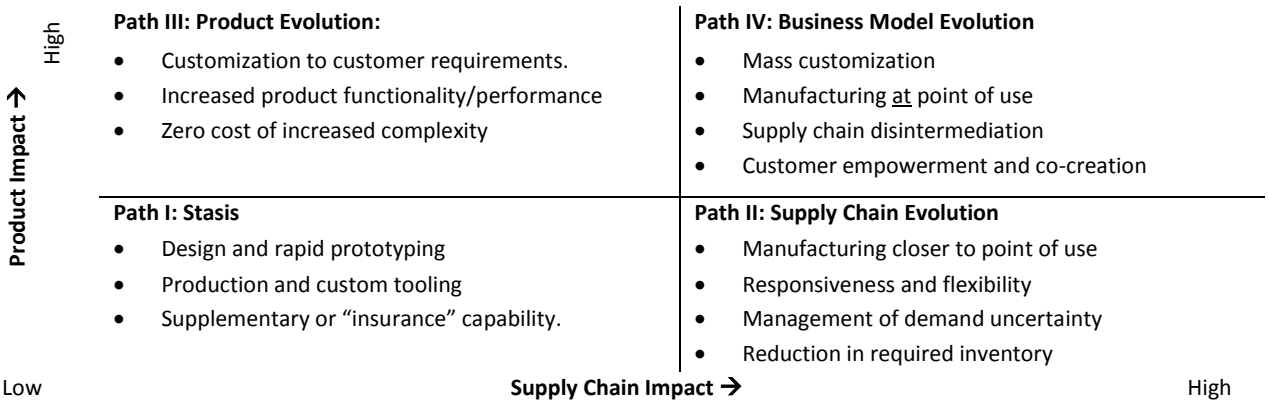

Figure 4: *Additive Manufacturing Impact on Products and Supply Chains* (Cotteleer & Joyce, 2014)

Path II 'Supply Chain Evolution' represents making use of the unique AM characteristics 'Decentralized production', 'Democratization of production' to benefit from flexible and responsive manufacturing closer to the point of use. Path III 'Product Evolution' represents making use of the unique characteristics of 'Freedom of Complexity' and 'Freedom of Variety' to offer superior product performance in terms of customization and/or complexity. Although both Path II and Path III can lead to Business Model change, simultaneously changing both product and supply chain parameters through application of AM technology implies making the largest, most significant changes in terms of value creation, delivery and capture, hence Path IV's name "Business Model Evolution".

Since AM is a production technology that can be applied by companies to both create new-to-the-world products and restructure the value chain, AM can be considered a disruptive technological innovation that has the potential to result in both product innovations and Business Model innovation (Cautela et. al, 2014). Markides (2006) argues that technological innovation, Business Model innovation and product innovations are three distinct types of phenomena that each produce different types of markets and have different managerial implications. Therefore, one should carefully analyze its practical application at an instance level as well in order to understand the implications of AM on the Business Model.

2.4.2 Theorized Business Model implications of Additive Manufacturing

From the academic literature, few articles can be found that directly describe the possible Business Model implications of AM technology. The findings from literature have been divided into two themes. Several scholars highlight a need for a larger degree of openness towards creative inputs (2.4.2.1). Furthermore, the theorized implications of AM can be structurally explained on a business model components level (2.4.2.2). Finally, the deployment of new business models for AM is considered (2.4.2.3)

2.4.2.1 Towards Open Business Models

According to Cautela et. al (2014), Business Models based on AM technology are based on the ability to structure and integrate creative inputs, crowdsourcing processes and market distribution networks. Therefore, the authors propose that AM encourages the creation of 'Open Business Models' (Chesbrough, 2006). Furthermore, Cautela et. al (2014) find that AM is not aligned with established distribution chains and therefore allows for the development of different distribution strategies. This is also shown in figure 4 by Path II. Examples of new distribution strategies are direct e-commerce, alliances with organized distribution, and new types of retail channels such as open design shops, in which the design of a customer is sold to other customers. Cautela et. al (2014) further argue that for these Open Business Models, brand power is reduced. Products that are well-suited to be AM manufactured, such as accessories, interior design items and jewelry, are typically brand-driven purchases. The value of the brand is therefore replaced by signaling the power of customization (Cautela et. al, 2014). With respect to the organizational activities, a focus is placed on the management of the creative networks, the management, selection and marketing of projects and on the management of market and/or distribution channels.

Bogers et. al (2016) specifically explore the possibilities and challenges that AM presents to consumer goods manufacturers' Business Models. Similar to Cautela et. al (2014), a particular focus is placed on both the potential to open up to a higher degree of consumer involvement, and on the associated implications for the organization of production activities. Bogers et. al (2016) explain that AM translates into internal value creation for the consumer goods company, since AM can solve supply chain challenges and provide the company with new possibilities to offer personalized products. AM technology translates into external value creation by means of differentiation and customization of products. However, this argument will only hold for those products for which the consumer actually perceives added value through personalization and customization. Furthermore, the successful adoption of mass customization requires developing appropriate toolkits, which ease the process of creating new ideas, products and

marketing materials for potential partners (Von Hippel & Katz, 2002). The research by Bogers et. al (2016) describe a shift from Business Models in which mass-production plays a central role, towards more consumer-centric Business Models in which products are co-created through a manufacturer's design platform with the consumer (figure 5).

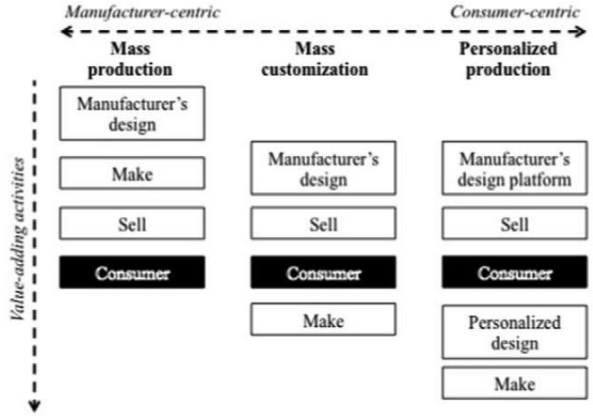

Figure 5: *Spectrum from manufacturer-centric to consumer-centric Business Models (Bogers et. al, 2016)*

In their research, mass customization is seen as an intermediary between manufacturer-centric and consumer-centric Business Models. For Business Model development, this implies managing organizational change and more openness to external sources.

The transition towards consumer-centric Business models for customized products may lead to so-called "long-tail" business models (Rayna & Striukova, 2016). Long-tail business models are about selling a high number of diversified niche products, each selling relatively infrequently (Anderson, 2004). The "long tail" target market segments used to be neglected for consumer products because of high initial costs of manufacturing. However, several authors have found that AM has significant impact on the costs of flexibility, individualization, capital costs and marginal production costs (Weller et. al, 2015; Berman 2012; Ruffo et. al, 2006). The long-tail can be identified as a specific pattern in the BMC. They specifically employ low inventory costs and strong platforms to make niche content readily available (Osterwalder & Pigneur, 2010).

2.4.2.2 Business Model components

On a Business Model components level, the implications of AM technology are discussed by Rayna and Striukova (2016) in terms of five key components. For the value creation component, they propose that the value of a co-created product may be higher than for a mass-produced product since customers become a far stronger element in the value network, enabling more value to be created. With regards to internal value creation, Rayna and Striukova (2016) propose that AM makes it possible to apply the crowdsourcing paradigm to manufacturing, in which a local network of AM machines can become a complementary asset of a company. In terms of the value delivery component, they expect AM to significantly alter distribution channels. Since the value chain of physical products becomes a digital value chain, elements of a value chain for Rapid Production would need to encompass elements such as software, policy (i.e., IP rights), or online services such as online design marketplaces (Piller et. al, 2015). Rayna and Striukova (2016) further expect that in terms of value

capture, companies will need innovative revenue models and make significant changes to their profit allocation structure. It is expected that when consumers are actively involved in the design of a product or even have to pay for manufacturing costs when using AM technology at home, they will be reluctant to pay as much as before unless they perceive that significant value has been added.

Furthermore, AM may have implications for the key activities that a company conducts. Thiesse et. al (2015) explain how the separation of product development and production may lead to new Business Models that focus either on services within product development or on offering manufacturing resources. This view is reflected in a research report by Cohen et. al (2014) who state that over time, AM could move the source of competitive advantage away from the ability to manufacture in high volumes at low cost and toward other areas of the value chain, such as design or even the ownership of customer networks. The report by Cohen et. al (2014) further states that initially, new competitors will be niche players, operating where consumers are willing to pay a premium for a bespoke design, complex geometry, or rapid delivery.

2.4.2.3 Deployment of Business Models for Additive Manufacturing

Bogers et al. (2015) point out that it is unlikely that consumer-centric Business Models, based on AM technology, will completely replace traditional mass-manufacturing Business Models. Instead they argue that the customer-centric Business Model for the customized AM produced product could become complementary to the existing Business Model. In such a situation, the Business Models would co-exist. This implies being ambidextrous, in which the management of today's business demands is aligned and efficient, while also being adaptive enough to changes in the environment to still be around tomorrow (Gibson & Birkinshaw, 2004). Since the new Business Model can offer a competitive advantage, it could complement and even augment the value that is captured through the traditional Business Model (Bogers et. al, 2015). It is likely that traditional Business Models for consumer product companies do not fit the technological and market opportunity presented by AM. Therefore, experimentation with new Business Models to find the right one, the right instance, is considered a must (Chesbrough & Rosembloom, 2002).

2.5 Research gap

In summary, there seems to be consensus amongst scholars that new, and in general a more "open" consumer-centric Business Models will be enabled by AM in which the concepts of mass-customization and co-creation play a significant role. In a more open Business Model, the management of a network of creators and other collaborators (i.e. customer relationship and partnerships) plays an important role. Although the long tail is proposed as a possible type of business model that may align well with AM, Bogers et. al (2015) specifically note that it remains unclear which types of Business Models consumer goods' manufacturers would have to employ in order to capitalize on the flexibility that AM offers. Furthermore it remains unclear how these changes would affect their operations and supply chain structures. When looking at the current use of AM for Rapid Production purposes in CPR, the technology is at a stage where pioneers are experimenting with ways to unlock the potential of AM. This implies they are likely to be experimenting with new Business Models for this purpose (Chesbrough and Rosenbloom, 2002).

From the literature on Business Models regarding AM presented above, it is interesting to find that although scholars are theorizing about the Business Model implications based on theoretical considerations within the domain of AM research, they are not based on any data, or instances, provided by actual practitioners. As such, theory based on empirical research on the subject of Business Models for AM in general is lacking. Especially when a specific focus is placed on Rapid Production in the CPR sector. Therefore, a gap in the literature and simultaneously a research opportunity exists. This thesis aims to partially fill this gap by looking at Business Model instances when AM is used for Rapid Production in the CPR sector. In order to do so, a structured approach is applied to gather primary data on the subject of Business Models for Rapid Production.

3. Methodology

This chapter describes the methodology that was applied during this research. Because of the general lack of theory based on empirical research, an exploratory approach was applied. The exploratory approach involved the collection of both externally and internally available data (i.e. at Capgemini). Since there was no previously used methodology available to identify instances of current Business Model configurations specifically for AM, the sequential, mixed method approach similar to the approach used by Dijkman et. al (2015) to identify Business Model configurations for Internet of Things (IoT) devices was applied in the context of AM. This sequential approach, based on the approach proposed by Teddlie and Tashakkori (2006) was also applicable for this research since there is a similar goal of identifying Business Model configurations for a new technology in an explorative manner. However, instead of two phases of data collection, this research has made use of three sequential phases of data collection which all contribute to the triangulation of the results and their discussion (figure 6).

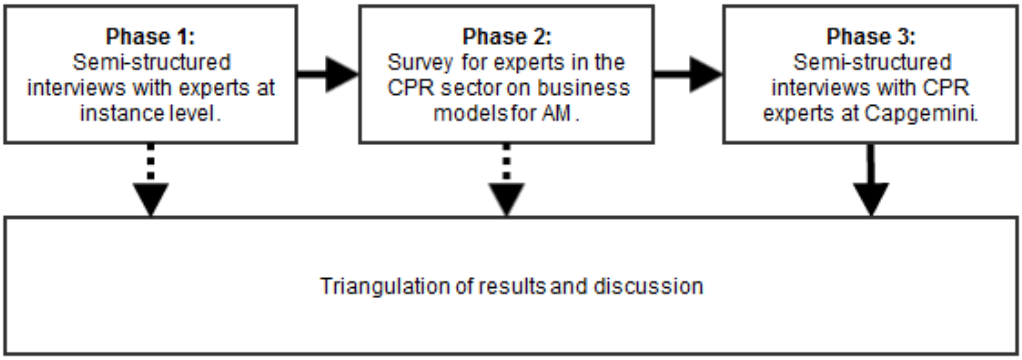

Figure 6: *Three phases of the research*

The ability to apply triangulation is the main benefit of using a mixed method approach, which strengthens both the internal and external validity of the results. As Chandy et. al (2003) note, triangulation is particularly important for initial research in an area, such as this exploratory research, because it facilitates more detailed descriptions and facilitates the interpretation of phenomena. As can be seen from figure 6, the first phase consisted of collecting qualitative data through interviews with Rapid Production Experts (3.1). In the second phase, a survey was conducted to capture the expectations of general experts in the CPR sector (3.2). In the third phase, qualitative data was again collected through interviews with CPR experts at Capgemini (3.3).

3.1 Phase one: interviews Rapid Production experts

The first phase was concerned with capturing and analyzing Business Model instances qualitatively through interviews. The first phase itself consisted of several steps. First of all, the participants for the research had to be contacted and selected (3.1.1). Secondly, semi-structured interviews based on the BMC were composed and conducted (3.1.2). Finally, the insights from the interviews were captured through transcription and data processing (3.1.3).

3.1.1 Selection of experts

For the selection of experts, companies were identified that are known to have launched a consumer product that is directly produced using AM or have a major AM produced component. This was done through online search, using search engines and popular websites in the AM industry. Since very few companies, even globally, use AM for Rapid Production in the CPR sector, the number of companies that were contacted was limited. External experts had to be contacted since there were no experts that have experience in using AM for Rapid Production purposes within Capgemini. However, company contacts of Capgemini were used to find experts that did. Table 3 features the list of companies, the role of the experts that were contacted and the type of product that they represented. One large consumer electronics company and its expert requested to stay anonymous and are referred to as CEC and Expert X respectively in this report.

Table 3: Selection of participating experts

Company:	Expert Role:	Product:
A. Boulton Eyewear	Co-Founder	Eyewear
B. 3D Trophy Factory	Product Manager	Trophies
C. YourEyewear	Technical Expert	Eyewear
D. ODD Guitars	Founder	Electric Guitars
E. Hema	Category Manager	Jewelry
F. Consumer Electronics Company (CEC)	Product Development and Innovation Lead	Electric Shaver
G. PrintPlus	Founder	Headphones

3.1.2 Interview construction and conduct

In the study by Dijkman et. al (2015), the BMC by Osterwalder (2010) was taken as the framework to discuss the Business Models for IoT products. Taking the BMC as the framework for Business Model configurations also applied for the present study from both a scientific perspective and practitioner's perspective. First of all, the framework is based on a meta-analysis of the generic Business Model literature and has been used to identify both existing and new Business Model configurations. Secondly, the BMC is popularly used in business settings, including the AIE at Capgemini.

Since there was only a small sample size for the interviews, quantification of the qualitative data that was gathered would not lead to statistically significant results. However, the qualitative data itself can be used for insights into the decisions that were made to configure the Business Model in a particular way. Furthermore, qualitative research facilitates quantitative research in a mixed method approach by informing the design of survey questions (Bryman, 2004). Since phase two includes a survey, the interviews were also used to identify elements that have not been considered by Osterwalder and Pigneur (2010) but are relevant within the context of AM Business Models.

The semi-structured design of the interviews (Appendix V) allowed for the detailed discussion of each of the nine components presented in the BMC. During the interviews, the goal of the research was first introduced, after which the BMC was explained in case the interviewee indicated that he was not familiar with the BMC. The nine components were discussed in the order as presented by Osterwalder & Pigneur (2010). To conclude the interview, the interviewees were asked to elaborate on the Business Models implications for consumer product companies in the CPR sector and were

also asked if and how they expected their own Business Models to transform based on their experience with AM technology.

3.1.3 Capturing the interview results

For each interview, a full transcript was first made to capture the qualitative insights into the Business Model configurations of the Business Model instances (Appendix C.I) (available on request). This represented a challenge because of the large amount of qualitative data that is documented (Bryman, 2004).Therefore, the general strategy of coding was applied to turn the data into fragments that can be labeled, separated, compiled, organized and analyzed (Bryman, 2004). Since the semi-structured design of the interview allowed for the categorical discussion of the components of the Business Models, the qualitative insights were coded accordingly. The qualitative data was further fragmented using codes that identified the elements as defined by Osterwalder & Pigneur (2010). When elements were identified during the interviews that did not fit Osterwalder & Pigneur's (2010) original description of the elements, the qualitative data was captured under a new code, which essentially represents an addition to the BMC. These findings led to an extended BMC (Appendix VI) that is used for describing the Business Model instances. Since one of the goals of the interviews was to identify elements that were not discussed by Osterwalder & Pigneur (2010), the additions to the BMC are regarded as results of the interview and are presented in Chapter 4.

After coding the transcripts, the coded data was used to present a detailed overview of the Business Model instances (Appendix VII). Based on these individual Business Models an abstract version of each Business Models instance was created using the extended BMC as a framework. The abstracted versions of the Business Models were then used to compare the different Business Models and capture the results. In order to validate the captured data, the transcript and detailed Business Model were sent back to the interviewee so they could be corrected if necessary. No major corrections were made for any of the interviews.

3.2 Phase two: survey CPR sector experts

In a mixed method approach, both qualitative and quantitative data is collected. In line with the approach taken by Dijkman et. al (2015) , the second phase of this research involved collecting quantitative data using a survey. The goal of the survey was to find out on which of the components and elements from the extended BMC experts in the Consumer Product and Retail Sector expect the focus to be placed when AM is applied for Rapid Production by companies in the sector (SQ3). The survey is informed by the findings and results from phase one (as presented in Chapter 4.1). In order to capture valid data, it was important to design the survey such that different types of respondents could be distinguished using filter questions (3.2.1). The survey questions and measurement scales were carefully constructed to ensure validity of the results (3.2.2). To maximize validity and prevent incomplete survey responses, care was also taken in phrasing the questions and structuring the survey (3.2.3). The survey was deployed using various online and offline channels to target professionals in CPR (3.2.4). After collecting the responses, the dataset was prepared for descriptive and exploratory analyses (3.2.5).

3.2.1 Survey design

The specific focus of the research on consumer products and consumer product focal companies (defined in chapter 1.6) was taken into account in designing the survey by excluding non-experts. In order to protect the validity of the results, the respondent's experience in the CPR sector and application of AM technology was considered. As shown in table 4, a distinction was made between four types of respondents that were divided over three categories: those that could reflect on the Business Model implications of AM for their current company (Category 1), those that could reflect on the Business Model implication of AM for companies in the CPR sector in general (Category 2) and non-eligible respondents (Category 3).

Table 4: Survey respondents categorization

Category:	**Respondent type and description:**
Category 1	▪ (Type 1) Respondents working in the CPR sector at a company that considers, will be using or uses AM for Rapid Production purposes
Category 2	▪ (Type 2) Respondents working for a company in the CPR sector, for which AM is not applicable for production or which has not yet considered the use of AM for production purposes. ▪ (Type 3) Respondents that have previous work experience at a company in the CPR sector.
Category 3	▪ (Type 4) Respondents that do not have any professional experience in the CPR sector.

Respondents in Category 1 were preferred since they could share their opinion on the Business Model implications of AM for their current company. Respondents in Category 2 have expert knowledge in the CPR sector because of their current or previous position, but were not eligible to reflect on the Business Model implications of AM for their current company. Therefore, they were asked to share their opinion regarding Business Models in the CPR sector in general. Finally, respondents in Category 3 did not have any experience in the CPR sector and therefore were not eligible to participate in the survey.

The survey was designed in the online tool of SurveyMonkey.com[5] (Appendix S.I). Because the survey was self-administered and internet-mediated, filter questions were used to identify the four types of respondents and separate them into three different branches (Saunders et. al, 2009). The structure of the survey is illustrated in figure 7.

[5] www.surveymonkey.com

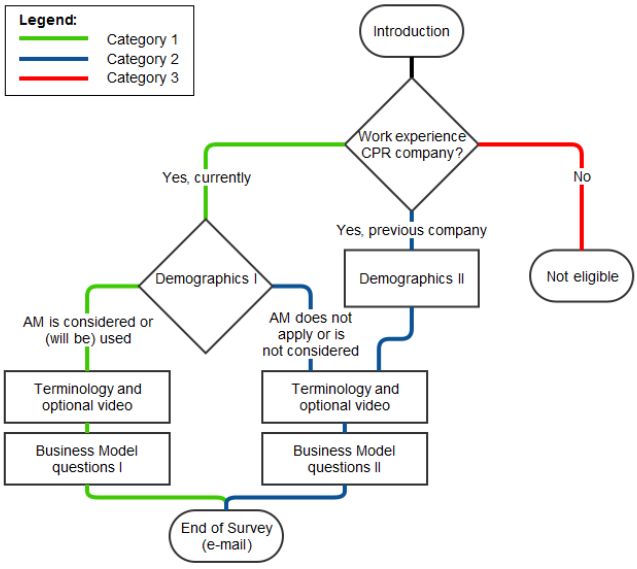

Figure 7: *Representation of the survey structure*

From figure 7, the different types of questions that were included in the survey can be deducted. After managing the expectations, explaining the research goal and presenting an incentive to complete the survey with the introduction, the first filter question was presented to determine whether the respondent was currently working for a company in the CPR sector (Category 1), had previous professional experience (Category 2) or was non-eligible (Category 3). Demographics I and II measured the experience level of the respondents in the CPR sector in number of years and their level of familiarity with AM technology ranging from "Not at all familiar" to "Extremely familiar". Although Lietz (2010) recommends to put demographics questions at the end of the survey, this survey used Demographics I to further filter between Type 1 and Type 2 respondents (table 4). In order to do so, Demographics I additionally included questions that asked to what extent AM was applicable and used to produce consumer products at the company of the respondent. If respondents answered that AM was not considered or not applicable for their company, they were re-categorized under Category 2.

3.2.2 Business Model questions

After filtering the respondents, both categories were informed about the terminology used in the survey. Furthermore, they were given the option to watch an informational video that presented the basics of AM technology and the BMC. Hereafter, the main questions on Business Models for Rapid Production were presented. Although existing survey scales are preferred (Saunders, 2009), none were found to specifically measure respondents attitudes towards the offering of business model elements in the BMC, except for the study by Dijkman et. al (2015). Although this may decrease measurement validity, the explorative nature of this research should be taken into account. Furthermore, the questions and featured elements are based on the original publication by Osterwalder & Pigneur (2010) and the interview results from phase one. The survey was pilot tested (Chapter 3.2.4) to check if the questions would be interpreted as intended. Similar to Dijkman (2015), rating questions in matrix format were used for all questions regarding the Business Model components (Saunders, 2009) (figure 8).

Q3: Per type of channel, how likely do you think it is that the channel is used by your company to reach the customer for 3D printed products?:

	Extremely Unlikely	Unlikely	Neutral	Likely	Extremely Likely
Owned Channels: Owned channels consist of either a 'Sales force', 'Web sales' or 'Own stores' or a mix of these.	O	O	O	O	O
Partner Channels: Partner Channels consist of either 'Partner stores' or 'Wholesales'.	O	O	O	O	O
Mixed Channels: A mix of Owned channels and Partner Channels.	O	O	O	O	O
(Optional) If you would like to elaborate upon your answer to the question above, please do so here:					

Figure 8: *Example of a Business Model matrix question from the Category 2 branch of the survey*

In each matrix question respondents were asked to share their opinion on the likelihood that the elements from the extended BMC, which is informed by the interviews from phase one (Chapter 4.1) would be offered in a context of using AM for the Rapid Production of a consumer product. Respondents were asked to rate each element per component using a 5-point Likert-scale that ranged from "Extremely Unlikely" to "Extremely Likely" (Vagias, 2006). Lietz (2010) note that between a 5- and 8-point Likert scale is considered optimal. Although a number of authors report evidence that supports the use of longer response scales (Lietz, 2010), a 5-point Likert scale was chosen because it was expected that it would be difficult for respondents to distinguish accurately between likelihood values on a rating scale of more than five regarding the abstract subject of Business Models and AM (Saunders, 2005). Likelihood was chosen as the most relevant type of rating scale because this translated directly to measuring the expectations of the respondents rather than their opinions on current business model instances. The 5-point scale is odd numbered and therefore includes a neutral 'middle' option that allows respondents not to commit themselves to a direction in their opinion. This has shown to increase reliability and validity while limiting random error variance (Lietz, 2010). Each matrix question also included an optional open question that asked respondents to elaborate on their answers. The "don't know" option was not included since a neutral answer measures the fact that the respondent does not have a strong opinion towards one of the extremes. Furthermore, previous studies show that the inclusion of a don't know option rarely result in a large significant difference regarding respondents' choice of substantive response options (Lietz, 2010). However, care should be taken in interpreting the results since a choice for the middle option may also be taken by those who do not know enough about the issue to form an opinion or those who do not want to reveal their true opinion.

Although the BMC consists of nine components, the components "Key Activities", "Revenue Streams" and "Cost Structure" were excluded from the survey. Since the rating of all elements using matrix questions resulted in a large number of individual items, pilot testing showed that the survey took approximately 13 minutes to complete. Since the survey was targeted at professionals, it needed to be shortened to at least less than 10 minutes in order to prevent respondent fatigue and incomplete responses due to the time investment required. Analysis of the interview results (Chapter 4.1) had shown that without exception, the production element in the Key Activities component was dominant,

which can be considered a given since consumer product focal companies are involved in activities related to bringing a product to market. Therefore, similar results would be expected from the survey. Similar reasoning applied for the monetization aspects of the Business Model. With a focus on consumer products revenues are very likely to originate from the direct sale of these products. Although alternative revenue models could possibly apply, where the user could for example be charged a usage fee for printing time, none of such instances were found with the interviews. Furthermore, the cost structure of AM produced products is extensively covered in literature (e.g. Hopkinson & Dickens, 2003; Ruffo et. al, 2006)

The final question of the survey was aimed at identifying to what extent respondents expected the Business Model to be affected by AM on a component level. Therefore, a matrix question that included all nine components of the BMC was created and a 5-point Likert scale that ranged from "No Affect" to "Major Affect" was used (Vagias, 2006). After this final question, the survey was concluded by thanking the respondents for their contribution and providing them the option to be informed of the results of the research or participate in a small prize draw by leaving their e-mail address.

3.2.3 Wording and structure

The literature review by Lietz (2010) provides recommendations in terms of question length, question wording and question order to avoid negative impact on sample quality or data accuracy. As noted by Wohlers (2014), 3D printing has become the de-facto standard term to refer to AM. In order to prevent confusion by using the term 'Additive Manufacturing', the term '3D printing' was used throughout the survey instead. In terms of question wording, questions for Category 1 always referred specifically to 'your company'. This enhanced specificity and made sure that Category 1 respondents responded in the intended context. Since the Business Model is an abstract concept, featuring abstract components and elements, it was decided to provide specific, contextual explanations of each element. These explanations were derived from the definitions from the extended BMC (Appendix VI). Finally, the survey was structured such that each page consisted of a maximum of three matrixes to prevent putting respondents off due to the survey length. This resulted in a total of eight pages regardless of being in the Category 1 or Category 2 branch.

3.2.4 Survey deployment

Before deploying the survey, it was pilot tested to refine the survey such that the respondents had no problems in answering the questions and to make sure the data was recorded correctly (Saunders, 2009). Pilot testing was conducted by five colleagues at Capgemini and the supervisor of the thesis at the TU/e. Importantly, the pilot test showed that a survey containing matrix questions for all nine components would be too time consuming as previously noted. This led to the exclusion of the previously mentioned three components. Furthermore, pilot testing resulted in the addition of the optional open questions per component and lead to minor grammar changes and corrections of small errors. From the pilot tests, the average completion time of eight minutes was derived. This information was added to the introduction to inform the respondents.

Because the audience for the respondents was relatively generally defined as "experts in the CPR sector", the survey was mostly distributed through online channels in order to reach the target audience. Although the filter questions of the survey intend to filter out non-eligible respondents, selective distribution was applied to target only those experts in the

CPR sector that were most likely to have a well-informed opinion on both AM and Business Models for CPR. This included product designers, product managers, NPD managers and experts on AM that are employed in the CPR sector. Because the survey was designed using an online tool the respondents could be targeted using online channels.

- LinkedIn groups (8x, total reach: 55,617)
- Facebook groups (3x, total reach: 63,421)
- Capgemini OneCPR Yammer (1x, total reach: 54)
- Shapeways Expo mailing list (Approximately 40 entrepreneurs/small businesses)
- Shapeways Consumer Product Designers (21x)
- i.Materialise Consumer Product Designers (58x)
- Personal contacts working in CPR (5x)
- Consumer Product Designers (6 design agencies)

Furthermore, exhibitioners for new consumer products at CES Unveiled Paris[6] were targeted directly at the exposition. When they expressed their interest in participating, an email was sent with the survey link. A more detailed overview of all distribution channels is provided in Appendix VIII. The survey was deployed on the 26th of October and the last response was captured on the 3rd of December.

3.2.5 Data analysis

By conducting the survey, quantitative data was collected that reflected the opinion of experts in CPR. In order to gain meaningful results from the collected data, the dataset first had to be prepared for analysis. This consisted of three steps:

1) **Coding of the data:** Since the survey was conducted using an online tool, the dataset had to be imported into SPSS. The data consisted of both nominal data (the filter questions and demographics) and ordinal data (the Business Model questions). The dataset was exported in both numerical values (1..n) as well as in actual text such that the numerical results could be checked against the actual text answers. The Business Model questions used the matrix format and therefore the results were already coded from one to five according to the 5-point Likert scale that was used (1 for “Extremely Unlikely” or “No affect”, 5 for “Extremely Likely” or “Major Affect”). The results from the filter questions were used to manually assign a numerical value of one to four for the respondent types and one to three for the respective categories.
2) **Data cleaning:** After importing and coding the data, several checks were conducted. First, it was checked whether the rules of the filter questions had worked correctly by checking each case in the dataset. The data was then cleaned of incomplete responses and several missing values were imputed.
3) **Validity checks:** Validity checks were conducted to check for measurement error and response biases in the form of extreme responding, mild responding and pattern responding.

After preparing the data, the data was analyzed. Both descriptive analysis, which is used to describe the dataset, and exploratory analysis, which is used to find previously unknown relationships were performed on the available dataset:

[6] http://www.ces.tech/events-programs/ces-unveiled/ces-unveiled-paris

- **Descriptive analysis:** The results from Category I and Category II respondents were compared to each other and analysis was performed to check whether there was a significant difference in the results based on the level of experience in the CPR sector and the level of expertise on AM technology. Both One-Sample Wilcoxon Signed Rank and One-Sample t-tests were conducted for the six matrix questions that focused on the business model elements. This resulted in a ranking of the elements within each component, indicating which elements are most likely to be offered in a business model for AM and which are less likely to be offered.
- **Exploratory analysis:** Although the descriptive analysis describes the expected likelihood of each business model element being offered per Business Model component based on the survey results, it was also possible to check for relationships between the Business Model elements within components and across components. In order to do so, a Spearman correlation analysis was conducted. Furthermore, since the goal of this research is to explore Business Model configurations for AM, fuzzy set Quantitative Comparative Analysis (fsQCA) was conducted, which is an addition to the approach applied by Dijkman et. al (2015). This technique is used to analyze causal complexity and presents outcomes as configurations of causes, some of which are necessary and others sufficient (Ragin, 1987). This research uses fsQCA 2.5 software (Ragin & Davey, 2014) and the data from the survey to explore which business model elements align with the offering of specific elements in the Value Proposition.

3.3 Phase three: interviews with experts at Capgemini

The third phase of this research presents another addition to the approach applied by Dijkman et. al (2015). Compared to the first two phases, phase three was more design-oriented in nature. Through an additional round of qualitative data collection, practitioner insights from CPR experts at Capgemini about the possible implications on the subject of AM for Capgemini's clients were gained (SQ4). Furthermore, the expert insights were used to explore opportunities in AM for Capgemini itself by gathering their input for the design of a tool that incorporates the results from phase one and two. Several steps were conducted in phase three. First of all, the participants for the interviews were selected (3.3.1). Secondly, the semi-structured interviews, informed by the findings and results from phase one and phase two (as presented in Chapter 4.1 and 4.2 respectively), were conducted. Finally, the insights from the interviews were captured through transcription and data processing (3.3.3).

3.3.1 Selection of experts

Similar to phase one, qualitative data was captured using semi-structured interviews (Appendix IX). However, where phase one involved the collection of data from external experts, this final round of interviews was conducted internally at Capgemini by interviewing experts in the CPR sector. In total, four experts that each had unique expertise within the CPR sector were found willing to participate in the interviews (table 5).

Table 5: Experts that were interviewed at Capgemini

Expert:	Function	Expertise
A. Leon Berger	Principal Consultant	Business strategy and IT solutions
B. Kees Jacobs	Management Consultant	Digital Proposition Lead & Future Value Chain Lead
C. Anika Siepel	Business Analyst	Innovation Designer
D. Sicco Maathuis	Business Technology Consultant	Project Manager Business/IT

3.3.2 Interview construction and conduct

Before discussing any of the results from the first phase and second phase, the experts were first asked to share their thoughts on which business model implications they expected for companies in the CPR sector based on their knowledge of the sector and AM technology in general. The experts were asked to use the BMC as a reference framework in discussing these possible implications. Since Capgemini has defined several specific segments within the CPR sector, the experts were also asked how they expected these segments to be affected by AM and opportunities for AM technology were discussed in detail when an expert was particularly experienced in one of the segments. After these initial questions, the results from the first and second phase of the research were shared with the experts and discussed. In particular, the experts were asked how they expected clients at Capgemini to deal with implementing AM technology and the possibly having to make business model changes or even design an entirely new business model. Since AM technology is not only relatively new to companies in the CPR sector but also to Capgemini as an IT technology, outsourcing and consulting company, the interviews were also used to explore possible business opportunities together with the experts. Furthermore, the experts were specifically asked what information they would require or would like to have available when talking to clients in the CPR sector on the subject of AM for Rapid Production. These insights were used as input in an iterative design process. Based on the formulation of an initial design, additions and alterations to the tool could be made following each interview. This iterative design process led to a final design of a tool that may help the consultants at Capgemini in supporting companies with the adoption or application of AM technology for Rapid Production.

3.3.3 Capturing the interview results

For each interview, a full transcript was first made to capture the qualitative insights provided by the experts (Appendix C.II (available on request). In order to validate the captured data, the transcript, detailed Business Model and abstract version of the Business Model were sent back to the interviewee so they could be corrected if necessary. No major corrections were made for any of the interviews. Through coding of the qualitative data, the insights that were gained were categorized under three main themes: 1) Business Model implications for firms in the CPR sector, 2) Opportunities for Capgemini and 3) Tool Design. The coded data was used in describing the results from the interviews (Chapter 4.3) and designing the final tool (Chapter 4.3.3).

4. Analysis and results

In this chapter the analyses and results from the three research phases are presented. Because of the sequential nature of the research, the results from each phase influence the data collection and thereby the results of the following phase. The results of the interviews with experts using AM for Rapid Production purposes are first presented (4.1). This is followed by the presentation of the survey results and the analyses that were conducted (4.2). Finally, the results from the interviews with CPR experts that were conducted internally at Capgemini are presented (4.3).

4.1 Phase one results

Through semi-structured interviews with experts in using AM for Rapid Production, qualitative insights about the used Business Model configurations were gathered. The firmographics are first introduced to gain an understanding of the context in which the results should be evaluated (4.1.1). Coding of the interviews has led to an extended BMC that was used to inform the survey of phase two (4.1.2). The extended BMC is used to present an overview of the Business Model instances in the sample (4.1.3). Furthermore, expert insights about their business model instances and the expected further implications of AM were gained (4.1.4).

4.1.1 Firmographics

The firmographics (table 6) show a high diversity in terms of company size. Four out of the total of seven companies can be considered very small, with less than ten employees. On the other hand, there were two large multinationals in the sample as well (Hema and CEC), which shows that both small and large companies alike are pioneering the use of AM for the direct production of consumer products. However, the intentions for the market offering of the two multinationals should not be neglected. Although their products are full commercial offerings, they were mainly intended as pilots to learn about AM and customer behaviour whereas the smaller companies intend to make a profit with their product.

Table 6: Phase one interview firmographics

Expert:	Company:	Age: (years)	Go-to-Market:	Size: (FTEs)	Company Revenue (€):	Product Description:
A	Boulton Eyewear	3.5	2015	2	35,000	Eyewear
B	3D Trophy Factory	4	2012	5	n/a	Trophies
C	YourEyewear	2	2016	n/a	n/a	Eyewear
D	ODD Guitars	4	2012	1	150,000	Electric Guitars
E	Hema	90	2014	10,000	1.14bln	Jewelry
F	CEC	125	2016	105,000	24.2bln	Electric Shaver
G	PrintPlus	2	2016	1	25,000	DIY Headphone

Interestingly, six out of seven companies used SLS technology to manufacture their product in nylon (company G did not) (Figure 9). Two experts indicate that the strength and resistance of the material make it well suited for a consumer product. The flexibility of the SLS print method and the option for a wide variety of finishes are cited as advantages of this method and material respectively. Furthermore, the experts regard the SLS print method and the material as having a great price to quality ratio. Two companies (Hema and ODD Guitars) also used AM to manufacture their product in metal.

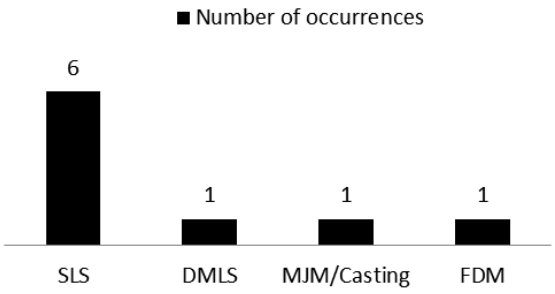

Figure 9: *Selected AM Technology*

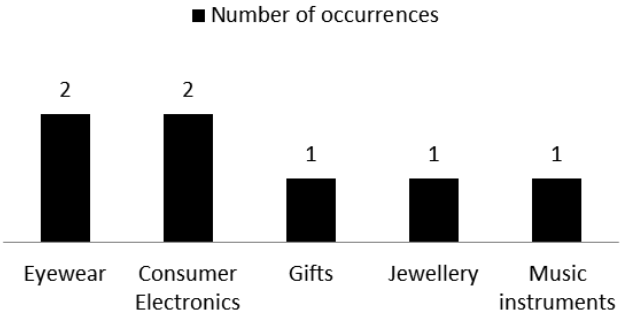

Figure 10: *Represented industries in the sector*

When looking at the industries within the CPR sector that are represented in the sample, it should be noted that two of the smaller scale companies offer customized frames for the eyewear industry (Figure 10). Since the other companies all act in different industries, this means that the eyewear industry is slightly over-represented in the sample. Therefore, care was taken to generalize the findings across different industries within the CPR sector. Furthermore, several notable characteristics of the product offered by the companies in the sample were identified (table 7).

Table 7: Product offering characteristics

Company	Niche Product	High price segment	Customizable / Personalizable	Wearable	Digital configurator	Digital store	Physical store	Lifestyle Product
A. Boulton Eyewear	x	x	x	x			x	x
B. 3D Trophy Factory	x	x	x		x	x		
C. YourEyewear	x	x	x	x			x	x
D. ODD Guitars	x	x	x	x				x
E. Hema			x	x	x	x		x
F. CEC	x	x	x		x	x		x
G. PrintPlus	x		x				x	x

From these characteristics, it becomes visible that most products that are offered could be categorized as niche products, most of which are offered for a higher price segment and can be worn visibly. Furthermore, most of the products (with the exclusion of the awards by 3D Trophy Factory) can be considered lifestyle products that can be used by consumers to express themselves (i.e. the eyewear products, electric guitar, jewelry, headphone and possibly even the electric shaver). Although the products are all customizable, none of the products had reached mass-customization levels in terms of production.

4.1.2 Additions to the Business Model Canvas

In total, four additional elements were identified that are relevant for discussing Business Model configurations in the context of this research:

- **Digital:** For the Key Resources component, Osterwalder & Pigneur (2010) make a distinction between physical, intellectual, human and financial resources. During the interviews, key resources such as the digital design files, front-end and back-end systems for webshop integration and in-house developed automation software were identified as being very important to offer the AM products. Although Osterwalder & Pigneur (2010) describe that IT systems are regarded a physical resource, they do not make a distinction between the physical system

themselves or the software that is running on the system. Therefore, the element "Digital" is added to the BMC framework in the key resources component. For the purpose of this research, it is defined as "Any digital product such as in-house developed software, design files, automation tools or webshops."

- **Marketing:** During the discussion of the Key Activities component three experts (B, C and E) specifically identified marketing activities as being a key activity. Although marketing could arguably be categorized as part of "production" activities, one of the experts indicated that if the product and idea was to grow, it had to be put out on the market and that "*the development of the product should always be there, it is a process that never stops. However, the focus has to shift at some point*" (Expert C, 2016). This exemplifies a distinction between design and production of the product versus putting it out on the market and selling it. Therefore, it was decided to make this distinction by adding "Marketing" as a unique element in the context of AM and CPR. This presents an addition to the "production" (i.e. designing, making and delivering a product in substantial quantities and/or of superior quality), "problem solving" or "platform/network activities" elements. It is defined as "*The activity, set of institutions and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large*." (Keefe, 2008)
- **Sustainability:** Surprisingly, sustainability is an element that was found lacking in Osterwalder and Pigneur's (2010) original BMC even though a sizeable number of consumers prefer eco-friendly offerings (Nidumolu et. al, 2009). Although mentioned by only a single company (company G) as being a key value proposition that is offered with their product, one of AM's key characteristics is "Less waste and by-product" (Lipsons & Kurman, 2003). Furthermore, new eco-friendly materials may be used with AM and therefore it is included as an element in the value proposition. The sustainability element is offered when value is created by being relatively less harmful or not harmful to the environment and depleting less or no natural resources during the production and/or use of the product, thereby supporting long-term ecological balance.
- **Co-production:** Since AM lowers the barrier of entry for production, there is a unique possibility that the consumer produces (a part of) the product on a personal AM machine after gaining access to the digital file provided by the company. One company in the sample (company G) relied on its customers to manufacture several of the plastic components of the end-product using consumer-grade FDM printers. This represents a new type of customer relationship, unique to AM, in which the customer is part of the production process. Therefore the element "co-production" is added to the customer relationship component.

Although Osterwalder & Pigneur (2010) make a distinction between buyer-supplier relationships and strategic alliances within the Key Partners component, they do not specifically explain the exact role of the partners when categorizing them using only this distinction. Therefore, four sub-elements were added to enhance specificity and elaborate on the role of the Key Partners. A fifth sub-element, "Innovation & Development" was added in the Key Activities component.

- **AM Production Partner:** Notably, all companies indicated that they worked together with a partner that specializes in AM production, such as Shapeways or Materialise, to outsource their manufacturing and sometimes even post-processing of products. Since the activities are outsourced to another company, the Production Partner" was added as a sub-element of the 'Buyer-Supplier relationship' element.

- **'Sales', 'Digital Technology' and 'Material and Machine Technology'** were added as sub-elements of 'Strategic Alliances' to make a further distinction between the role of the key strategic partners. Both companies in the eyewear industry (company A and company C) indicated that they collaborate with opticians who acted as sales partners. Although this could also be considered a buyer-supplier relationship, the opticians also provide the scanning service and deliver the data that is needed to create the product. Furthermore, they provide input in the design, which lead to the classification of strategic partner.
- **Innovation and Development:** Since some of the companies are still experimenting with AM as a technology and regarded their product more of a pilot than a full market offering with the objective of making a profit, the sub-element 'Innovation & Development' was identified as a sub-element of 'Production' in the Key Activities component. It is defined as the explorative activities a business conducts that lead to the development and market offering of new products and procedures.

Finally, Osterwalder & Pigneur's (2010) definition of the 'Design' element, which is part of the Value Proposition, was extended to include not only superior designs but also the "uniqueness" of the design, in which value is added through AM's flexibility to produce new and complex designs that may not only be functionally superior, but also aesthetically unique.

4.1.3 Combined results of Business Model instances

Through coding of the interviews, the Business Model configurations for the products discussed by the experts were identified. Although the sample size is not sufficient for the results to be statistically significant, a cumulative overview of the results can be created. This 'heat map' shows a summarized cumulative overview of the elements that were offered in the Business Model instances represented in the sample. Color codes are used to show which components were cited as being particularly important regarding the Business Model around the AM produced product (Figure 11). More detailed results are featured in Appendix X.

Key Partners		Key Activities		Value Propositions		Customer Relationships		Customer Segments	
Strategic Alliances (non-competitive)	7	Production	7	Customization	7	Personal assistance	5	Niche Market	6
Materials & Machine Technology	6	Innovation & Development	4	Design (+ Uniqueness)	4	Self-service	4	Mass Market	1
Digital Technology	3	Marketing	3	Convenience	3	Dedicated personal assistance	1	Segmented	0
Sales	3	Problem solving	0	Accessibility	3	Co-creation	1	Diversified	0
Buyer-Supplier Relationship	6	Platform/network	0	Price	2	Co-production	1	Multi-sided platforms or markets	0
AM Production	6			Brand/status	1	Automated services	0		
Coopetition	0	**Key Resources**		Newness	1	Communities	0		
Joint Ventures	0	Intellectual	6	Performance	1	**Channels**			
		Digital	6	Risk reduction	1	Owned Channels	4		
		Human	3	Sustainability	1	Partner Channels	2		
		Physical	3	"Getting the job done"	0	Mixed Channels	1		
		Financial	0	Cost reduction	0				
Cost Structure						**Revenue Streams**			
Value-driven	6					Asset sale	7		
Variable costs	5					Usage fee	1		
Fixed costs	4					Lending/Renting/Leasing	0		
Economies of scale	3					Licensing	0		
Cost-driven	1					Brokerage fees	0		
Economies of scope	0					Advertising	0		

Relative importance of components:

= 7x
= 3x
= 2x
= 0x

Figure 11: *Quantified results of the interviews*

Based on the results in figure 11 and the qualitative data on which it is based, SQ1: *"Which configurations have experts that are applying AM technology for Rapid Production in the CPR sector applied in their Business Models?"* is answered.

The results show that all seven companies indicated that the Value Proposition was an important component. Furthermore, within this component, all companies focused on offering the 'customization' value proposition by providing a product that can be customized by or for the consumer. Four experts (companies B, D, F and G) also indicated that their companies create value because of the (unique) design of their product. Furthermore, both accessibility (companies A, C and E) and convenience (companies B, E and G) were value propositions that were offered relatively frequently. Accessibility was directly related to the customization value proposition since experts mentioned that consumers previously lacked access to customization services because they were either non-existent or only offered by specialists such as goldsmiths for jewelry. For two of the companies offering this accessibility to customization (A and E), the use of AM technology also translated into offering a relative price advantage compared to traditional specialist services. Two of the companies (B and E) offering the 'Convenience' value proposition mentioned that they offered an easier way of customizing or personalizing the product by offering a digital configurator. Surprisingly, only company G specifically focused on the benefits that could be offered in terms of sustainability even though this is a key characteristic of AM. This expert indicated that sustainability was offered by selecting only sustainable materials for the plastic parts and the additional components that were needed to make their headphones. Furthermore, by having consumers produce the plastic parts of the product with their own printers, Company G was able to reduce shipping volume significantly and thereby enhance their sustainability proposition by only sending the components that could not be produced by the consumers themselves such as the electronics and ear cushions. This was also the only company to offer both the 'risk reduction' and 'convenience' value propositions, which were based on the modular design of its product. By having the customer produce the plastic parts on their own parts, any part that would break could simply be replaced by the consumer. The modular design of the product also allowed for the modular replacement of the electronics.

Besides the value proposition, the 'Key Activities' and 'Key Resources' components scored relatively high. Within the 'Key Activities' component, all companies indicated their involvement in production activities, which is not surprising considering the focus of this research on consumer product focal companies in the CPR sector (Chapter 1.6). Furthermore, four experts (companies A, E, F and G) indicated that a lot of their efforts on the subject of AM were still related to experimentation with the technology and learning from the outcomes of the market offering.

In terms of Key Resources, the 'Intellectual' element was often cited as being particularly important. Intellectual resources that were often mentioned were the in-house knowledge and established networks with partners. Because of the digital nature of CAD design and its close relatedness to AM the 'Digital' element in the Key Resources component was considered particularly important. To exemplify this, companies B, E and F offered their product through a user toolkit in the form of an online product configurator. This allowed the customer to customize or personalize the product themselves, which also lead to the offering of a self-service relationship. These configurators were also directly linked to a webshop to sell the finalized design. Interestingly, the two experts from the companies in the eyewear industry (company A and C) explained that their product is an offline product rather than an online product. However, this is

possibly a characteristic of the industry, in which online sales are traditionally low according to the expert representing company A. However, the expert also indicated that it may be due to a need for the customer to physically evaluate the custom product before purchasing. Because of the fact that a custom-fit is required and the technology required to provide this custom fit is offered by the sales partner, the consumer physically needs to experience the customization process through an in-store experience combined with personal assistance. Furthermore, as the expert representing Company A explains, the online customization process is not user friendly enough at the moment. The Key Partners are cited as being a particularly important component by companies C and company D. When looking at the results of the Key Partners component, it becomes apparent that six out of seven companies (with the exception of company G) use AM production partners in the form of a Buyer-Supplier relationship. Furthermore, all companies also have strategic partnerships that are considered key in offering their AM produced product. Three companies (A, C and G) use sales partners that help them in providing data for customization purposes (companies A and C) or market the product in store to help sell more products (company G). Digital technology partnerships are key for companies B, E and F. These digital technology partners were required by those companies who offered their product through a digital configurator, which they did not develop in-house themselves. Finally six companies (A, C, D, E, F and G) indicated that strategic partners are used that help with material development, selection and other technically oriented decisions.

On the other components, no particular additional focus is placed. The customer segments show a clear preference towards niche markets. This is not surprising when taking into account the firmographics (paragraph 4.1.1), showing that some of the companies operate on a very small scale and none of the companies had high sales volumes. Although customization is the key element in the Value Proposition, it is interesting to find that only company D actively pursues a co-creation relationship with the customer. The expert of this company explained that a product is co-designed with the customer through a long conversation (up to a year), in which the design is constantly iterated upon. This expert further noted the very personal, friendly relationship which is formed through this collaboration process. Because of the digital nature of AM, webshops are offered by four companies (B, E, F and G) which lead to a self-service relationship. However, due to the customization aspect of the products that are offered, a ‘personal assistance’ relationship is also commonly cited. To reach the customer, ‘owned channels’ in the form of social media and company owned websites are predominantly used to raise awareness, allow for further evaluation and eventually to sell and deliver the product. When discussing distribution channels with the expert representing company E, which was one of the multinationals in the sample, the expert highlighted the importance of the company’s existing capabilities in the delivery of personalized products. These capabilities were normally exclusively reserved for the distribution of custom photo albums and other photography products to distribute its AM products. Since this company had already developed capabilities to offer and distribute products for which customization is central to the proposition, they could apply the processes that were already in place for their AM products.

The experts all applied the traditional ‘asset sale’ element in their Business Models, which simply is revenue gained from the transition of ownership of the product. Company D was the only company to also apply the ‘usage fee’ element. This was a direct result from offering the co-creation relationship, which lead the expert of the company to charge for the time that was spent on designing the product although he did not use a fixed hourly fee. Although most companies did

mention that their costs had to be such that a competitive price could be offered, the cost structures around the products showed that six out of seven companies in the sample (excluding company G) focused on value-driven costs, which is in line with offering high-value, niche products. Company D explained that for his company, the main reason was that the maker of the product spends time with the customer to customize it. "*That's where you're paying typically for the labor and the customization of the guitar, as much as for the guitar itself*" (External Expert D, 2016). The two experts representing the multinationals (companies E and F) also explained that they did not focus on minimizing costs since the objective was not to make a profit, but to learn from their market offering. They did note that the price that was set for their products was such that it would not distort the market although this left them with a minimum to no margin. Five of the experts (representing companies A – E) explained that their cost structures revolved around variable costs for the production of their product, which makes sense since the AM produced products are produced on-demand and dominantly featured AM produced components. Four companies (B, C, F and G) featured products that had major AM produced components but also included fixed costs for non-AM produced components and human capital. In two cases (companies F and G) this lead to more dominant fixed costs in the overall production of the product.

4.1.4 Identified future implications of Additive Manufacturing

The experts also provided insights into how they expected AM to further impact their Business Models and the CPR sector in general in the future. This paragraph therefore answers SQ2: "*On which Business Model components and elements do these experts anticipate a strategic shift based on their understanding of and experience with AM technology?*".

On the subject of customization, one of the eyewear experts (company A) indicated that he is expecting to provide customization services without requiring in-store personal assistance in the near future. According to this expert, this opportunity is enabled when devices such as smartphones become equipped with depth-sensing cameras, making it possible to automate the custom-fit based on a scan made by the consumer. Although automation of the design process is key according to this expert, he expected that the customer would perceive added value through a more personalized self-service experience instead of the personal assistance relationship that was now required. On the other hand, both of the eyewear experts also highlighted the current importance of in-store evaluation of the product since people want to physically experience the product before deciding to purchase. Furthermore, the expert that represented company D indicated that physical evaluation of an AM produced product may even be a necessity, especially if it is an expensive product such as the AM produced guitars that he offered.

Another subject cited by two of the experts was the scalability of their Business Models. These experts indicated that for a co-created product, in which a discussion about the design of the product is held with the customer, the Business Model is not scalable in the long term. A possible solution that was proposed by the expert representing company D was offering a "standard" product, with parameters that can be customized by the customer through an online user toolkit and sold through a webshop and network of trusted partners as was offered by others in the sample. One of the experts (company C) expressed concerns regarding co-creation because of a lack of consumer creativity. Although communities would provide an opportunity to co-create with the customer, especially the more creative customers, none of the

companies in the sample had built such a community around their consumer product. Two of the experts (companies B and G) expressed interest to do so in the future but had no concrete plans yet.

Finally, all of the experts indicated that they expect to continue collaboration with strategic partners and AM production partners, similar to the way manufacturing capabilities are currently outsourced to production specialists. Noticeable was the fact that these production specialists were mostly local partners such as Shapeways and Materialise, which have production facilities in the same or a neighboring country. Although the SLS print method and the nylon material are regarded as having a great price to quality ratio, one of the experts from the multinationals (company E) also stated that for their existing products, mass manufacturing may be a hundred times cheaper. The challenge according to this expert is to find these truly new-to-the-world products, that can only be made by using AM. The search for such a product presents a major challenge for his company. The limitations of current AM technology were expressed by most of the experts as being something that has to be improved, and which they also expected to improve, in order to further grow their business. Similarly, one of the experts (company C) explained that for existing products which people can find around their house, Rapid Production with AM will most likely not replace traditional manufacturing. The experts seemed to all agree that traditional mass manufacturing would not be replaced by AM in the near futures, except for those products or product parts for which customization or added complexity truly represents added value for the customer. Initially these are high value products in niche markets, as were mostly offered by the companies in the sample. However, one of the eyewear experts (company A) indicated that he expected price drops in AM production due to expiring patents and new technology which could lead to a larger range of products for which AM can be considered a viable production method.

4.2 Phase two results

In Phase two, a survey was conducted that aimed to measure on which of the components and elements from the extended BMC experts in the Consumer Product and Retail Sector expect the focus to be placed when AM is applied for Rapid Production. Analysis of the data first required preparing the dataset by cleaning the data from incomplete responses and checking for errors and other irregularities (4.2.1). After removal of these cases, the dataset was further analyzed by performing validity checks (4.2.2). After conducting the preparation steps, the descriptive for the dataset was provided (4.2.3). Using the prepared dataset, descriptive analysis in the form of comparison of Means was performed (4.2.4). Furthermore, possible correlations between Business Model elements across Business Model components were explored (4.2.5). Finally, the results of the fsQCA analysis are presented, which lead to the identification of various Business Model configurations and core elements in offering a specific value proposition (4.2.6).

4.2.1 Cleaning the data

The survey resulted in a total of 104 cases. These cases were first imported into excel and codes were added to identify the respondent category and type. All cases were assigned unique ID's (1 to 104). Categorization of the respondents was performed per table 4 (Chapter 3.2.1). Based on the categorization of the respondents, 26 Type 4 respondents were removed because they were non-eligible. The dataset was then checked for missing data. Two cases (ID's 41 and 57) were removed that couldn't be identified as a particular type of respondent since these respondents had only partially

filled out Demographics II. Of all identified Type 1 respondents, 18 were removed that had dropped out (16 of which did not start with the Business Model questions at all). A particular Type 1 case (ID = 11) had provided at least one answer per Business Model question, but also featured 38 missing values and was therefore removed. Four Type 2 cases and seven Type 3 cases were removed because of incomplete response.

The remaining dataset was then checked for obvious irregularities and errors. First of all the logic of the filter questions was checked, which showed that the branching of the respondents had worked as intended. A double entries check was performed by attempting to identify identical IP addresses. This did not result in the removal of a case since there were no identical IP addresses. Response times for individual cases were checked in order to remove any cases that were filled out too quickly. Based on the pilot test completion time of eight minutes, two cases (ID's 4 and 81) were removed that were completed in less than five minutes. This resulted in 44 retained and 60 removed cases. In total, 26 respondents of Type 1 (Category 1), and 18 respondents of Type 2 and Type 3 (Category 2) remained.

Seven of the remaining cases (ID's 13,23,47,62,73,98,104) featured a single missing value on an item in the Business Model questions. One case (ID = 61) featured two missing values and another case (ID = 54) featured three missing values. The missing values were dealt with by performing Little's Missing Completely At Random (MCAR) test (Little, 1988). The two branches featured slightly different questions (i.e. Category 1 respondents were asked to respond at the instance level for their current company and Category 2 for the CPR sector in general) (figure 7). Therefore the MCAR test was performed separately for the Category 1 and Category 2 branches. It was found that the missing values could be interpreted as being 'Missing Completely At Random' for both branches. This allowed for imputation of the missing values per category, which was done using Expectation-Maximization (Appendix XI).

4.2.2 Validity Checks

Several checks were performed to validate the input from the respondents. However, first the validity of the survey questions themselves were assessed based on the provided answers (4.2.2.1). The dataset was also checked for multiple types of response bias (4.2.2.2).

4.2.2.1 Measurement validity

The validity of the survey questions is mostly determined by the survey design (Chapter 3.2.1). However, the responses can give a further indication of the measurement validity. The open questions in which respondents were given the option to elaborate on their choice of answers revealed a total of three comments on the survey. One Category 1 respondent (ID = 33) revealed that Business Model Question 4 may have been "*Kind of a difficult stated question, I don't understand what you're asking.*" Upon visual inspection, the respondent provided neutral answers for this question. At the end of the survey, one of the respondents indicated that it would have been easier to understand what was being asked if only one sentence per line was used. During the design of the survey, priority was given to improve specificity of the survey questions, which resulted in slightly longer sentences. One particular Category 1 respondent dropped out after stating being put off by the use of jargon. Although unfortunate, an attempt was made to enhance understanding of the terms by providing explanations per Business Model element (e.g. figure 8) and by giving the respondents the opportunity to watch an instructional video. However, the subject of Business Models remains quite abstract, which may

have resulted in dropout of some respondents. Since a high number of dropped respondents on a particular question can indicate that the question was particularly difficult to understand or impossible to answer, dropout was checked for the respondents that remained after the first filter question (Appendix XII).

4.2.2.2 Response bias

Response bias can occur when respondents do not reflect their true beliefs, typically because a question is framed in a leading manner or because a given response is considered more socially acceptable. The dataset was checked for response bias in the forms of extreme responding, mild responding and pattern responding.

- **Extreme responding** is the tendency to prefer using the extreme points on a rating scale. On the 5-Point Likert scale that was used, this would result in the respondent predominantly using (1's and 5's). The problem with extreme response bias is that one cannot ordinarily distinguish whether an extreme rating indicates a strong opinion by the respondent or is actually the result of the preference to use extreme points (Robins et . al, 2009). As Robins et. al (2009) explain, there is no standard instrument for assessing extreme response bias. Furthermore, it is also dependent on whether the Mean departs substantially from the scale midpoint (3 = 'Neutral'). Since this research uses a five point scale instead of seven, there is an increased likelihood of a higher number of extreme responses per respondent. Checking of the standard deviations was combined with a count of extreme responses per respondent (Appendix XIII). This did not result in the removal of a case.
- **Mild responding** is the opposite of extreme responding. Mild responding occurs when a respondent has the tendency to predominantly use the middle option. Again the standard deviations per respondent were checked and a count was made of the respondent's use of the scale midpoint (Appendix XIV). No cases were removed from the dataset based on this check.
- **Pattern responding** occurs when respondents simply mark their responses in a physical pattern (e.g. 1,2,3,4,5,1,2,3,4,5 or when the respondent uses a single answer for all questions). A visual check was performed to check whether there were any identifiable patterns per respondent (Robins et. al, 2009). No obvious patterns were found in the dataset. It was found that some respondents had filled in the same value for all items in a particular question. For these cases, it was checked whether this was systematic behaviour by calculating the standard deviation of the respondent's answers per Business Model matrix question (Appendix XV). Again, this did not result in the identification of non-plausible responses and therefore and no cases were removed.

Since there was practically no limited set of respondents (e.g. as would be the case when the number of respondents would be limited to an internal mailing list at a company), non-response bias was not an issue for this survey.

4.2.3 Data descriptives

Since no more cases needed to be removed after conducting the validity checks described above, the finalized dataset consisted of 44 cases of which 26 were Category 1, and 18 were Category 2 respondents. Although this represents a relatively small sample size (N = 44), the research that is conducted is explorative in nature and therefore the survey results can best be interpreted as an indication of Business Models for Rapid Production in CPR. Furthermore, the

respondents are characterized by a very high experience level on the subject of AM overall, with 32% indicating that they are “moderately familiar” and 52% indicating to be “extremely familiar” on the subject. This increases the validity of the research results. The experience level within the CPR sector was more evenly distributed, with 27% having between 0-2 years of experience, but also 27% with over 10 years of experience. Company size was measured for Category 1 respondents, which showed that 80% worked for a company with less than 10 employees in total. This is not surprising considering the fact that AM is currently mostly used by smaller companies or individual entrepreneurs in niche markets. Of all Category 1 respondents, 19% worked at a company with more than 5000 employees. An overview of all descriptives that were gathered is presented in Appendix XVI.

4.2.4 Comparison of Means

In preparing the dataset, Category 1 and Category 2 respondents were treated separately. This was done deliberately since Category 1 was asked to respond at the Business Model instance level (for their current company), whereas Category 2 was asked to answer in the context of Business Models for consumer product companies in the CPR sector in general. However, in order to be able to eventually create a single generalized ‘heat map’ of the Business Model elements and components, it was preferred to combine the answers in both categories in order to do a single analysis per item in the Business Model questions (4.2.4.1). After combining the data for Category 1 and Category 2, a comparative analysis was performed for the Means of the Business Model Elements (4.2.4.2). A similar comparative analysis for the Business Model components themselves was performed using the answers of Question 7 (4.2.4.3).

4.2.4.1 Group comparison and Category combination

Before combining Category 1 and Category 2 data, an assessment was made to determine whether the different groups based on AM experience, company size or CPR experience represented in the sample would influence combining both categories.

Additive Manufacturing experience

The respondents’ experience level with AM and within the CPR sector (asked for in both Demographics I and II) needed to be taken into account in combining the data. The data descriptive show that there were no respondents in the dataset that were not at all familiar with AM (Chapter 4.2.3) This also meant that the sample size for the group of respondents that was not very familiar with AM (score of 1 or 2) (Total N = 3) was too small to perform a meaningful comparison between the two groups. The small sample severely limits the effect that differences in experience level within the dataset could have.

Company Size

Because only Demographics I featured a question on company size, the only possibility for a comparison based on company size was to compare the results from respondents of Type 1 (Category 1) and Type 2 (Category 2) separately. Respondents were further divided into two groups; those that work at “smaller companies” (less than 25 employees, score 1,2 and 3), for which sample size was N (Type 1) = 20 and N (Type 2) = 3, and “Large companies” (more than 500 employees, scores 6,7 and 8), for which sample size was N (Type 1) = 4 and N (Type 2) = 2. Because of the low sample sizes for respondents working at “Large companies”, a comparison based on company size would not be very

meaningful. It must be noted that the relatively small sample size for respondents working at “Large companies” does imply that the results may be biased towards Business Models for smaller companies in the CPR sector.

Consumer Products and Retail experience

In terms of experience in the CPR sector there was more variety amongst the respondents as shown in the sample descriptives (Appendix XVI). Because of the relatively small sample size of “very experienced” respondents (score of 3 or 4) and “less experienced” respondents (score 1 or 2) within each Category, the choice was made to conduct an Independent Samples Mann-Whitney U test, which tests for significant differences in the number of times a score from one sample is ranked higher than a score from the other sample within Category 1 and Category 2 separately. The results showed that there was no significant difference in the results on the basis of CPR experience per category (Appendix XVII) and therefore the results from different levels of experience can be combined in further analysis.

Category 1 and Category 2 respondents

Since both sample sizes of Category 1 (N = 26) and Category 2 (N = 18) were relatively small, the Independent Samples Mann-Whitney U test was conducted to check for significance in the number of times a score ranks higher or lower between categories per item. However, Norman (2010) argues that parametric tests can be used reliably with Likert data from small sample sizes with unequal variances and with non-normal distributions. Therefore, an Independent Samples t-test was also conducted to cross check the results and see if similar conclusions could be drawn. For the questions regarding Business Model elements (Q1..Q6), the data from Category 1 and Category 2 respondents featured almost virtually no statistically significant differences and could therefore be combined. For the last question (Q7) regarding the affect of AM on a components level, a significant difference was found by both tests for four of the nine components, i.e. “Value Proposition”, “Revenue Streams”, “Key Activities” and “Key Partnerships” (Appendix XVIII). Therefore, the decision was made not to combine the Category 1 and Category 2 for the Business Model component-level question (Q7) during further analysis.

4.2.4.2 Business Model elements Mean comparison

By combining the data from Category 1 and Category 2, the increased sample size (N = 44) allowed for the interpretation of the results on an interval scale. This made it possible to determine the Means per Business Model element. The comparison of the Means by themselves can lead to a ranking of the relative likelihood that an element is offered per component in a Business Model for AM. In order to create the configurational “heat map” that was aimed for as a research result, the Means of the business model elements were compared to the Mean of the combined Business Model elements within a component using a One-Sample t-test. Although strictly speaking the distribution of the Means per Business Model element is not normally distributed due to the use of ordinal variables, the interpretation of the results on an interval scale allows for assumed normality when sample size increases. Additionally, the One-Sample t-test is known to be robust to approximately non-normal data and even extreme cases (De Winter & Dodou, 2010; Norman, 2010). Furthermore, the ranking of the Means themselves should be seen as the leading indicator, whereas the One-Sample t-test is merely used as an explorative indicator of which elements are relatively more likely to be offered and which ones are relatively less likely to be offered within a component. The statistics per t-test that was conducted are

presented in Appendix XIX. Summarized results are presented per Business Model component that was tested below. The 'heat map' analogy applies in interpreting the results shown in the figures. Those elements that received statistically significantly higher scores are shown in red, those with statistically significant lower scores in green and when no significant difference is found the yellow color is used. The component Mean is represented by a vertical line.

Customer Segments

Niche Markets received statistically significant higher scores (M = 4.36, SD = 0.53) compared to Mean score in Customer Segments, t(43) = 11.26, *p* = 0.000. The Means of Segmented, Diversified and Multisided markets do not deviate significantly from the Customer Segments Mean. Mass Markets received statistically significant lower scores (M = 2.52, SD = 1.23) compared to the Mean score in the component, t(43) = -5.09, *p* = 0.000 (figure 12).

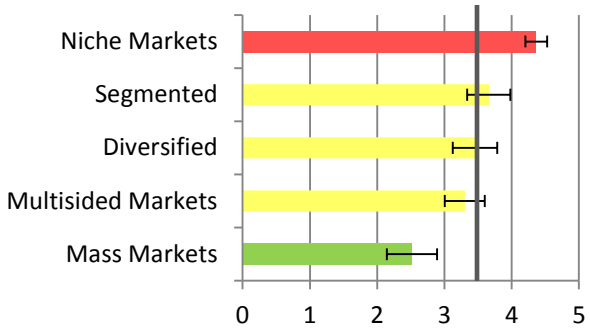

Figure 12: *Customer Segments elements Mean comparison*

Value Proposition

Three out of twelve elements within the Value Proposition component (figure 13) received statistically significant higher scores compared to the component Mean. These are Customization (M = 4.46, SD = 0.82), t(43) = 8.86, *p* = 0.000; Design (M = 3.91, SD = 0.88), t(43) = 4.12, *p* = 0.000 and Newness (M = 3.89, SD = 0.81), t(43) =4.29, *p* = 0.000. No statistically significant results were found for Accessibility, Getting The Job Done, Convenience, Brand/Status, Risk Reduction and Performance. The elements Sustainability (M = 2.89, SD = 1.13), t(43) = -2.78, *p* = 0.008; Cost Reduction (M = 2.80, SD = 1.19), t(43) = -3.14, *p* = 0.003 and Price (M = 2.39, SD = 0.84), t(43) = -7.68, *p* = 0.000 received statistically significant lower scores.

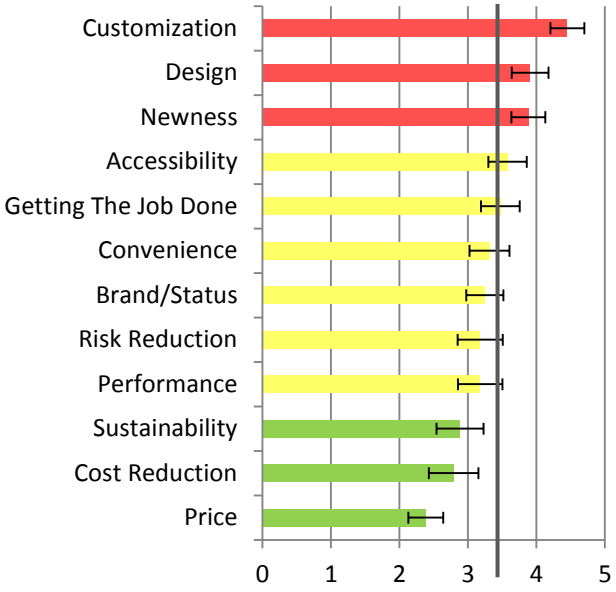

Figure 13: *Value Proposition elements Mean comparison*

Channels

The scores for the elements Owned Channels, Mixed Channels and Partner Channels elements show no statistically significant higher or lower scores than the component Mean (figure 14).

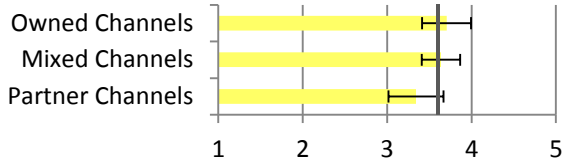

Figure 14: *Channels elements Mean comparison*

Customer Relationship

Two out of seven Customer Relationship elements show statistically significant difference in Mean score compared to the component Mean (figure 15). Co-Creation received statistically significant higher scores (M = 3.91, SD = 0.80) than the component Mean t(43) = 3.88, p = 0.000. No statistical significance is found for Personal Assistance, Automated Services, Dedicated Personal Assistance, CoProduction and Community Relationships. The SelfService relationship received statistically significantly lower scores (M = 3.02, SD = 1.15) than the component Mean, t(43) = -2.41, p = 0.021.

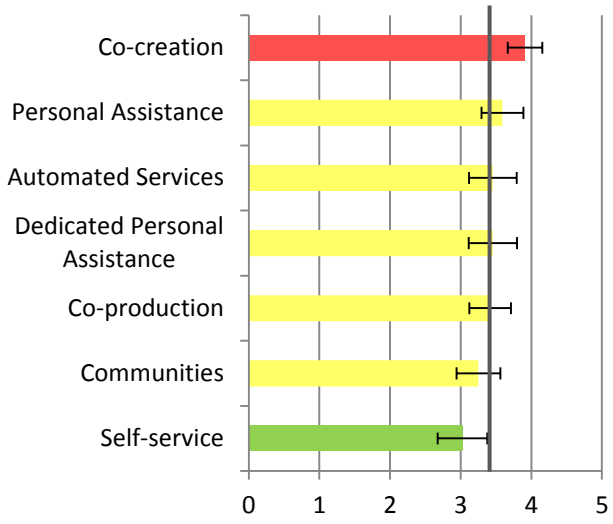

Figure 15: *Customer Relationship elements Mean comparison*

Key Resources

In the Key Resources component (Figure 16), only the Digital element received statistically significant higher scores (M = 4.48, SD = 0.70) than the component Mean, t(43) = 5.77, p = 0.00. Statistically insignificant results were found for the Intellectual, Human and Physical resource elements. The Financial element received statistically lower scores (M = 3.36, SD = 0.81) than the component Mean, t(43) = -4.15, p = 0.000.

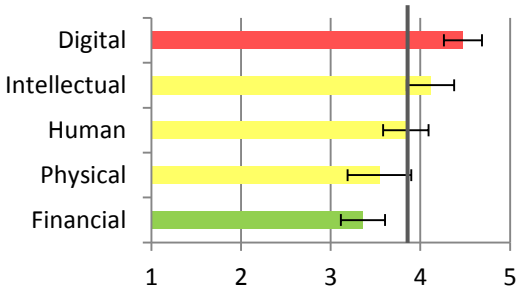

Figure 16: *Customer Relationship elements Mean comparison*

Key Partners

The AM Production Partner (M = 4.18, SD = 0.82), t(43) = 4.25, p = 0.000; Digital Technology Partner (M = 4.05, SD = 0.81), t(43) = 3.17, p = 0.003 and Buyer-Supplier (M = 3.93, SD = 0.70), t(43) = 2.59, p = 0.013 elements received statistically significantly higher scores compared to the component Mean. For Materials and Machine Technology Partners, Strategic Alliances and Sales partners no statistically significantly results were found. For Joint Ventures (M = 3.25, SD = 0.81), t(43) = -3.36, p = 0.002 and Coopetition (M = 3.05, SD = 0.89), t(43) = -4.59, p = 0.000 statistically significant lower scores than the component Mean were found.

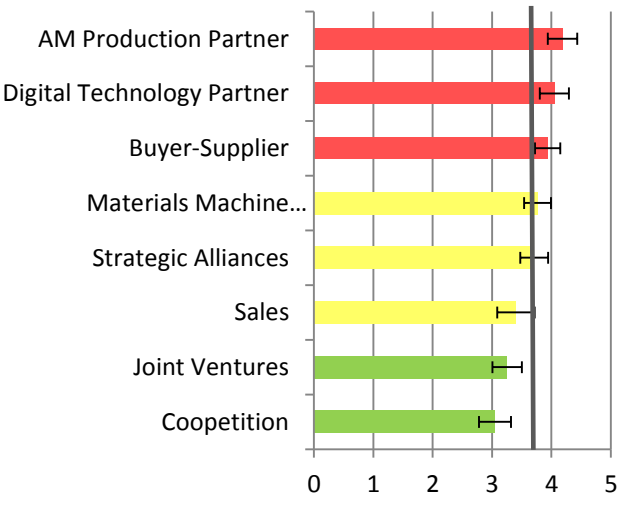

Figure 17: *Key Partners elements Mean comparison*

The statistics presented above allow for the answering of SQ3: "*Which elements are most likely to be offered when AM is applied for Rapid Production by companies in CPR according to general experts in the sector?*".

The results show that similar to the interview results, the 'Customization' element and 'Design' element are considered most likely to be offered as value proposition elements. Also similar to the interview results is that products are likely to be offered for a niche market. Further similarities to the interviews show that 'Digital' key resources and established key partnerships in the form of 'Buyer-Supplier Relationships' with 'AM Production Partners' and strategic 'Digital Technology Partners are considered to be elements likely to be offered in a Business Model for Rapid Production in CPR. The survey also resulted in the identification of those elements which are significantly less likely to be offered compared to the other elements within a component according to the CPR experts. Not surprisingly "Mass Markets", being the opposite of "Niche Markets", are currently not considered likely target markets for AM products in CPR. Furthermore, the 'Sustainability', 'Cost Reduction' and 'Price' elements are not considered likely to be offered elements in the value proposition. Although the respondents expected that the 'Self-service' relationship is less likely to be offered compared to the other types of customer relationships in general, it cannot be concluded that such a relationship is less likely to be offered in general. The same argument holds true for the 'Financial' element in key resources, and key partnerships in the form of 'Joint Ventures' and 'Coopetition'. All are significantly less likely to be offered compared to other elements within their components but should not be considered unlikely to be offered in general.

The data that was gathered also allowed for the comparison of elements against each other per component using Paired t-tests. The results of this test show whether a particular element is significantly more likely to be offered than a particular other element within the component. The results of these comparisons are captured in Appendix XX.

4.2.4.3 Business Model Components comparison

The scores that were gathered with Question 7, regarding the business model components were compared separately for Category 1 and Category 2 respondents (as discussed in Paragraph 4.2.4.1). However, since this involved a smaller sample size per Category, some would argue that the One-Sample t-test is inappropriate. Therefore its non-parametric counterpart, the One-Sample Wilcoxon Signed-Ranks test was used. When the null-hypothesis was rejected, indicating that the component ranks were significantly higher or lower than the Median value for the component, the component Mean (a Business Model component) was used to determine whether the item scored significantly lower or higher than the Median because the direction is not indicated by the test. The parametric One-Sample t-test was conducted to cross-check the results, which lead to the same conclusion. In order to visualize the results, the Means per Business Model component are shown in figure 18 for each category and explained in detail in Appendix XXI.

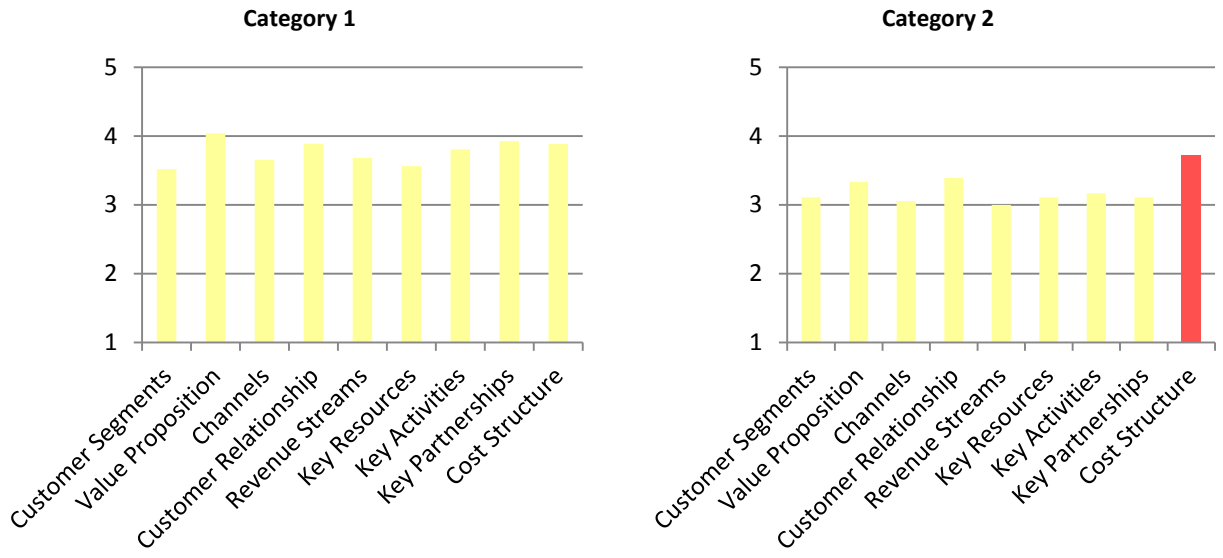

Figure 18: *Question 7 Business Model Components results*

The results from the test show that for Category 1, there is not one particular component for which the number of times its median ranks were higher or lower than the combined median is significant. For Category 2, similar results are found, although it must be noted that Median of the components combined differs (*Mdn = 3*). The only component for which both the One-Sample Wilcoxon Signed-Ranks test and the One-Sample t-test showed statistically significant results was "Cost Structures" ($Z = 73$, $p < 0.005$) and ($M = 3.72$, $SD = 0.83$, $t(43) = 2.58$, $p = 0.020$) respectively.

4.2.5 Exploring correlations

As explained in the theoretical background (Chapter 2.1.1), each of the components discussed above constitute part of a generic Business Model and can be used to differentiate between Business Models, but none of the components in isolation can capture a Business Model as a whole. The Business Model describes all of these components and corresponding elements together and the relationships between them (Zott et. al, 2010). Therefore, correlation analysis was conducted in order to explore whether there are significant relationships between elements within and across components. Both the Pearson Product-Moment and Spearman's Rank-Order correlation analysis were considered in choosing for the correlation analysis to be used for the dataset. Similar to findings by Norman (2010), both analyses result in virtually identical results. However, small differences between which elements can be considered statistically significantly ($\rho(rho) < 0.05$) correlated to each other are found. Since Spearman's Rank-Order correlation analysis does not make any assumptions about the distribution of the data and therefore seems to be preferred to find correlations between ordinal variables, it was chosen to use the results from this analysis (Appendix XXII). The test aims to answer whether there is a statistically significant relationship between participant responses for the Business Model elements questions (Q1..Q6).

4.2.6 Fuzzy Set Qualitative Comparative Analysis

Although the correlation analysis explores possible relationships between elements within and across components, it does not account for analysis of combination of more than two variables. However, even though two Business Model instances may offer the same value proposition(s), they are often represented by different combinations of all available elements. As such, an analysis of possible Business Model configurations should preferably take into account the possibility of different combinations of elements. Therefore, fsQCA was conducted as this technique can be used to analyze and identify different causal configurations of variables that lead to the same outcome. The approach is based on the idea that causal relations are frequently better understood in terms of set-theoretic relations rather than correlations (Fiss, 2011). This research employs fsQCA in an explorative manner to identify different possible Business Model configurations for AM that align with the offering of a particular Value Proposition, using the BMC. The analysis first involved selecting outcome and causal conditions based on the previous results (4.2.6.1). After calibrating the raw scores from the survey results into fuzzy set scores the analysis was conducted (4.2.6.2). This led to the identification of several 'recipes' that align with the value propositions being offered with AM (4.2.6.3).

4.2.6.1 Selection of conditions

From the One-Sample t-test results (Chapter 4.2.4.2), it was found that the Value Proposition elements that are most likely to be offered are 'Customization', 'Newness' and 'Design'. In order to identify which Business Model configurations align with each of these value propositions, these elements were regarded as the "outcomes" in the analysis, each tested for separately. In theory, any combination of elements for which scores were obtained with the survey could be regarded as a possible combination of causal conditions. In practice however, fsQCA relies on the knowledge of the researcher to specify which combination of elements should be considered for analysis. Therefore, this research identifies only those elements that are most likely to be offered in a Business Model for AM as possible causal conditions for this analysis. As such, the outcome of this analysis indicates which different configurations, from a selection of the most likely-to-be-offered elements across components, align with each of the three Value Propositions described above. The causal conditions that are selected are 'Niche Market', 'Co-creation', 'Digital', 'AM Production Partner', 'Digital Technology Partner' and 'Buyer-Supplier Relationship'. Since the Value Proposition elements can be offered in combination with each other as shown by the interview results (Appendix X), the two Value Proposition elements that remained when a possible "outcome" was analyzed were also included as possible causal combinations.

4.2.6.2 Specification of thresholds

After specifying the elements that were included in the analysis, the 5-point Likert scores from the survey results that were taken as input for the analysis needed to be converted into fuzzy set scores (any value ≥0 and ≤1) by means of calibration. The direct method of calibration was applied, which is based on researcher-specified thresholds for full membership (calibrated as 0.95), full non-membership (calibrated as 0.05), and the crossover point (calibrated as 0.5) to account for irrelevant variation in the data (Ragin, 2008). Since ordinal scales were used as input for the analysis instead of interval scales, there was no issue of calibrating for irrelevant variation. Ragin (2008) notes that it is good practice to avoid, if possible, using the 0.5 membership score (which signals maximum ambiguity) when assessing degree of membership in a causal condition. Furthermore, in setting the calibration thresholds a focus was placed on creating

fuzzy-set scores that represented strong membership in casual conditions and outcomes. Therefore, similar to the calibration of a 5-point Likert scale by Muñoz and Dimov (2015), the crossover point was set above the middle of the five-point Likert scales (3.5), the threshold for full membership was set close to the maximum score (4.5) and the threshold for full exclusion close to the minimum score (1.5). Using the calibrated scores, a truth table was constructed for all three Value Proposition elements. The truth tables (Appendix XXIII) list the different logically possible combinations of conditions along with the number of cases (respondents) conforming to each combination. Importantly, not all combinations of possible conditions are observed empirically and the combinations that have been observed have different frequencies. Therefore, a frequency threshold of one observation was set, which is recommended when the aim of the research is to build theory from a relatively small sample of cases (Muñoz & Dimov, 2015). Furthermore, consistency thresholds of 0.90 were set when a gap in the consistency scores was found as recommended by Ragin (2008). The consistency scores specify the minimum acceptable level to which a combination of conditions is considered reliably associated with the outcome. Using these thresholds, the truth tables are reduced to solution tables (Appendix XXIII) comprising simplified combinations of conditions, which are the 'recipes' for the outcome (Ragin, 2008). By using the parsimonious solutions, a further distinction was made between core conditions, which are decisive in distinguishing a particular configuration, and peripheral conditions, which are complementary to the core conditions (Ragin, 2008).

4.2.6.3 Configurational analysis results

Because a frequency threshold of one observation was used, each of the solution tables yielded a relatively large number of viable configurations. In order to facilitate intuitive understanding of the results, only high coverage solutions (i.e. solutions with raw coverage ≥ 0.25) were selected (Muñoz & Dimov, 2015). This lead to the identification of three configurations each for 'Customization' and 'Newness' and one configuration for 'Design' as shown in table 8.

Table 8: Summary of empirically relevant configurations

Configurations for	**CUSTOMIZATION**			**NEWNESS**			**DESIGN**
	Customization 1		**Customization 2**	**Newness 1**			
ELEMENT (Component)	CP1	CP2	CP3	N1	N2	N3	D1
NICHE MARKET (Customer Segments)	•	•	•	●	●	•	•
CUSTOMIZATION (Value Proposition)				●	●	-	-
NEWNESS (Value Proposition)	-	●	●				•
DESIGN (Value Proposition)	•	-	•	-	•	●	
CO-CREATION (Customer Relationship)	●	●	●	•	•	⊗	⊗
DIGITAL (Key Resources)	•	•	•	•	•	•	•
AM PRODUCTION PARTNER (Key Partners)	●	●	-	•	-	•	•
DIGITAL TECHNOLOGY PARTNER (Key Partners)	-	•	•	●	●	•	●
BUYER-SUPPLIER RELATIONSHIP (Key Partners)	•	-	•	-	•	•	•
Consistency	0.96	0.98	0.97	0.93	0.91	0.97	0.97
Raw Coverage	0.50	0.58	0.44	0.69	0.52	0.26	0.27

Black circles indicate the presence of the condition, and circles with "X" indicate their absence. Large circles indicate core conditions; small circles indicate peripheral conditions. Blank spaces indicate irrelevant condition (Ragin, 2008; Fiss, 2008).

In analyzing the results, a focus is placed on the solutions with the highest explanatory power. Furthermore, solutions for which core conditions overlapped were combined into super-sets. This is in line with current practice and allows for greater parsimony while maintaining the integrity of each solution term (Muñoz & Dimov, 2015).

For the Value Proposition 'Customization', the union of CP1 and CP2 lead to the super-set Customization 1. This super-set can be interpreted as follows: "*the Business Model for an AM produced consumer product that offers a 'Customization' value proposition exhibits a combination of a Co-creation customer relationship and the use of AM Production Partners. Furthermore the Business Model is likely to focus on a Niche Market and the use of Digital key resources combined with either 'Newness', 'Design', 'Digital Technology Partner' and 'Buyer-Supplier Relationship' elements"*. A second super-set was identified through the union of CP2 and CP3. This super-set can be interpreted as: "*the Business Model for an AM produced consumer product that offers a 'Customization' value proposition exhibits a combination of 'Newness' value proposition and a Co-Creation customer relationship. Furthermore the Business Model is likely to focus on a Niche Market and the use of Digital key resources combined with either 'Design', 'AM Production Partner' or 'Buyer-Supplier Relationship' elements".* For the Value Proposition 'Newness', the union of N1 and N2 lead to the super-set Newness 1. This super-set can be interpreted as: "*the Business Model for an AM produced consumer product that offers 'Newness' as a value proposition is likely to focus on a 'Niche Market' combined with the offering of the 'Customization' value proposition and the use of 'Digital Technology Partners', along with a 'Co-Creation' customer relationship, the use of 'Digital' resources and either the complementary 'Design', 'AM Production Partners' or 'Buyer-Supplier Relationship' elements."* For the 'Design' Value Proposition, one viable configuration was identified (D1). For this solution, identified core conditions are 'Digital Technology Partners' and the absence of 'Co-Creation'. Furthermore, 'Niche Market', 'Newness', 'Digital', 'AM Production Partners' and 'Buyer-Supplier Relationship' elements are identified as peripheral conditions.

4.3 Phase three results

The design-oriented nature of the third phase involved semi-structured interviews conducted with CPR experts at Capgemini and served three specific purposes. First of all, the experts provided qualitative data regarding the possible implications of AM for large established firms such as the clients of Capgemini in the sector (4.3.1). Furthermore, the experts expressed their view on the business opportunities for Capgemini in the context of Rapid Production (4.3.2). Finally, input for the iterative design of a tool was provided by the experts (4.3.3).

4.3.1 Identified implications for Capgemini's clients

When discussing the subject of AM in the context of large companies in the CPR sector such as Capgemini's clients, the experts indicated that AM is currently not a top priority for their clients. Although the adoption of AM for Rapid Production can lead to significant changes or entirely new business model designs, the experts indicated that company executives are currently more concerned with the ability to change, rather than focusing on technological developments such as AM that could lead to the change itself. Expert B indicated that the leading companies in the sector are in pilot-mode and explore new technologies "*Including the possibilities of 3D printing, setting out tests and learning with it and*

looking for collaboration with partners and technology companies" (Capgemini Expert B, 2016). From coding the interviews, several specific themes that could be related to business model implications came forward.

In terms of customer relationship, expert B expected AM to reposition the customer as a more central entity in the value chain. This expert indicated that the adoption of AM is about "t*he repositioning of added value entities that used to simply follow each other sequentially. Now there are more dynamic networks in which the consumer is positioned centrally. Therefore, the consumers' path to purchase and the industry's path to delivery is changing.*" (Capgemini Expert B, 2016). The repositioning of the consumer results in a different relationship where consumers become more involved with each other and the companies that serve their needs. During the interviews with experts A, B and D, the possibility of a Co-production relationship was brought forward. Expert A questioned the existence of the retailer model when it would be possible to just buy the designs from the consumer product focal companies. The experts indicated that a Co-production relationship is likely to follow from the further adoption of consumer-grade AM technology. If further adopted, consumers would simply buy 'recipes' in the form of designs (Capgemini Expert D, 2016). However, the technological limitations in terms of quality, materials and speed are for now considered too large to overcome.

On the topic of customization, expert B indicated that large scale mass-customization starts with consumer engagement in general. This includes both increased digital engagement and physical engagement in stores. An excellent example of the importance of the in-store experience for customized products was provided by Expert D who had professional experience at a large sports brand that is at the forefront of customization. He explained that this company dedicated a significant part of one of their flagship stores to the customization process of their shoe models. Self-service, in the form of customization of the product on a computer was done in-store, combined with personal assistance by a customization specialist who could help finishing the product and making the choice to actually buy the product. The need for complementary assistance for customized products was also described by Expert C, who had experience with AM from a project at a large consumer electronics company. She explained that "*because customization presented too many opportunities for the customer, the possibilities had to be limited in order to prevent the paralyzing power of choice*" (Capgemini Expert C, 2016). This expert also indicated that big data and automated learning systems could help customers in making choices, which would imply an automated services customer relationship (Osterwalder & Pigneur, 2010).

The experts were not concerned about a possible loss of brand power due to AM technology (as theorized by Cautela et. al (2014)). In fact, Expert D indicated that AM technology can in fact be used to enhance brand power by creating and offering high-end, niche products. "*Through these differentiated products, the brand name distinguishes itself again, which also justifies why you can ask a higher price for your normal products because you have cool products that are actually too expensive"* (Capgemini Expert D, 2016). As was noted by Expert B, AM technology in CPR should, for the moment, predominantly be considered for those products that feature personal engagement, such as personal lifestyle products with which people can express themselves. Furthermore, expert A indicated a general trend in the sector showing that many products are becoming commodities. "*Product value is zero and service is the only thing people are willing to pay for*" and "*Added value comes with the brand or how I deliver the product, things surrounding the product*

itself. Companies will earn less from the product itself but more from the things surrounding it" (Capgemini Expert A, 2016). By applying AM technology to produce high-end, niche lifestyle products in the current market combined with more in-store or digitally enabled customer engagement, companies could potentially position themselves as an innovative company and possibly enhance brand power.

4.3.2 Identified opportunities for Capgemini

When discussing the different segments in CPR, an overriding theme during the interviews was that the experts of Capgemini saw added value for their clients not only in the customization of products, but also in situations where inventory overhead could potentially be minimized by applying AM production. Since the large companies that are clients of Capgemini often have tens of thousands of parts in stock, this leads to high overhead costs for items that have low turnover. Besides customization opportunities, Expert C identified a possibility for CPR companies, especially those in consumer electronics and household equipment, to extend product lifecycles by offering spare-part services. In these segments of the market, the business case for AM could possibly be proposed by Capgemini and then executed in collaboration with the client. As Expert A indicated "*it is always easier for Capgemini to do something with costs and stock than to create new products*" (Capgemini Expert A, 2016). This vision was also expressed by expert C, explaining that Capgemini does not have overlap of interest at the product development side. Instead, Capgemini is better positioned to focus on the IT technology that can support the offering of new products that are developed by their clients.

As a company specializing in helping companies to transform their IT environment, the primary role of Capgemini in the context of AM that came forward in all of the interviews is that of a system integrator. Especially when industrial scale printers are required for the production of consumer products, an efficient order management process needs to be in place in order to make sure the product is printed and delivered to the consumer or the retailer. A problem that was described by Expert A is that the large companies in CPR have big legacy systems supporting their current operations, that they will want to keep. Expert B indicated that companies first have to be able to integrate and manage digital resources that are required for customized products or redesigned supply chains in which products are produced on-demand. This first requires a transition towards digital leadership. As also expressed by Expert A, "*You give the example of someone making an order through the front-end, well, the minimum you need is a website that is able to offer that front-end."* Expert D confirmed that current digital leaders are more likely to be exploring new technologies such as AM as well.

By identifying these digitally more innovative companies and initiating projects in the context of AM, a possibility exists for Capgemini to collaborate in pilot projects with these companies. This can further position Capgemini itself as an innovative partner on the subject of AM. As Expert D explains, this would be a great reference towards the less innovative companies in the market. By building expertise on the subject of AM, Capgemini will be well positioned to collaborate with these less innovative companies at a later stage, at which point Capgemini can use the expertise gained from previous projects to propose business cases and run and maintain AM integration services.

4.3.3 Expert input for tool design

Based on the research by Dijkman et. al (2015), an initial concept for the design of a tool to be used by Capgemini was proposed. This initial design featured the BMC as the underlying framework, on which the most important elements based on the interview and survey results are identified and presented. The three value proposition elements that are most likely to be offered in the context of Rapid Production according to the results are made to be interactive. The user of the tool can click on any of these three value proposition elements and will then be presented with other elements that are statistically significantly correlated with it. Furthermore, when clicking on an element, the super-sets from the fsQCA analysis are taken into account by highlighting the elements that are considered core conditions.

Since the tool is intended to be used by the consultants at Capgemini, their input as eventual users of the tool was essential. The initial design explained in the previous paragraph was set as a starting point for the design of the tool. Starting with the first interview, an iterative design approach was applied in which the tool evolved based on the input provided in the interviews. This resulted in three iterations (Figure 19).

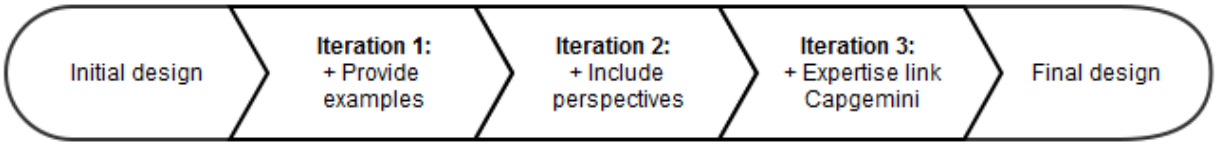

Figure 19: *Design iterations based on expert insights at Capgemini for tool design*

During the first interview, the initial design was first validated by discussing the concept. Although expert A indicated that it was interesting to be able to distinguish the elements that are more important from the ones that are not, he expressed some concerns regarding the usefulness of a tool with such abstract elements when having a one-on-one conversation with the client. Therefore, the idea was proposed to provide use case examples for some of the key elements to enhance the story that could be told. This addition to the tool was confirmed in all subsequent interviews. The second iteration of the tool was initially brought forward by expert B and involved the inclusion of more than just the company perspective. During conversations with a client, the value proposition that AM provides not only needs to be considered from the perspective of the company, but also from the consumer's perspective. This remark was also confirmed by experts C and D. Therefore, the idea was proposed to include the consumer's perspective in the tool. Based on the input from experts B, C and D, the third and final iteration made involved including linkages to areas of expertise of Capgemini such as its Industry 4.0 Framework (Appendix XXIV) at consulting. The final design implemented the requested features by creating three distinct paths in the tool (i.e. Business Model examples, Research Results and Capgemini and AM) that can be explored in detail by the user.

5. Integration of results

The results presented in Chapter 4 answer the first three sub-questions of this research. In this fifth chapter, the answers to these sub-questions are integrated into a single research result. By integrating the results from the research, a single overview can be presented regarding the Business Model configurations that companies in CPR should consider when applying AM for Rapid Production. This chapter therefore partially answers the main research question: *"What possible Business Model configurations and implications should companies in the Consumer Products and Retail sector consider when applying AM for Rapid Production?"* To fully answer the main research question and conclude the research, the Business Model implications of the findings from a theoretical as well as practitioner's perspective are answered in the discussion section of this research (Chapter 6). In order to integrate the results, the observed differences between the research results of each phase are first discussed (5.1) Based on the results and the discussion, the findings are integrated into a single integrated overview (5.2).

5.1 Discussion of identified differences

The similarities between the research results have been highlighted in the previous paragraphs. However, comparison of the results also leads to the identification of several notable differences. Within the value proposition component, the 'Newness' element is considered likely to be offered according to the survey results, whereas this was a value proposition that did not frequently come forward during the interviews. However, when reflecting on the characteristics of the products that are offered, one could argue that all of the products can be considered new products in their respective markets although some may have competitors also using AM for similar products (i.e. eyewear and jewelry). Therefore, even though 'Newness' was not explicitly mentioned during the interviews as being a value proposition, it may be either assumed to be offered or indirectly offered through the combination of the other value proposition elements. Also, there may possibly be overlap in the interpretation of the 'Design' (i.e. uniqueness of the design) and the 'Newness' elements.

Further differences between the results were found for the 'Price' element in the value proposition. Although two Business Model instances discussed in the interviews stated they were able to offer a price advantage, this was relative to traditional customization services in their respective markets. The general consensus, which was reflected in the survey and interviews with experts at Capgemini remains that the costs for AM is a limitation of the technology, resulting in higher prices compared to mass produced products. The value proposition of 'Price' should therefore be considered contextually. When compared to traditional customization services for products such as eyewear and jewelry, AM technology can be applied to offer the same or more value for a lower price. However, compared to mass produced products, the current limitations of AM technology most likely do not allow companies to do so (e.g. Ruffo et. al, 2006; Hopkinson & Dickens, 2003).

Another surprising finding from the survey results show that 'Sustainability' is an element that was considered unlikely to be offered whereas this is considered to be one of AM's key principles (Lipson & Kurman, 2013; Bikas et. al, 2014; Cautela et. al, 2014; Garrett, 2014; Thiesse et. al, 2015; Cozmei & Caloian, 2012). However, the interview results also showed that only one Business Model instance focused on offering 'Sustainability' as a value proposition, which was

combined with the offering of four other value proposition elements. On the basis of these exploratory findings, it therefore seems that the 'Sustainability' element can be considered a possible peripheral condition to be offered in the value proposition. Even though AM promises to enable more sustainable production, it is unlikely to be the main value proposition that is offered for consumer product.

Besides the value proposition elements, a notable difference was found in the Customer Relationship component for the 'Self-Service' and 'Co-creation' elements. The interview on the Business Model instances revealed that the self-service relationship was quite frequently established whereas the survey results showed that, although it is not unlikely that this type of relationship is established, it is expected less likely to be established compared to other types of customer relationships. Importantly, the answers to all the sub-questions imply that the personal assistance relationship is most important and may complement the self-service relationship if it is established. Furthermore, the Business Model instances showed that the self-service relationship can only be established when there are digital resources, specifically in the form of digital product configurators. For the co-creation elements, the survey results show that this type of relationship was expected more likely to be established whereas only one Business Model instance had actually realized such a relationship. The difference could explained by the fact that the survey results measure expectancy towards future Business Models whereas the interview results reflect current Business Model instances. Furthermore it should be taken into account that the experts that currently apply AM in their Business Models did express interest in establishing the Co-creation relationship. No major differences were found for any of the other elements.

5.2 Business model configuration for Rapid Production in CPR

Since the qualitative data collected in phase one is limited in quantity but does reflect real world Business Model instances instead of expectations (phase two), their contribution to the combined research outcome were carefully weighed in integrating the research results. Integration of the results was performed according to set criteria (5.2.1). By applying these criteria, a configurational heat map of Business Model configurations for Rapid Production in CPR was created (5.2.2).

5.2.1 Criteria for integration

The elements that are both frequently identified (≥ 4) in the Business Model instances and significantly more likely to be offered according to the general CPR experts can be considered validated and are therefore most likely to be part of a Business Model configuration for Rapid Production in CPR.

Elements are considered partially validated when:

- Frequently identified in the Business Model instances but not expected to be offered significantly more or less than other elements in the component by the general CPR experts, or
- Occasionally identified (1 ≤ instances ≤ 3) in the Business Model instances and expected to be offered significantly more likely than other elements in the component by the general CPR experts.

The elements that are possibly valid as Business Model elements in a configuration for AM are either:

- Occasionally identified in the Business Model instances and not expected to be offered significantly more or less likely than other elements in the component by the general CPR experts, or

- Not identified in the Business Model instances but expected to be offered significantly more likely than other elements in the component according to the general CPR experts, or
- Frequently identified in the Business Model instances but expected to be offered significantly less likely than other elements in the component according to the general CPR experts.

Elements are considered not likely to be valid Business Model elements in a configuration for AM when:

- Not identified in the Business Model instances and not expected to be offered significantly more or less likely than other elements in the component by the general CPR experts, or
- Occasionally identified in the Business Model instances and expected to be offered significantly less likely than other elements in the component by the general CPR experts.

Finally, elements are considered highly unlikely to be valid Business Model elements for configurations for AM when not identified in the Business Model instances and expected to be offered significantly less likely than other elements by the general CPR experts.

5.2.2 Conclusion: Configurational heat map

Based on the results of the three research phases and the discussion of the similarities and differences, this research is able to present a single configuration 'heat map' of Business Model configurations for Rapid Production in CPR. This heat map provides insights into the possible Business Model configurations that may be offered and is essentially a Sub-(Meta)-Model (figure 20).

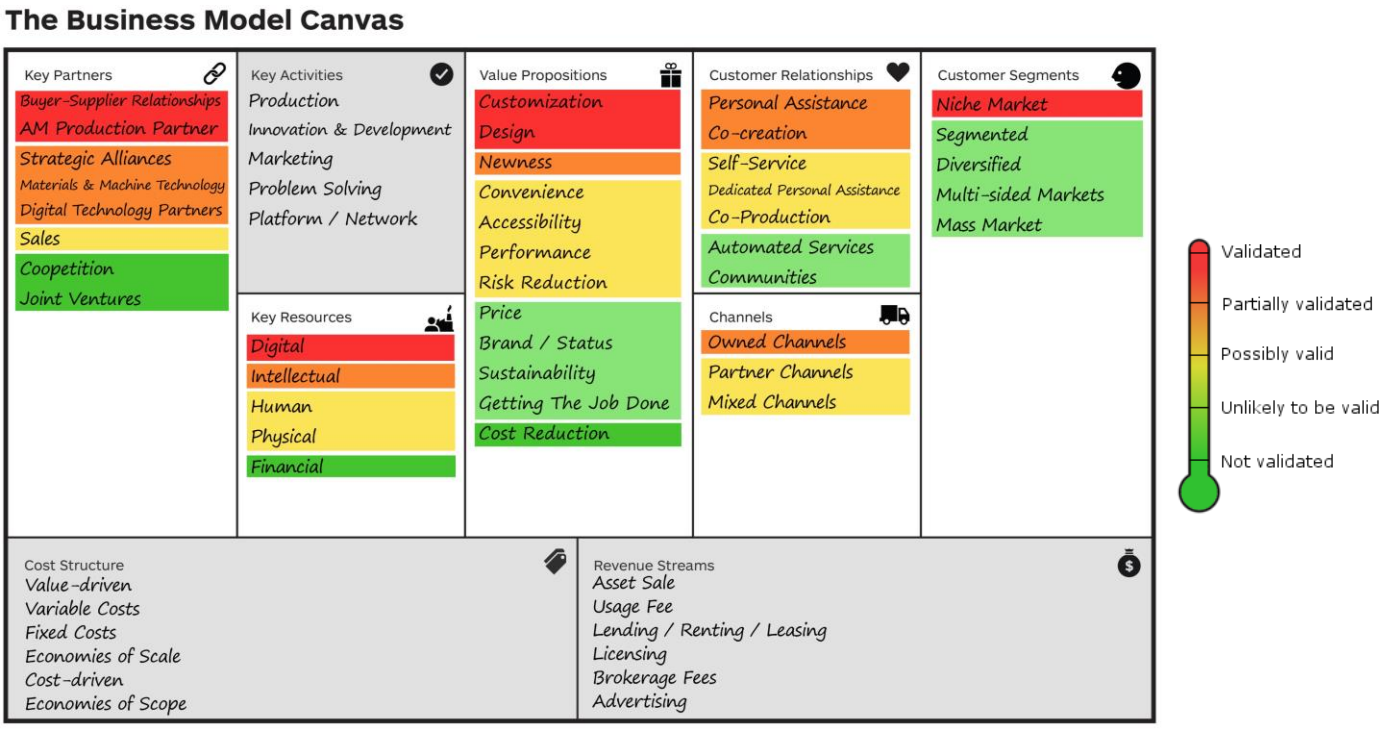

Figure 20: *Configurational heat map of Business Models for Rapid Production in CPR*

Figure 20 shows those elements that are validated in red. These are the most relevant elements considering Business Model instances for Rapid Production in the CPR sector. Since the components 'Key Activities', 'Cost Structures' and 'Revenue Streams' were not featured in the survey, their elements couldn't be validated through triangulation of the data. Therefore, the elements featured in these components are sorted in the order of importance based on the results of the first phase of this research only.

From figure 20, the relatively most important elements that should be considered for Business Models configurations for Rapid Production in the CPR sector can be identified. The configurational heat map shows that such Business Models revolve around the value propositions of 'Customization' and 'Design', with products targeted at 'Niche Markets'. Furthermore, 'Digital' resources are key and 'Buyer-Supplier relationships', particularly those with 'AM Production Partners' are important elements. The least important element for the Value Proposition component is 'Cost Reduction'. This is not surprising considering the focus on niche markets and the focus on the high-end price range that was a common characteristic of the products offered by the Business Model instances (table 7). Furthermore, the 'Financial', 'Coopetition' and 'Joint Ventures' elements can be considered the relatively least important elements in their respective components. Based on the fsQCA analysis results it should be noted that when offering the 'Customization' value proposition, the core elements to be considered in particular are 'Newness', 'Co-Creation' and the use of 'AM Production Partners'. When offering the 'Design' value proposition, the absence of the 'Co-Creation' element and making use of 'Digital Technology Partners' are core conditions to be considered in particular.

6. Discussion

In concluding the research, the research relevance in terms of contributions to the literature are discussed (6.1). The managerial implications discuss the general practical implications of the research and those specifically aimed at Capgemini, thereby answering SQ4 (6.2). In interpreting the research findings, the limitations of the research have to be taken into account (6.3). Furthermore the exploratory nature of this research allows for further research opportunities on the subject of Business Models for AM (6.4).

6.1 Research relevance

The lack of research into Business Models for AM was identified by multiple scholars (e.g. Hahn et al, 2014; Garret, 2014; Bogers et. al, 2016; Rayna & Striukova, 2016; Beyer, 2014; Weller et. al, 2015). As such, one of the goals of this research was to contribute to filling this gap in the literature. By reflecting on the literature background (Chapter 2) and the research findings, some additional observations are made that can be regarded as the identified Business Model implications in this research. These observations contribute to the literature on AM (6.1.1) and the literature on Business Models in general (6.1.2).

6.1.1 Contribution to AM Literature

In the midst of much excitement about AM and its potential for Rapid Production purposes, this research has contributed to AM literature in two ways. First of all, this research has taken a first step in empirically exploring the characteristics of Business Models instances when consumer product focal companies specifically used AM for Rapid Production purposes. This has led to initial insights into the considerations regarding these Business Model instances that are made by experts in the field. Secondly, this research has explored which common characteristics are likely to be offered across Business Model instances for Rapid Production in the CPR sector. By using a mixed method sequential research approach, additional elements were added to the BMC and the most important characteristics for such Business Models were identified and validated, essentially resulting in a Sub-(Meta)-Model for Rapid Production in the CPR sector.

The findings of this research show that in the context of Rapid Production in the CPR sector, customization plays a very important role since this was the dominant element in the value proposition. Also highlighted is the importance of customer-centric Business Models, in which the concepts of customization, co-creation and the ability to manage creative inputs and a network of (local) partners play a significant role (as also suggested by Cautela et. al, 2014; Bogers et. al, 2016). Furthermore, the shift towards a more customer-centric focus was identified by practitioners during the interviews with Capgemini experts, although this was related to a general trend towards more customer centricity in the sector which includes the adoption of AM amongst other technologies. One can conclude that although co-creation is expected to play a significant role in future Business Models, it is not yet effectively applied in current Business Model instances. Therefore, the importance of the ability to manage creative inputs remains somewhat limited currently. Similar to the co-creation relationship, the co-production relationship with the consumer is much anticipated (Bogers et. al, 2016). Although it was identified in one of the Business Model instances, it was not validated or partially validated through integration of the results. The co-production relationship depends largely on the technological evolution of

personalized production systems and the adoption of such systems by the consumer. Instead, the use of Key Partners in the form of professional local AM production hubs that can manufacture products that have been configured online (Digital Key Resources) or in-store combined with efficient distribution networks seems to be a more viable alternative currently. Especially considering the current limitations of AM technology, professional grade systems are more likely to produce consumer grade products in the near future versus personalized production systems. This would allow companies to keep more control over the service and experience surrounding the product, which was identified as being important for customized products in this research.

Finally, it should be noted that a conservative view applies regarding mass-customization in CPR. Although the 'Customization' value proposition is identified as being particularly important in this research, it remains to be seen if mass-customization will be adopted at large scale in the CPR sector. None of the companies interviewed had reached mass production levels. This is likely to be a characteristic of the market and current level of adoption of AM technology for Rapid Production purposes. As Markides (2006) explains, new Business Models attract different customers from those that established companies focus on. As such, the products for which these Business Models are designed are likely to be niche products offered on niche markets, which was shown by the Business Model instances. Over time, these new Business Models may attract more attention, shifting towards mass markets and eventually dominant designs will emerge. Still, one of the most prominent challenges regarding the use of AM for Rapid Production in the CPR sector is identifying or creating those products or finding those markets for which the conditions needed for AM to be viable hold. As Weller et. al (2015) note, the market environment for AM to currently be viable for Rapid Production is characterized by uncertainty, high product variety or fluctuating customer tastes. Although viable Business Models can be designed for high-end consumer lifestyle products such as custom running shoes, musical instruments, eyewear and jewelry, it remains to be seen whether their Business Model designs can become more dominant and make the transition towards mass markets in the CPR sector.

6.1.2 Contributions to Business Model literature

Although the empirical findings in this research do not specifically contribute to the general Business Model literature, the research approach that was applied may provide insights for further research in the context of Business Models. First of all, this research has further validated the use of the BMC as a measuring instrument to determine the common characteristics (Sub-(Meta)-Models) of Business Models for emerging technologies such as AM or IoT (Dijkman et. al, 2015). Although the use of the BMC as a measuring instrument can be applied for more than just emerging technologies, the explorative nature of these topics is particularly well-suited since it aligns well with the focus of the BMC on facilitating description and discussion (Osterwalder & Pigneur, 2010). Secondly, this research has extended the approach applied by Dijkman et. al (2015) by conducting fsQCA analysis based on the survey data. With a focus on identifying configurations of causal conditions for certain outcomes, the fsQCA analysis is a particularly useful contribution to the research approach since it aligns with the focus on identifying configurations in Business Models. The identification of super-sets using this method provides another layer of depth into the configurational nature of Business Models. Depending on the value proposition that is offered, various configurations may be considered viable and different core conditions across these configurations should be considered.

6.2 Managerial implications

Apart from the theoretical contributions of the research, the research also results in the identification of managerial implications on the subject of Business Models for Rapid Production in the CPR sector. Furthermore, since the research featured a design-oriented additional phase to the research approach by Dijkman et. al (2015), recommendations specific to Capgemini are identified. Therefore, this paragraph answers SQ4: *"Which possible business model implications for Capgemini's clients and what opportunities exist for Capgemini?"*

First of all, this research may provide initial insights for consumer product focal companies in terms of which subjects they should consider in adopting AM. Bogers et. al (2015) specifically note that it remains unclear which types of Business Models consumer goods' manufacturers would have to employ to capitalize on the flexibility that AM offers. In this regard, the results of this research can be used by practitioners to focus their future efforts on the elements which are considered relatively most important and may direct them in exploring Business Models. Therefore, these findings may serve as a tool to guide the configuration of Business Models for Rapid Production in CPR.

Based on the interviews with the CPR experts at Capgemini it became clear that the limitations in terms of quality, speed and costs that are recognized as limiting factors for current applications by Capgemini's experts in CPR. Although AM is therefore not a priority for Capgemini's clients currently, some are exploring its potential uses for production purposes in the form of pilot market offerings. As was also identified in the literature on Business Models for AM, the CPR sector is seeing a general trend in which the consumer is repositioned into a more central role in the value chain. The focus that is placed on offering customization possibilities through the use of AM requires companies to further engage with their customers both digitally, as well as provide new services and experiences in physical stores. The need for personal assistance, which can be offered in stores to help with the customization process as well as making the actual sale is thereby further highlighted. This is also in line with a general trend in the CPR sector showing that most products on the market are regarded as being commodities which implies that companies have to focus on differentiating themselves by means of the service and experience that they offer. In order to do so, companies in CPR may be able to use AM to differentiate their product offering and brand from competitors with new, innovative niche products aimed at higher-price segments, featuring unique service and experiences surrounding the customization value proposition. This represents applying an ambidextrous approach, in which the traditional mass-manufacturing based Business Model is not replaced, but is instead complemented by the Business Model for Rapid Production (Bogers et. al, 2015). Furthermore, such an approach would especially allow larger, established companies such as Capgemini's clients to explore the value propositions and corresponding Business Model configurations that can be offered with AM.

Companies will need to have the digital resources available to offer services and experiences around customized products. This is highlighted by the validation of the digital key resources element and also suggested in previous research (Piller et. al, 2004). This dependence on digital key resources is an opportunity for Capgemini as a digital transformation leader to help CPR companies further in their efforts to become digital leaders. By doing so, they can be ready to offer services and experiences in the context of AM. Although not identified in this research, there may be opportunities for Capgemini's clients to offer new services in terms of inventory management and spare parts services,

which were identified as being a possible viable business cases in the near future by Capgemini's experts. Importantly, whether focused on customized products or supply chain reconfigurations, it is recommended that Capgemini initiates a conversation about the prospects on AM. The tool that is provided with this research may help Capgemini in doing so. Furthermore it may help in discussing the possibilities and identifying viable business cases with their clients. When clients adopt AM technology, the primary future role that was identified for Capgemini in the context of AM should be that of a system integrator. In this role, Capgemini can help companies to integrate and support new order management processes into current legacy systems or built new IT environments altogether. Based on the identified relative importance of 'AM Production Partners' and 'Strategic Alliances', it is further recommended that Capgemini starts establishing relationships with specialist and local partners such as Shapeways, Materialise, Blue Oceanz and Twikit. These partners are particularly well-suited to become part of Capgemini's AIE ecosystem and would significantly strengthen the position of Capgemini in a potential future role as a system integrator of AM related solutions for its clients.

6.3 Limitations

There are several limitations that have to be taken into account in interpreting the findings of this research. At a general level, an important limitation of this research is that the exploratory approach that was applied lacks the specificity of a more detailed approach that targets single components. Therefore, the detailed Business Model instances were abstracted in order to identify the common elements amongst them. Although this allows for a shared language to discuss different Business Model instances and find their common characteristics, it can also result in oversimplification of Business Model complexities.

On the topic of data collection, the sample sizes in all three phases of the research were relatively small. Especially due to the sequential nature of the research, these low sample sizes may lead to bias in the results since each phase is influenced by the previous phase. However, because of the explorative nature of this research the results are intended to be interpreted as initial empirical insights within the specific scope of the research. Furthermore, the configurations of the Business Model instances were analyzed as they were at the time of the interview whereas the survey measured the expected likelihood of the various Business Model elements being offered. Although this was taken into account in interpreting the results, validation of the Business Model elements may have been influenced by a difference in interpretation. The survey respondents show a high degree of experienced AM users. Although this increases the validity of the results, it could also indicate a bias towards respondents that are users of the Shapeways or Materialise platforms. These users, who are often entrepreneurs or have a small business fall within the scope of the research and are comparable to the companies from phase one. However, a possible bias towards smaller entrepreneurial initiatives should be taken into account in interpreting the survey results since their Business Model characteristics can differ greatly from those of larger established companies. This also impacts the relevance of the results for Capgemini and may partially explain why Capgemini's experts identified possible business cases focused on inventory management and spare part solutions that were not identified with the Business Model instances.

In terms of data analysis, Saunders (2009) notes that questionnaires are usually not particularly good for exploratory research. Although the research method itself was previously applied by Dijkman et. al (2015), there were no standardized questions available which means that the validity of the questions and their interpretation should carefully be considered. However, positive signs show a low drop-out once respondents had started questions on Business Model elements and there were only a few critical notes regarding the survey questions (Chapter 4.2.2.1). Furthermore, the explorative fsQCA analysis that was conducted was based on quantitative data whereas this type of analysis is mainly used for qualitative data or a combination of both. This also resulted in the mechanical calibration of the fuzzy set scores which is not recommended by Ragin (2008). Therefore, it is important to realize that the identified configurations for the various value propositions and their core components are reflections of the survey data. Also, three of the nine components ('Key Activities', 'Cost Structure' and 'Revenue Streams') of the BMC were not included in the survey. Although this was a deliberate choice, it does influence the results since the elements within these components could not be validated. This also means that these elements were not taken into account in the (incomplete) configurational fsQCA analysis. Finally, in terms of practical relevance for Capgemini there was no input from clients of Capgemini in phase one or phase two of the research which decreases the interpretability of the results for Capgemini. Furthermore, although the tool was designed based on input provided by Capgemini experts using an iterative design process, its practical relevance must still be validated by using it.

6.4 Suggestions for further research

Since this research has resulted in the identification of common Business Model characteristics for Rapid Production in CPR based on explorative empirical research, it can serve as a future starting point for further research into Business Models and particularly Business Model instances for AM. The extended BMC that is provided in this research may be useful for detailed research into specific components of the BMC. Furthermore, the current research did not validate the Business Model elements in the components 'Key Activities', 'Cost Structures' and 'Revenue Streams'. Configurational analysis that includes these components could be performed in order to get a fully validated overview of the common Business Model characteristics for Rapid Production in CPR. One of the challenges that was identified in this research was finding those consumer products for which AM is a viable production method. Although the necessary market characteristics as theorized in previous research by Weller et. al (2015) seem to hold for the identified Business Model instances, further research could specifically focus on identifying the consumer product characteristics that are required for Rapid Production in the CPR sector. Furthermore, as discussed in the limitations, this research may be biased towards smaller companies in niche markets. Future research may scope specifically for larger companies, especially when more of these companies start exploring the use of AM for Rapid Production and the Business Models that align with this purpose.

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