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Advanced Strategies for Adopting Additive Manufacturing in The Netherlands and Belgium

Robert Martens
info@3dstrategies.nl
Rotterdam University of Applied Sciences

Susan K. Fan
sfan@purdueglobal.edu
Purdue University Global

Gael Clarenc
Rotterdam Business School

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Abstract – The purpose of this qualitative multiple-case study was to explore strategies that companies in the Netherlands and Belgium used to adopt additive manufacturing into their business models. This research provided the positioning of additive manufacturing technology, including the manufacturing perspective on business models, frameworks of adoption, and strategies for implementation. A multiple-case study was conducted at manufacturing firms in two countries from various industries that adopted 3D printing. Data were collected using desk research, questionnaires, semi-structured interviews, member checking, and company documents, which provided insights into how adopting additive manufacturing technology was adopted and impacted their business models. Christensen's Theory of Disruptive Innovation was applied as a conceptual framework. The findings of this study help companies to integrate additive manufacturing technology into their business models. Additionally, this study may assist in harnessing the full potential of 3D printing by thinking beyond prototyping and understanding how this technology can benefit their business and what it means for production.

Keywords – 3D Printing, Additive Manufacturing, 3DP, Technology Adoption, Disruptive Innovation, Business Models

Introduction

1.1 The emergence of Additive Manufacturing

Three-dimensional printing (3DP) or additive manufacturing (AM) has emerged as a new and disruptive manufacturing technology that has the potential to change the way companies produce and supply almost everything (Varsha Shree et al., 2020). Various scholars suggested that AM on a large scale will affect global production while potentially introducing an era of mass customization (e.g., Akbari and Ha, 2020; Hannibal and Knight, 2018; Savolainen and Collan, 2020). AM is the collective term for technologies using 3D printing to create physical objects by printing successive layers of materials on top of each other using digital models. While this technology can revolutionize the way products are being designed, made, and delivered to customers, it also challenges companies to find new strategies to adapt and reinvent their business model (Bogers et al., 2015).

AM is a manufacturing process born in the early 1980s used for prototyping (Hull, 2015). Since then, this technology has emerged as a viable manufacturing option for companies due to significant improvements in part quality, price, and process time. The critical applications for consumers taking advantage of AM techniques include direct product manufacturing, tools and molds manufacturing, and bioprinting of tissue and organs. The potential of using AM to design and produce products for a wide range of industries has generated much attention over the years. For instance, 3DP has been described as having the ability to transform manufacturing and contribute to the new industrial revolution, Industry 4.0 (Agostini & Nosella, 2019; Nascimento et al., 2019). However, Shanler and Basiliere (2016) projected that mass acceptance of AM would not occur in the next five to 10 years.

1.2 AM Industry Applications and Impact

The AM industry has grown tremendously over the past five years, and 3DP has left behind its status as a niche technology. Driven by lower cost, rapid technological development, and new applications for 3DP, AM is employed worldwide. The manufacturing industry is the largest AM user. In 2018, 18% of manufacturing firms used 3DP, and that number was expected to increase to one-third of all businesses in the next five years (PWC, 2018). AM equipment comes in a wide range of prices, from a few hundred dollars to over $750.000 (Fassio & Grilli, 2020).

Examples of manufacturing industries using 3DP include healthcare, aerospace, construction, automotive, and electronics (Heikoff, 2020). The AM sector is estimated to grow to $ 22.6 billion by 2030 (PWC, 2018). This hyper-flexible technology will provide specific opportunities and challenges for companies to develop new business models (Piller et al., 2015). Additionally, AM offers a wide range of technologies to serve many consumers. The primary AM technologies comprise over 12 different processes, including fused filament fabrication, selective laser sintering, material jetting, direct light processing, and Stereolithography (Gibson et al., 2015).

1.3 Study Objectives and Methodology

We applied a multiple case study research design to explore strategies manufacturing companies used in the Netherlands and Belgium to adopt AM technology into their business model. We had two main objectives for this study. Our first objective was that the findings from this study might assist managers in determining suitable strategies and deploying plans before a possible disruption caused by 3DP could displace their company. We have discovered that disruptive technologies may dislodge existing industries and often lead to social change. Using AM, production may shift employment back from developing to developed countries, which could attenuate unemployment rates in deprived areas and reduce international transportation (Gebler et al., 2014; Laplume et al., 2016; Tatham et al., 2015). Some firms in the medical sector use 3DP to make items, such as implants, prostheses, medicines, or rehabilitation devices (Ford, 2014; Kietzmann et al., 2015), thereby reducing the costs of medical treatments, improving people's quality of life. This insight led to our second objective, which was that the results from this study would contribute to positive social change by providing solutions companies could use to deploy AM technology.

2 Literature Review

The review commences with the theory of disruptive innovation and its effects aspect on business models. Next, an overview of the history, technology, application, and social impact of 3DP is provided. Furthermore, the disruptive aspects of AM for existing firms and their managerial and social implications are discussed.

2.1 Disruptive Innovation

Extant literature indicated that 3DP has the symptoms of disruptive innovation because of its effects on supply chains and business models. Nagy et al. (2015) posited that disruptive innovation could be explained using Rogers (2003)'s diffusion of innovation theory. In this theory, Rogers described how customers implement innovations, following a bell-curve pattern starting with innovators, early adopters, early majority, late majority, and laggards. Where Rogers based the theory on innovations initially aiming at the most demanding customers, Christensen's (2016) theory of disruptive innovation targets neglected and least demanding customers, a situation better reflecting the rise of AM. Therefore, the theory of disruptive innovation was used as the theoretical framework for this study, a lens Fassio and Grilli (2020) also used. Christensen et al. (2015) referred to disruptive innovation as transforming an expensive and complicated product into something much more affordable and accessible, allowing more people to use it.

Christensen et al. (2015) argued that successful disruptive innovation has three main components. First, it must contain an enabling technology: an invention making a product more affordable and accessible to a broader range of people. Secondly, an innovative business model must target new users who previously did not buy products in a specific market or low-end customers, generally the least profitable customers segment for existing companies. Finally, the novel technology must have a coherent value network satisfying the needs of supply chain members such as distributors, customers, and suppliers. Disruptive innovation ultimately creates new markets while reshaping existing ones.

For this reason, companies looking for growth opportunities in this fast-changing world must make sure to be disrupters instead of disrupted. As the AM industry grows, incumbent companies can no longer ignore its effects on their business models and supply chains. The world is entering an era of significant growth in 3DP, and the industrial market for AM products and technologies will rise to 22.6 billion by 2030 (PWC, 2018).

Later, Christensen (2015) explained the difference between disruptive innovation and sustainable innovation as why established companies fail to adapt to the new market situation created by disruptive technology. While big players focus on sustaining innovation by upgrading an existing product to attract more profitable customers, they ignore regular customers who need a low-cost and straightforward product. A gap is created in the market for those newcomers using disruptive technology to improve their products and slowly take over the market. Because reaction time is slower amongst well-established companies, the innovators can move upmarket quickly by delivering the high performance required by their customers. Disruptive innovations are a positive force bringing tremendous benefits to the industry it disrupts. Apart from the traditional business sense, disruptive innovation creates value socially and economically, making industries such as healthcare, education, global development, aerospace, and automotive more accessible and affordable to a broader population (Phillips, 2015).

2.2 Additive Manufacturing

Quick prototyping was the first application of 3DP technologies. Conventional subtractive methods create products by cutting away materials from a more substantial part. Conversely, AM builds a product by adding successive layers on top of each other based on a digital file without a mold. AM uses a computer-aided design (CAD) to convert the design into a 3DP object. The printing process uses various materials such as plastic, metals, glass, wax, sand, ceramic, and even human tissue to create the final product (Gao et al., 2015a; Steenhuis & Pretorius, 2017). Additionally, parts manufactured using 3DP technologies require post-processing to enhance the printed object's quality (Kubáč & Kodym, 2017).

Three-dimensional printing quickly captured the market through platforms such as Do-it-Yourself (DIY) and the Maker Movement (Gao et al., 2015b; West & Kuk, 2016). AM is not a single type of technology. Even though all AM system uses a layer-by-layer building process, various kinds of AM technology exist. Phillips (2015) argued that 3DP uses multiple types of technology, materials, and methods to create the final product. AM technology has not been fully developed; Gibson (2017) emphasized AM comprises many different technologies at different stages of maturity

Building items layer by layer brings design freedom and generates less waste. As a result, products made by AM can be lighter or more robust than products made by traditional manufacturing processes (Duchêne et al., 2016; Lindemann et al., 2015; Liu et al., 2014a, 2014b). Moreover, Thiesse et al. (2015) mentioned that the adoption of AM enables the creation of products that companies cannot make using any other manufacturing process. Resulting from AM's unique manufacturing aspects combined with the possibility to optimize product design, some companies have achieved remarkable results in improving the parts used in their products. To illustrate: engineers at Airbus used AM to create parts that were 67% lighter, and

General Electric redesigned fuel nozzles as one unit, originally consisting of 18 parts, reducing their weight by 84% (Camisa et al., 2014; Knofius et al., 2016). Other examples are Lockheed Martin's joint strike fighter brackets and Airbus' aircraft components, using 90% less energy and weighing 30-55% less (Camisa et al., 2014).

2.3 The Disruptive Characteristics Of Additive Manufacturing

Scholars, writers, and politicians have mentioned the disruptiveness of AM. Researchers like Amshoff et al. (2015), Bogers et al. (2016), Yao and Lin (2016), Gibson et al. (2015), and Hahn et al. (2014) considered AM to be a disruptive innovation. American President Obama (2013) stated that 3DP has the "potential to change the way we make almost anything" (5:30). While AM is not as widely adopted as traditional manufacturing methods, Andrews (2015) argued that 3DP started the third industrial revolution. Waller and Fawcett (2013) argued that 3DP would outdate traditional business models and supply chains and underlined AM’s disruptive aspects: little economies of scale, consistent quality, less capital investment, and the maker movement where consumers become product designers and producers.

2.4 Business Models

AM technologies can be highly disruptive, leading to significant business model innovation. Business models tend to evolve, and firms must sometimes shift from one business model to another to gain more revenues and growth (Savolainen & Collan, 2020). By nature, AM moves from one business model to the other less risky because products can be manufactured on-demand at a minimal cost. Companies looking to enter existing or new markets only need to adjust their business model rather than change it substantially. However, Amshoff et al. (2015) argued that disruptive technologies, such as AM, can be a threat or offer opportunities to incumbents as they affect existing value chains and create novel business models. Besides, Savolainen and Collan (2020) argued that AM enables changing the level of vertical integration by rapidly moving upstream or downstream. For example, firms can perform the design, services, and manufacturing simultaneously. Companies can more easily adapt their business model based on the types and number of activities they want to achieve across the value chain. Such variations enable firms to develop a more innovative business model centered around their customer's needs (Rayna & Striukova, 2016).

Different business models exist to successfully adopt AM into existing supply chains (Bogers et al., 2015; Brennan et al., 2015). Also, supply chains exhibiting both lean and agile characteristics called leagile have made the adoption of AM technology simpler for organizations (Christopher & Ryals, 2014). Mashhadi et al. (2015) identified four possible business models. The first model refers to the transition from lean to leagile supply chain, which favors a system based on responsiveness and lead time rather than cost (Mashhadi et al., 2015). The second model refers to the supply chain's ability to be flexible and quickly adapt to changes. This framework is called structural flexibility and can include two different methods (Mashhadi et al., 2015). The first one is local for local. To produce the requirements for the local market, this model shares the assets in terms of capacity and inventory. The second method is economies of scope, which refers to companies delivering a broad set of distinct products using similar processes. To be fully optimized, this model must determine the appropriate level of diversification for each product and the markets companies are serving. The third business model is the virtual supply chain (Mashhadi et al., 2015). This model refers to the shift from an inventory-based network to an information-based system where firms provide their designs to local manufacturers. Adding the design function to the current supply chain will optimize the network as the flow of information increases. The fourth business model that Mashhadi et al. (2015) identified is cloud manufacturing. This setup enables clients to send their designs to companies owning 3DP equipment to manufacture their products based on the designs they created. This model also offers more complexity and variability to the customers who can choose from various suppliers to print their parts.

2.5 Strategies to Adopt Additive Manufacturing

Oettmeier and Hofmann (2016) argued that using AM for rapid prototyping and industrial manufacturing requires a different organizational infrastructure. When AM is used for prototyping, the focus is on computer systems and design methods, but when applied in an industrial setting, implementation and integration in the existing organization are paramount. Savolainen and Collan (2020) concluded that AM could be implemented in a firm's business model in an open, closed, incremental, or disruptive manner. Recently, Martens et al. (2020) studied how manufacturing firms in the Netherlands adopted AM technology into their business model and discovered three essential items. First: identify business opportunities for AM technologies. 3DP has been described as disruptive innovation and has attracted many companies who believe they could use the technology to gain a competitive advantage. Martens et al. further argued that understanding the market that valued such benefits and conducting market research to identify competitive advantages, such as professional opportunities, cost-saving opportunities, and lead time reduction, was of the essence. Companies had to identify markets where customers would value AM's unique features, such as high customization, low volumes, short lead time, and high complexity. Often, those customers are operating in niche markets frequently ignored because traditional equipment setup costs are too high. Companies targeting those niche markets such as the medical implants, spare parts, and the tool sector might gain a competitive advantage by adopting AM. Besides, to establish a competitive advantage, manufacturing firms need to set themselves apart by developing competencies competitors cannot replicate.

Experimenting with AM is another crucial factor. Firms that strategically decided to implement AM had to develop a trial-and-error approach by experimenting with 3DP technology (Martens et al., 2020). Three subthemes represented crucial steps in a solid ability to implement AM: internal piloting, joint internal piloting, and joint external piloting. Several ways exist in which companies can experiment with AM technology. Firms can explore AM technology through a lab by following an individual experimenting approach. The lab's mission is to investigate the opportunities 3DP could bring to the customers by solving their supply chain challenges. Another method is for firms to test the equipment themselves in a production environment. Testing equipment is a crucial step for companies willing to acquire 3DP technology because it will decide which material to select based on the firms' needs and requirements. Also, firms can experiment with AM technology in a joint pilot program. This program enables companies from various backgrounds in AM to come experiment and test the different AM equipment and materials to find the best-tailored solutions to their needs (Martens et al., 2020). In addition to the different experimenting approaches, firms must involve their customers early in the design process to optimize the finished product.

Martens et al. (2020)'s third finding was embedding AM technology and adjusting the firm's business model accordingly. Disruptive technology brings a whole new set of perspectives and challenges when implementing. Steenhuis and Pretorius (2017) argued that companies adopting AM must either improve their existing product by using their actual business model, create a new model, or do both. Accordingly, four types of AM adoption could be distinguished: (a) stasis or equilibrium, (b) supply chain evolution, (c) product evolution, and (d) business model evolution.

In summary, Martens (2018) discovered that manufacturing firms adopted 3DP to benefit from the technology's competitive advantage instead of attempting to disrupt the industry. Firms are implementing the technology to serve primarily niche markets where customers value the unique attributes of AM. Additionally, Martens (2018) argued that firm managers must understand AM's possibilities and perform extensive market research to identify customers and potential marketplaces. Furthermore, managers must select the proper business model and recruit the right talent to adopt AM into their business model successfully.

3 Study Design and Methodology

The research question that this study attempted to answer was: What strategies do companies use to adopt additive manufacturing into their business models? The participants for this multiple-case study were companies from The Netherlands and Belgium that successfully adopted 3DP into their business models; they comprised three manufacturing firms serving various industries, including those from the medical and automotive sectors. Data were collected using desk research, questionnaires, semi-structured interviews, member checking, and reviewing company documents. For the interviews, the participants consisted of three managers, each one from a different manufacturing company. The sample size survey was 14 manufacturing. Yin's (2016) five-step approach and methodological triangulation were applied to ensure the validity of the data collected through interview transcripts, member checking, company documents, and questionnaires. The limitations of this study included the sample size, the selection of the participating companies, and their willingness to participate. This study's delimitations focused only on manufacturing companies in the Netherlands and Belgium that have adopted AM technology. Service companies in other sectors or industries using AM were excluded.

3.1 Methodology

We decided not to select a quantitative method because we were not seeking answers to hypothesized relationships or differences among variables. Quantitative and mixed-method research contains the element of testing predetermined hypotheses (Eisenhardt et al., 2016), which did not support the exploratory nature of a qualitative study. Instead, we used a qualitative method to understand better the participating companies' goals, vision, mission, processes, procedures, and participants' lived experiences (Eisenhardt et al., 2016). A qualitative method is appropriate to identify and explore alternative or new views on a particular topic (Yin, 2014). Several qualitative research designs exist, including grounded theory, ethnography, narrative, phenomenology, and case study (Creswell, 2013).

3.2 Design

Researchers who aim at developing a theory grounded in data collected from the field would use Grounded Theory. Such research design would require interviewing at least 20 or more individuals and studying the interactions of many individuals involved in the process (Creswell, 2013), but this was not the focus of our study. Ethnographic studies are grounded in anthropology, and researchers use ethnographic design to explore cultures (Moustakas, 1994). Our study does not involve a group with similar cultures, so it would not be appropriate to use this research design. Narrative research design is mainly used to develop a narrative about the stories of individuals' lives (Creswell, 2013), which was not the intent of our study. Phenomenological research design's primary focus is to understand the lived experiences of individuals who shared the same experience, and that was not the purpose of our study. Case study research design involves collecting data from multiple sources, including interviews, observations, documents, artifacts, and analyzing cases to look for emerging themes across cases. As this was the intent of our study, we selected a case study design for our study. Yin (2014) suggested case study is appropriate for exploring the unique characteristics of a particular case. However, our study was conducted in multiple companies in two different countries. Therefore, a multiple case study design was more appropriate for this study.

3.3 Validity and Reliability

Yin (2016) argued that four tests need to pass, such as construct validity, internal validity, external validity, and reliability, to have a valid study. Researchers address issues of validity and reliability by using multiple sources of evidence to enhance internal validity (Yin, 2014). To assure rigor in this

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qualitative research, we included factors from credibility, dependability, confirmability, and transferability. We recognized that every step in the data collection process could influence the reliability of the research; therefore, we took steps to ensure a detailed description of the purpose and data collection process. We collected data from multiple sources such as desk research, questionnaires, semi-structured interviews, member checking, documents, and questionnaires. We applied methodological triangulation of data to demonstrate the validity and reliability of our data.

4 Results and Discussion

The participants interviewed for this study were from three organizations, A1, A2, and A3, and they are contract manufacturers serving various industries. A1 operates in the healthcare industry and manufactures medical equipment for various paramedic sectors. Companies A2 and A3 operate as traditional machine shops, serving various sectors. M1, M2, and M3 respectively represent the managers of those three companies. The three major themes that emerged from this study were: (a) identifying business opportunities for AM, (b) experimenting with AM technology, and (c) integrating AM.

4.1 Themes Discovered

To successfully adopt AM into their business model, managers begin by taking a broader strategic perspective by asking themselves how 3DP may transform their organization and supply chain (Öberg & Shams, 2019; Piller et al., 2015). The first finding was that strategies used by managers to adopt AM resulted from understanding the market opportunities and the advantages the technology brought to their companies. Once managers understand those opportunities, they can use a wide range of strategies dedicated to harnessing the full potential of AM technology. Companies adopt AM to gain from the technology's various benefits and establish a competitive advantage over their competitors. According to the participants, benefits such as lead time reduction, cost per part, mass customization, and innovation speed represent the main factors for adopting the technology.

By implementing AM into their business model, firms aim to establish a competitive advantage and develop new capabilities their competitors cannot easily replicate. To capture the benefits AM technology provides while attracting new clients, firms must emphasize several aspects: (a) high levels of customization, (b) complex geometry, (c) short time to market, (d) cost reduction, and (e) elimination of obsolete parts.

Another opportunity AM technology provides to its users is the high customization and complex geometry associated with the products. Mass customization has always been one of the first and most prominent benefits of AM. For A1, a high degree of customization while being able to design complex structures is what gives them a competitive advantage.

All the participants noted some customers approached them, not knowing what to expect from 3DP but then quickly became amazed when discussing the technological aspects of AM, discovering the immense possibility the technology can provide. One participating company that produced spare parts for Formula One cars noted AM enabled them to solve their customers' problems much faster than any other manufacturing method. Another way for companies to develop a competitive advantage is through market research. All participating companies mentioned that one of the most critical aspects of AM even before adopting the technology was to develop a thorough understanding of the market forces in which the firm operates. Being able to combine both manufacturing methods to fit their clients' needs is what gives those companies a competitive advantage in their industry.

Understanding customers' needs and transforming them into tangible products using AM technology is another successful approach. However, for such an approach to be fruitful, the firm needs to know exactly which materials and technology are optimal for producing a specific product. According to M1, this knowledge comes from extensive experimentation with AM technologies. According to M3, one of the significant aspects of AM is the ability to understand the technical problems their customers face and solve those problems using 3DP. With a close collaboration with their customers, 3DP enables them to innovate and remain ahead of the competition rapidly.

Organizations whose aim is to maximize value and stay ahead of the curve would require continual experimentation with disruptive technologies, rethinking their business process, and developing their capabilities (Manyika et al., 2013). All firms participating in this study performed extensive experimentation with 3DP before adopting the technology. The experimentation varied from testing the types of AM technology, the materials, and the equipment which better suited their objectives. Such experimenting intended to understand and perfect the manufacturing process AM offers.

As Chaudhuri et al. (2019) expected, participants emphasized that experimenting with AM was critical to harness the technology's advantage fully. Only by experimenting with AM technology can an organization understand the manufacturing process, such as the proper equipment setting, the correct placing of items in the machine bed, and the right speed. M3 declared: "In the future, the real value will be selling knowledge of 3DP with engineering and innovation".

The findings revealed that all participants explored AM opportunities to improve their current and future business models. While those companies have strategies with a clear view of the potential and impact AM technology may bring, most firms are also investing quite heavily in R&D. Regularly, such firms enter joint programs, jointly investing with partners to experiment with various AM technologies to acquire relevant knowledge and capabilities. Partnering with other firms using 3DP enables a more open environment, which boosts the development of the technology and lowers the overall cost when companies experiment independently (Hannibal & Knight, 2018).

All participants in this study involved their customers to a certain degree in some phases of their business model. M1 argued that the strategy of high customer involvement was a fundamental aspect of their business model, which would be highly beneficial for both the company and its clients. A2 also involved their customers across most of their activities.

When companies acquire new 3DP equipment and meet their customers to offer them these extra services, these ideas are often dismissed. Manufacturing firms who do not influence the product designs often have limited options to offer to their customers and using AM will then typically lead to a higher cost. As these companies' clients often request them to print the exact product they have traditionally made, it becomes commercially unattractive. Being a machine shop with no influence on product design significantly limits the scope of AM operations. As a result, those companies must find new customers, markets, and industries interested in the products and benefits AM can provide. Looking for those new opportunities can take companies several years and negatively affect their business. If they had decided to do all the work upfront and work closely with their customers initially, they might have decided to invest in different equipment or maybe not to invest. By optimizing the design and working in close collaboration with their customers, companies can create fully customized and complex products specifically meeting the need of their clients.

Successfully embedding AM into a company business model requires the constant adjustment of the firm's business model even after adopting the technology (Savolainen & Collan, 2020). Adopting AM does not radically change a firm's business model but instead brings an adjustment period, enabling the organization to align its vision with what AM offers (Rayna & Striukova, 2016). However, A1 noted that for broader adoption of AM into a company's business model, one major thing needs to happen. There is a need for an increased focus on improving the infrastructure supporting AM as a whole; this represents all the things making 3DP possible such as additive design, manufacturing workflow, and improved materials. Having a robust infrastructure on which the company relies will empower the organization to harness the potential of AM technology fully.

Because of its disruptive nature, implementing 3DP can lead to significant business model innovation, and companies looking to enter existing or new markets only need to adjust their business model rather than change a substantial part of it (Savolainen & Collan, 2020). M2 confirmed this stance by explaining that when A2 decided to implement AM and enter a new market, they adapted their business model to offer the most cost-effective approach to their customers. When A2 adopted AM, their business model evolved, and they were able to adopt the new technology directly into the organization, thus providing a complete solution centered around their customer's needs. According to A2, the flexible nature of AM made this move possible as the company can now quickly adapt to different kinds of activities.

Participants A1 and A3 mentioned that they used the trial-and-error methods to find the most suitable business model for their activities. Both firms explained that they designed and tested alternative business models until they found the one which best suited their ambitions. However, this process can come at a high cost, discouraging companies with limited resources from moving ahead with the experimentation process. For A1 and A3, this method was possible by having constant access to 3DP technologies, which enabled the companies to test and try various business models at a lower cost. With AM, ideas and design can be tested much quicker than traditional manufacturing methods. Moreover, companies using trial and error can learn more rapidly from the testing experience of other firms. Having this 'ecosystem' enables AM firms to learn from other members' trials to progress and drive innovation within their heuristic process.

When implementing a disruptive technology, Christensen and Raynor (2003) recommended establishing an autonomous business unit. Two out of the three companies created a separate business unit when adopting the technology. Managers from those two firms decided to do so out of practical circumstances because they deemed it necessary to dedicate a separate business unit to handle the AM activities of the company. Also, because AM technology requires an entirely different set of operational skills, the firm had to hire new talents with AM expertise. Later, the firm slowly merged both units to offer a comprehensive service to its customers.

Moreover, all the participants noted the importance of senior management to align their different business units towards the same goal by providing the path forward and developing guidance. For this reason, A2 and A3 created cross-functional teams within the organization, with clear roles and responsibilities for every member to better integrate the technology. The respondents noted that this strategy represented a crucial step towards adopting AM into their business model. On the other hand, A1 did not create a separate business unit but embedded the AM capabilities directly in their medical division. In the beginning, it seemed like the right thing to do as their AM operations were just starting to get traction. However, after the company saw a sharp rise in their AM-related orders, it forced them to expand and acquire more AM equipment to answer to the needs of their fast-growing customers.

Another critical aspect of the strategies used by managers to adopt AM is the importance of continually remaining at the forefront of the technology. As this technology matures, new materials and equipment become available, forcing companies to update their knowledge and capabilities. During the piloting phase of the technology, all the participants noted the importance of keeping their fingers on the pulse and closely monitoring the technology evolution. M3 added, "staying updated with the most recent trends in 3DP is crucial for companies to keep ahead of the curve and accelerate product development for their customers".

Keeping up with the latest technology means companies must test new materials and technology consistently, which will ensure they develop their capabilities to the very edge. This approach also allows companies only to apply AM technology where it makes sense to them. A2 and A3 noted that by having a deep understanding of each process used in AM, they could assist their customers more profoundly and at any given stage of the 3DP process. With the flexibility that AM provides, A2 and A3 can jump in at any step of the process to serve their customers. Based on their knowledge of AM, they know precisely which materials and technologies to use to respond to their customers' needs. This ability to step in and serve their customers at any given time gives those companies a competitive advantage in their industry, mainly where 3DP hubs are growing and constantly competing with manufacturing firms for customers and market share. As a result, manufacturing firms must differentiate by combining their various manufacturing competencies and providing unique selling propositions. To attract and retain their customers, manufacturing firms must stand out and provide them with benefits other 3DP hubs cannot replicate.

AM impacts business models and supply chains, the technology also revolutionizes how organizations structure and manage their workforce. Disruptive technologies such as AM require a more competent workforce with highly skilled employees than traditional manufacturing methods requiring workers with lower skills levels (Vázquez Sampere et al., 2016). To capture the full potential of AM, companies must focus on developing a skilled and competent workforce adapting quickly to new designs and materials while going beyond their original professional experience. A2 and A3 explained the importance of hiring people with prior experience in 3DP as part of their strategy to adopt AM quicker into their business model. All the employees in A2 and A3 were educated to master's and doctoral levels.

As Chaudhuri et al. (2019) also found, all the participants experienced having a skilled and competent workforce represents a substantial factor in adopting AM. The research findings showed that all the participants invested substantial resources in acquiring relevant knowledge and capabilities individually. Besides, when it came to engineering 3D printed parts, most companies would instead hire new people than train existing employees. Whereas when it came to operating 3DP equipment, companies would instead train their existing workforce instated of hiring new people.

The substantial difference with traditional manufacturing methods relates to the operation, work preparation, and technology; AM requires companies to acquire the right workforce with the required skillset (Kothman & Faber, 2016). A1 emphasized that having the right talents was essential to operate the technology and represented an essential part of their business model. Furthermore, A2 confirmed that hiring people with prior experience in 3DP was crucial but represented quite a challenge, mainly because of the 3DP equipment used in their organization. Using a carbon printer, M2 explained the difficulty in operating such devices on the technical and operational side. Being the only firm using this equipment made it difficult to operate, and due to the novelty of the technology, few people had the knowledge to use it properly. As a result of the complicated use of their machinery, all employees at A2 have a least an engineering degree or a master's degree, thereby overcoming Thomas-Seale et al. (2018)'s most significant barrier to the successful adoption of 3DP. However, M1, M2, and M3 all noted for their organization that one of the most significant barriers to successfully adopting 3DP was the lack of experienced engineers have in designing products with AM. M1 also argued that in their case, whiteout a well-trained workforce capable of adapting to the technicalities and application of AM, it would have been challenging to implement AM successfully.

All the managers interviewed for this study noted the importance of having employees capable of understanding and operating 3DP equipment to the best of their abilities. However, the participants noted that the soring demands for skilled labor in the AM industry face a talent shortage, especially regarding AM engineers, where a scarcity of qualified workers is imminent. One of the main reasons for this situation, as M1 explained, is the lack of senior AM employees with long-lasting experience in 3DP. As a result, managers and workers must learn by experimenting and testing as the technology progresses.

The findings of this study confirmed that early adopters of the technology could have a competitive advantage, difficult to replicate by later entrants. This study also confirmed the findings of the strategies used by managers to adopt AM into their business model. After comparison of the findings from both pieces of research, it can be noted that themes one, two, and three from Martens (2018)'s study were: (a) identifying business opportunities for AM technology, (b) experimenting with AM technology, and (c) integrating AM technology has re-emerged during this study. Both studies came to a similar conclusion by outlining the importance for managers to identify the right opportunities and take advantage of the benefits the technology offers. The findings showed that thorough market research and a deep understanding of the technology were vital elements for organizations to develop a competitive advantage in their industry.

Furthermore, this study revealed that experimentation with AM technology represents a crucial aspect for managers to acquire 3DP knowledge and develop their capabilities to serve their customers better. All the participants in this study emphasized the importance of experimenting with AM to adopt the technology faster and efficiently. Even though the way companies experiment with AM may differ, it remains a crucial step for adopting the technology into a firm business model. This research has also shown the importance of companies involving their customers before and after adopting the technology. Besides, this study found that industry members are developing an active 3DP ecosystem in which companies can experiment with the technology and exchange information more rapidly.

To further validate the data, a questionnaire was distributed online to participants operating as manufacturing companies within the 3DP industry. Fourteen answers were collected from various respondents and analyzed to provide the following results. Of the questionnaires collected, 42% of respondents implemented 3DP in their company within three to five years, and 47% are using AM a few times a week compared to 23% using AM a few times a day. Furthermore, 41% of the participants stated the main effect of 3DP on their business was offering new products to their customers.

The main benefits of using AM were producing complex geometries and reducing their lead time by 31%, followed by a 27% cost reduction. Moreover, 53% of the respondents observed that the adoption of 3DP had no direct effect on their revenues, whereas 18% noticed an increase in their income ranging from 10 to 25%. Further looking at the data reveals that only 35% of the respondents noticed no change in their net profit, and 30% of the participants confirmed their profit increased from 10 to 25%. Forty-nine percent of the participants indicated an increase from 0 to 25% in their customer base after adopting the technology. Thirty percent of companies involve their customers only in the engineering phase, 24% involve their customers in the design phase, and 24% in all stages.

As part of their business strategy, 65% of the respondents confirmed that AM represents their core strength, which gave them a competitive advantage in their industry. Forty-seven percent of the respondent companies significantly influence the design of the products they are making, and 60% approached their clients before deciding to invest in 3DP. The data also showed that 67% of the respondents created a separate business unit when adopting AM; 44% observed that the adoption of 3DP had a medium impact on their business model. Furthermore, 50% of respondents confirmed they received moderate support from their suppliers during the implementation process, and 75% said not to have used any framework to adopt AM into their business model. Subsequently, 64% of users stated hiring people with prior experience in 3DP was moderately important, while 50 % required their employees to have a master's degree. Besides, 66% of respondents decided to train their employees in-house for engineering the 3DP parts and operating the equipment instead of hiring new people.

4.2 Summary and Conclusion

The research question that this study attempted to answer was: What strategies do companies use to adopt additive manufacturing into their business models. AM has become more than just a technical innovation. The technological advancements and applications of 3DP suggest it can affect organizations’ business models and revolutionize entire supply chains.

5 Contribution to Practice and Science

This study may be helpful for managers considering using additive manufacturing in their companies. Our research revealed opportunities and potential issues related to implementing this novel manufacturing technology. Considering the limitations of this project, opportunities for further research exist.

5.1 Business Practice Contribution and Recommendations

The findings indicated that manufacturing firms' managers adopted 3DP to benefit from the technology's competitive advantage. The findings also revealed that to harness the full potential of AM, managers need to think beyond prototyping and understand how 3DP can benefit their organization and what it means for their production. Moreover, participants took a leap of faith regarding the adoption of AM in their organization. Many are now seeing themselves amongst the leaders of their industries. All the participants were early adopters of AM, implemented a few years ago, enabling adequate time to understand, experiment, and successfully implement the technology. Now, the participating companies harness the full spectrum of opportunities AM offers to their business. Due to the rapid advancement of the technology, the previous hesitation managers had has evolved into excitement towards future possibilities of AM. However, further technological development, a decrease in the knowledge gap, and a reduction in the acquisition cost are the main factors required for the technology to be a viable option for most manufacturing firms in the future. For later adopters of AM technology, catching up with the early users will require substantial effort and resources. Hence this study can provide professionals in the industry with insights and strategy guidelines on how to adopt AM in a firm's business model to grow their business.

One of the insights of this study was the importance of managers understanding AM's benefits to their company and the opportunities that might arise from using 3DP. Next, managers must conduct thorough research to identify potential markets and customers who could benefit from products made with AM. Managers can use the findings presented in this study to proceed to the next step by conducting thorough market research to improve their business development. Also, companies need to understand their customers and help them overcome the challenges they are facing by better answering their needs. To achieve such results, firms must choose the right technology, equipment, and process to embed AM in their business model.

Additionally, firms must conduct extensive experimentation with AM to understand the process and learn how to operate the technology to attract potential customers. Companies must keep at the forefront of the technology if they want to keep their competitive advantage and unlock the total potential value of 3DP. Finally, managers must select the appropriate business model to adopt the technology and train existing employees or recruit new talents with the right skills and education to operate the equipment.

5.2 Academic Contribution and Recommendations

The limitations of this study were the relatively small sample size and geographic boundaries, which only focused on two countries in Europe. We suggest that further research using a quantitative research method on a larger participant size could reveal more insights into the strategies used by companies to adopt AM; this could include manufacturing firms using 3DP in other countries across Europe. Additionally, the inclusion of different industries that have adopted AM, such as aviation and construction, could offer additional meaningful insights. The 3DP industry is still developing fast. Today, the technology finds its application pass product prototyping as companies are increasingly adopting it for production in various industries. According to the Gartner hype cycle of emerging technology, 3DP will reach *the plateau of productivity*, which corresponds to the mainstream adoption of AM in the years 2020-2025 (Shanler & Basiliere, 2016). The arrival at this level means a significant rise in the adoption of 3DP. For future organizations to adopt a disruptive technology and harness its entire potential several factors must be considered. Managers considering adopting AM into their business model must have a sound understanding of the technology, including comprehending the challenges AM could have on their organization and the opportunities for their business model. Managers must understand where the technology should be applied to enhance the end-to-end processes and increase their supply chain's efficiency. However, managers adopting AM should not underestimate its disruptive effect on their organization and society. The success this technology can bring to their organizations should outweigh managers' hesitation to implement AM into their business models.

6 Conclusion

We have explored strategies companies used to adopt additive manufacturing into their business models using Christensen's Theory of Disruptive Innovation as the conceptual framework. This study's findings revealed that business leaders must align the organizations' goals with the application of 3DP. They must carefully evaluate each of their processes individually to see if AM will enhance their value, which will ensure the firm harnesses the benefits the technology provides most optimally. Moreover, the findings of this study suggest that companies within the AM industry in the Netherlands and Belgium could further develop an ecosystem approach where members of the 3D community can exchange and interact freely. This sector should encourage more partnerships between members of the 3DP community to bring the entire industry to the top. Such an ecosystem could bring additional value to AM users and facilitate the experimentation process with AM technology. The industry could further benefit from building a solid network where firms can exchange data and work together to boost technological development. Creating a vibrant ecosystem regrouping all industry members, such as machine shops, manufacturing firms, 3DP hubs, and logistics service providers, can provide companies with the tools to adopt AM technology faster. Such an approach will enable a more robust ecosystem centered around 3DP that could benefit the various community members and help drive the evolution of the technology. Finally, further exploration could be conducted on the practical implications and impact of AM on different industries, supply chains, and society.

7 Authors

Dr. Robert Martens, DBA, MSc, FCIPS, is an Associate Professor at The China University of Petroleum, Beijing, and a Principal Lecturer in Logistics Management at the Rotterdam University of Applied Sciences. Dr. Martens is a fellow of the British Chartered Institute of Procurement and Supply (CIPS), and he is the owner and principal consultant of 3D Strategies. Previously, Dr. Martens served as a Director of Procurement and Supply Chain Management at various multinational enterprises worldwide.

Dr. Susan K. Fan, DM, MBA, MA, has worked as a management professional in various leadership positions for several Fortune 100 companies. Dr. Fan is currently an Adjunct Faculty with Purdue University Global MBA program. Additionally, she has worked as a Doctoral Mentor and Chaired Doctoral Committees. Dr. Fan is working towards professional licensure in the mental health field.

Gael Clarenc MSc was a master student in Global Supply Chain Management at Rotterdam Business School and is now working as Logistics Project Leader at the Mauritius Freeport Development.

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