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3D printing: a challenge to existing business models

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Abstract

Technologies labelled as "disruptive" challenge conventional business procedures. The development of 3D printing technology and additive manufacturing (AM) is expected to transform product design and manufacturing. 3D printing technology makes it possible to produce complex and unique physical products from digitally designed CAD models. It is estimated that the effects of 3D printing on business will be diverse and far-reaching. Hence, it is vital for business owners to observe how 3D printing may impact on business models and business networks, considering also the effects on stakeholders' value propositions and on value creation. This paper reports on the potential impact of 3D printing technology on business models within the metal and machinery industries.

Key words: Business model, value delivery, value networks, 3D printing

1. Introduction

It is estimated that the digitization of manufacturing will transform the way goods are made. 3D printing has been referred as the third industrial revolution, involving not only the way products are manufactured, but also how they are designed (The Economist, 2012). 3D printing offers the potential to design forms and structures that are impossible with traditional methods. In addition, it is expected that 3D printing will accelerate product development cycles, shorten product delivery time, modify the profit structures of companies, and possibly reshape future professions and jobs (Cohen, Sargeant, & Somers,2014; The Economist, 2012). The diffusion of a new technology is a slow process, but it can ultimately have immense consequences (Davis and Venkatesh, 2000). It seems likely that business managers will have to re-evaluate their business models, here bearing in mind the circular process by which the reinvention of a business model can itself accelerate the adoption of a new technology (Ardilio and Seidenstricker, 2013). It appears that the overall digitization of manufacturing will be a factor accelerating the diffusion of 3D printing. Business managers would be well advised to understand the change-producing agents at work in 3D printing, and to anticipate how the technology may impact on business models. Due to a limited number of research on how 3D printing impacts business models (Rayna & Striukova, 2014), business network, and value creation, the aim of the study reported here was to determine how 3D printing influences and might shape an existing business model and its components, including the product, the value network, the value delivery, and the revenue model.

2. 3D printing

Three-dimensional printing can be taken to include rapid manufacturing, rapid prototyping, or additive manufacturing. It utilizes methods of adding materials, such as stereo lithography and laser sintering. Various materials – including metal, composites, polymers, and ceramics – are used in 3D printing processes (Cotteleer et al. 2013). The technology used with metal 3D printing follows laser sintering or laser melting principals. The laser beam melts thin metal powder layers and the product is produced by adding the material layer-by-layer. As a result durable and hard product is printed. (AM Finland, 2016.) Petric and Simpson (2013) note that 3D printing and additive manufacturing are perceived as synonyms, since both refer to a layer-by-layer production method.

Petric and Simpson (2013) describe 3D printing as a disruptive technology. By this they mean that 3D printing has impacts on how products are designed, built, and delivered. Also the traditional economies of scale of the conventional manufacturing are challenged by economies of one (Petric and Simpson, 2013). 3D printing technology is based on digital computer-aided design (CAD) (Liu and Zhou, 2010). It involves the creation of a series of digital images of an object, which are then transferred to a 3D printer (Ford 2014). A physical model is formed from the digital image by adding materials cumulatively (Liu and Zhou 2010). The greatest advantages of 3D printing are cost-effectiveness, reduced time to the market, a movement from mass production to more customized or tailor-made products, and environmental benefits. Users have also mentioned the features of variety in materials, flexibility in design, and improved accuracy (Cotteleer et al. 2013; Ford 2014; Mertz 2013). Some authors (e.g. Petric and Simpson 2013) have gone so far as to suggest that almost anything that can be imagined can be produced by 3D printing.

During recent years 3D printers and materials have improved, as have 3D software and digital platforms. 3D scanners and software compatible with 3D printing have been developed for a variety of applications. Platforms such as Autodesk and Spark offer 3D design services, optimized for 3D printing. The main industries to benefit from 3D printing have been in the consumer sector, and in the fields of electronics, automotive industries, space, and medical instruments (Mertz 2013; Petric & Simpson 2013). For instance, the automotive industry has benefited from 3D printing in terms of producing tool prototypes and small customized parts. The aerospace industry, for its part, uses 3D printing to produce lighter and stronger components, and to print small numbers of geometrically complex parts from materials such as titanium and plastic (Ford 2014). Nasa (2015) recently announced 3D printing as a key technology for improving space vehicle design and manufacturing; indeed, it indicated that it is coming closer to building an entire rocket engine with a 3D printer. The medical industry has increasingly benefited from 3D printing; thus medical instrument companies can often manufacture unique products, and set up small runs of complex parts (Ford 2014; Mertz 2013; Petric & Simpson 2013).

3. Business models

Business models have attracted academic interest for decades (Zott et al. 2011). Scholars have studied business models from various perspectives to determine many aspects, including how firms can organize their activities (Magretta 2002), create value for partners and end-users (Teece 2010), make a profit (Morris et al., 2005), and enter foreign markets (Ojala and Tyrväinen, 2006). To advance our understanding on business models, scholars have developed models and theoretical frameworks that explain how business models can be planned and developed. For instance, Osterwalder and Pigneur (2010) have developed a business model canvas that can be used as a tool to develop a new business model or to advance the existing one. The canvas is a very useful chart for the purposes of explaining business activity in the context of given organization. However, the recent theoretical framework by Ojala (2016) takes a wider perspective, explaining business model creation and development in the context of a whole industry or ecosystem. Because Ojala's framework includes the aspect of change, it was selected as a theoretical model for this study.

The business model framework by Ojala (2016) includes four different components that might change when a firm develops its business model further. The first component, the product/service, is linked to how the product creates value for other actors in the business ecosystem, i.e. the network of partners. The second component is the value network. The value network includes all the key actors that the firm cooperates with, either directly or indirectly. The third component, value delivery, refers to the actors in the second component, and how the value, based on the product or service, is exchanged between them. The fourth component, the revenue model, explains how the revenue is created among the partners in the network.

In the framework by Ojala (2016), the components of the business model change constantly when a firm operates in the market. The first business model is created through enactment of a business opportunity. This new business model is "tested" in the market to see how it works, and how partners and customers react to the model created. Based on actions in the market, the model might require reassessment, since there can be changes in technology, market conditions, and so on. This leads to the business model development phase, in which the model is developed further to better respond to the needs and requirements in the market. In the final phase, new elements are added.

4. Research method

This study applied a qualitative research method and a semi-structured interview procedure, since the aim was to explain contextual information, and to understand the interpretations and perspectives of the actors. A qualitative study allows actors to articulate their perceptions of situations in the past, and to evaluate the elements affecting their development in the future. In addition, a qualitative research method examines the study phenomenon with a view to understanding people operating within a certain social context (Myers and Avison 2002). For its part, the semi-structured interview is flexible, with good possibilities for in-depth data collection and a detailed understanding of the research phenomenon (Gillham, 2005).

The study covered face-to-face interviews with two companies. One interview was conducted with the CEO of a metal 3D printing company, and two interviews were conducted with the project manager in tractor manufacturing company. Additional information was collected via email communication and from company web-pages and brochures.

The themes and structure of the interviews were pre-planned, and the same questions were asked of all the interviewees. The interview questionnaire was divided into three themes: (1) the company's background and current use of 3D printing, (2) 3D printing´s impacts on the existing business model and its elements, (3) estimations of the impacts of 3D printing on future business model development. The interviewees were able to give comments freely, and to provide feedback. The interviews were audio recorded for later transcription and analysis. The average interview length was approximately 40 minutes.

5. Research findings from case companies

5.1. A metal 3D printing company

The metal 3D printing company offers products for customers in various industries. The owner, who has a background in metal additive manufacturing, considered metal 3D printing to be a promising business. He executed the first market survey in the dental sector, and a second survey some years later in the jewelry industry. Because respondents in the survey indicated an interest in 3D printed metal crowns, bridges, and superstructures, and subsequently, prototypes for items of jewelry, the company created its first business plan for dental products and jewelry products. However, obstacles came up immediately, since financial institutions were not willing to fund the still unknown 3D printing technology; the institutions would advance only 25−30% of the cost of 3D printers, whereas the lending value for CNC (computer numerical control) machines is 80%. Despite some promising signs, it was difficult to get the new business off the ground, and it took another year for the company to find funding. Finally, a German 3D printing machine manufacturer offered a financing solution. The machine was acquired, and the project was able to continue. In addition, the business manager found several private capital investors who were willing underwrite the new 3D printing business operation. In October 2014, the company received its 3D printer, and the first 3D printed metal components were delivered to customers a few weeks later.

"It was a long and rocky road to bring the new technology and business to Finland. Since financial institutions do not understand what 3D printing is about and what is done with the machine, they are unwilling to take risks." (T. Heikkinen, personal communication, October, 27th, 2015.)

After this bumpy start the first business model evolved (Table 1). All the business model components *(the product, the value network, value delivery,* and *the revenue models*) have undergone improvements. The first and the second business model included products only for the dental and jewelry sector, but the company currently offers a wide selection of 3D printed metal components for final and prototype use, providing them to various b-2-b customers in a range of industries. The new business areas seem likely to include metal spare parts to cars. The number of printed products has steadily increased, and in addition to single products, the company also delivers mini-series, such as 20-60 items product orders. Since customers increasingly require finished products, or products resembling end-use items, the company is considering extending finishing services as part of its product portfolio.

Table 1: The business models of the metal 3D printing company

Business model	Products made of steel, cobalt-chrome, silver, and bronze	Value networks	Value delivery factors	Revenue model
Business model #1 and #2	Metal dental bridges, crowns, and superstructures. Metal components for the jewelry market.	Investors, 3D printer manufacturer, customers, trade associations.	Rough product versions. Delivery time. Cost-efficiency.	B-2-B customers.
Business model #3	Metal dental bridges, crowns, and superstructures. Metal components for the jewelry market. Wide selection of metal components and prototypes for various customers. Spare parts for cars. Mini-series production, 1-60 items. Demand for finishing services.	Investors, a 3D printer manufacturer. Customers. Trade associations. Other 3D printing companies. 3D designers. Educational institutions.	Rough product versions. Delivery time. Cost-efficiency. Finished products. Dimensional and quality accuracy. Local service better than in low-cost countries. No interruptions in the customer´s normal production process.	B-2-B customers. Collaboration with other 3D printing companies.

During the years of operation, the value network has evolved from investors, 3D printed manufacturers, and customers, to include also other 3D printing companies, 3D designers, and educational institutions. The company is actively participating in industry-related workshops and seminars, and it collaborates closely with national trade associations and city administrations, aiming to increase knowledge of 3D printing knowledge and the business opportunities surrounding it.

In addition, the business model's value delivery component underwent improvements. The first product versions lacked refinement; however, the company is now able to provide larger and better metal 3D printed components. Customers have indicated that the local 3D printing company provides better metal 3D printed products in terms of materials, dimensional accuracy (20–60 µm), overall quality, and delivery time, as compared to products from low-cost countries. Product accuracy and delivery time are particularly highly valued, since these save costs and benefit the customer´s total production time. Other value delivery elements mentioned included the point that the customer should pay only for the materials and time used to manufacture the 3D products; furthermore, if a customer occasionally needs single parts, the customer's normal production line should not be interrupted due to delays in the 3D printing.

> "Two weeks ago one customer made the point that the product material must be exactly what he has ordered. The customer said that in ordering from low-cost countries, you never know if the strength values or weldability will be correct. Even though the product may be cheaper, the final result is not the same if the material is wrong. This is important. In addition, our delivery time is 3–7 working days, which means added value for customers." (T. Heikkinen, personal communication, October 27, 2015.)

The company is willing to deliver more mini-series for end-use, so long as the quality meets the customer's requirements. Mini-series increase the value experienced by the customer, bearing in mind that having the manufacturing tools and other instruments for small numbers of pieces can prove extremely expensive.

As regards the revenue model, the company earns revenue from products delivered to the customer. The first operating year ran at a loss; however, due to customership and to extension of the product portfolio, the yearly turnover has increased. It is estimated that the turnover will be 4−5 times higher within the next five years. However, the company is still searching for a "cash-cow" product range, i.e. one that would have a truly dramatic impact on revenue. To minimize the business risk, the company prefers to collaborate and co-create value with customers. In future, finishing services will extend the revenue model.

5.2. A tractor manufacturing company

The second case company, a tractor manufacturer, belongs to a corporation providing solutions for the agriculture industry on a global basis. The company´s core business is the production of customized tractors worldwide. The company recently established its own facility called *The Unlimited Studio,* which provides customers with even more precisely tailored and specialized solutions. The studio attends to the customer´s individual needs by providing customer-specific accessories and equipment, i.e. items that are not available directly from the production line. Examples include special lamps and painting finishes, tailored automated extinguishing systems, and alcohol ignition locks. The annual need for special accessories is about 10 – 300 units per year. The company has used 3D printing for prototype and mold purposes (Table 2) as part of its R&D for several years, but in 2015 the company decided to acquire its own plastic 3D printer for R&D, allowing industrial designers to study the 3D printing technology more closely. The research areas of special interest include the capabilities and restrictions of 3D printing, and how it can be applied to mini-series production. The company is investigating the utilization of 3D printing at its Unlimited Studio.

Table 2 A tractor manufacturer´s business models

Business model	Product material: plastic and aluminum	Value networks	Value delivery factors	Revenue model
Business model #1	Customer-specific accessories. 3DP used internally for mold and prototype purposes by R&D + industrial users.	Internal industrial designers and R&D personnel. Customers. Various domestic and international stakeholders. External domestic and international 3D printing service providers. Would benefit from metal printing, if the service was available. Plastic materials are too fragile for the final product.	Easier to outline the entire product and to detect design errors in the early phase. Ability to execute functional tests in the early development phase. Cost effective compared to traditional mold costs. Easier to demonstrate the sketched product to the customer. Improves product quality. 3D printing is utilized increasingly. Depending on the product volumes, decompression molds have greater utility. If 3D printer prices fall and if materials develop, it will be possible for final products to be printed. This will affect the business model.	Reduced cost structure. Quicker production time.

Business model #2	Own printer for R&D and for industrial designers.	Internal industrial designers and R&D personnel. Customers. Various domestic and international stakeholders. External domestic and international 3D printing service providers. Domestic 3D printing manufacturer.	Own 3D printer has improved product development and project schedules. 3D products are ideal for examining product dimensions and durability.	Reduced cost structure. Quicker production time.
Business model #3	3D printed special accessories at business unit called *Unlimited Service.*	Same as Business model #2, complemented with subcontractors, who offer marginal 3D printed accessories for Unlimited Studio.	Marginal accessories cost-effective compared to current methods. More unique accessories.	Reduced cost structure. Quicker production time.

The company´s value network consists of internal and external actors. The external actors consist of customers, plus various domestic and international stakeholders and 3D printing subcontractors. The external 3D printer manufacturer complemented the value network when company acquired own 3D printer. If the quality of the 3D printing fulfils end-use product requirements, the company is interested in using 3D printing subcontractors for Unlimited Studio´s production of special accessories. The reason for using subcontractors is they have the best expertise, notably in printer use, in materials and material properties such as thermal expansion, and in finishing and pricing.

One of the value delivery elements the company mentioned was the designers´ ability to outline the whole product easily, and to detect design errors at an early stage. In addition, the designers were able to examine the product structures, dimensions, and ergonomic aspects. Sculptured samples are no longer needed when prototypes are digitally designed, with the 3D product emerging precisely as designed.

> "Industrial designers no longer need to sculpt the prototype from wood; instead, the product is digitally 3D designed and 3D printed. The designed product is tested and modified if necessary. 3D printing accelerates the design process." (S. Rauhaniemi, personal communication, October 19, 2015.)

With 3D printed prototypes it is easier to illustrate the sketched product with the customer and to run functional tests before the final products. This improves mutual understanding, and thus reduces the time and costs applicable to the final product. 3D printed prototypes are less expensive than molds produced traditionally, and the delivery time is a few days instead of several weeks. This has impacts on the final product costs. By possessing its own 3D printer, the company has been able to improve project schedules and the overall efficiency of the product development process. Even though the superficial quality of the product surface remains low, it is considered good enough to examine product dimensions and durability.

> ”For example, if we need to validate, if the feel of the handle is sufficient for the fingers; it is difficult to observe this in a display. The 3D printed prototype thus

accelerates the schedule for the project." (S. Rauhaniemi, personal communication, October 19, 2015)

As a result of 3D printing, the customers receive individual tractors more quickly. For the company, 3D printing has reduced the final product costs and the time used in design, molds, and materials. This has impacted positively on the revenue model. The marginal accessories offered through Unlimited Studio are currently fairly expensive to produce. However, customers are willing to pay extra for individual and tailored parts. Provided that the cost structure for 3D printed special accessories is reasonable, and provided quality expectations are met, 3D printing can prove to be a solution. The company is actively investigating this option, since it will affect the future revenue of Unlimited Studio.

6. Discussion

Considering the impacts of 3D printing technology on company business models, we would argue that 3D printing is connected to changes in the *product, value network, value delivery,* and *revenue model* components of the business model (Ojala, 2016). The manner in which 3D printing impacts on the products relates first of all to the way in which the technology gives greater freedom for product design. For industrial and R&D designers this means possibilities to design and produce new prototypes with new forms and structures, including items which can be difficult or even impossible to produce via traditional methods. As an example, metal 3D printing enables to print nested forms and internal funnels for metal nuzzles. With traditional method, this would be challenging or even impossible. This has a positive influence on product innovations, and on improvements to old products. 3D printing has also extended the product range, both for existing and new customers. The companies´ product portfolios have improved so that they cover a range of prototypes, molds, metal components, and end-use products. It appears 3D printing is important in machinery industry as the costs of 3D printed molds are fractional compared to molds produced traditionally. Both case companies expressed a demand for finishing services, but from different perspectives. The tractor manufacturer indicated an interest in external finishing services if the company were to initiate 3D special accessories for its customers. The metal 3D printing company is evaluating the provision of finishing services, in line with constant customer demand.

The value network varied between case companies, since they represented different business roles in the market. As a private family business, the value network of the metal 3D printing company has evolved to include other 3D printing service providers, in addition to investors, b-2-b customers, and 3D printer manufacturers. For the tractor manufacturer, the most significant actors in the 3D printing value network have been customers, 3D printing subcontractors, internal designers, and a 3D printer manufacturer. The reason for preferring 3D printing subcontractors was they have the best expertise regarding printer use, and in materials and material properties such as thermal expansion, finishing, and pricing.

The value expectations of 3D printing are seen as bound up with a movement from mass-production to mass-customization (Berman, 2012; Ford, 2014). The need for unique and tailored products is increasing; however, with traditional production methods such tailoring is limited due to the cost structure. 3D printing makes it possible to produce unique and tailored products with affordable costs and time, since the customer pays only for the materials and time used in the printing process. 3D printing is also suitable for mini-series, since the unit costs remain reasonable. Both of the case companies preferred to have customers involved with the product design and development process. This is because 3D printing makes it easier to illustrate the sketched product for the customer, and to experiment with its structures, surfaces, and dimensions. Co-creation of the product with the customers increases the experienced value, since it improves communication and mutual understanding of the final product. It thus strengthens the trust between the firm and the customers, while at the same time deepening the customers´ role in the value network. The metal 3D printing company integrated customers with product co-creation, noting that this reduced business risks. It was found that customer involvement reduces the overall project time and costs.

3D printing impacts on the final business model component – the revenue model – in line with more or less traditional revenue models. The metal 3D printing company´s revenue model was based on customer invoicing per orders. Co-operation agreements and the number of products ordered have an impact on pricing. In any case, yearly turnover is expected to increase, due to new customers and to the possibility to provide larger components through partner companies who do 3D printing. For the tractor manufacturer, 3D printing has streamlined and reduced the overall costs of projects. This has an indirect positive impact on the revenue model. In future, 3D special accessories, tailored for end-use, will foster changes in the revenue model, and also in the other business model components.

7. Conclusions

3D printing technology has experienced dramatic growth, with increasing exploitation by various industries. One significant reason for companies to use 3D printing is that it liberates product designers; they can now design and produce personalized and tailored products that would previously have been impossible. For example, metal 3D printing makes it possible to produce individual items and small volume mini-series for various industries including dental, machinery and jewelry industries in a manner that is cost- and time-effective.

It appears that with localized 3D printing, the value perceived by customers improves, due to better product quality, delivery time, and service. Local production improves communication, and it allows the co-creation of product innovations between the customers and the 3D printing companies. This helps the company to be more flexible and agile in adapting or renewing its business model.

Even though 3D printing is now applied in many industries, there are numerous industries and companies that have not yet realized the hidden potential of 3D printing. 3D printing technology is improving rapidly. Combined with other emerging technologies (such as IoT), 3D printing technology could have huge (and still largely unexamined) potential for product innovation and value delivery. This will provide multiple new perspectives for the business models adopted.

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