Author(s): Hämäläinen, Mervi; Ojala, Arto

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Additive manufacturing technology: Identifying Value Potential in Additive Manufacturing Stakeholder Groups and Business Networks

Mervi Hämäläinen
University of Jyväskylä
mehamala@student.jyu.fi

Arto Ojala
University of Jyväskylä
arto.k.ojala@jyu.fi

Abstract

The development of additive manufacturing (AM) technology is expected to transform product design and manufacturing. It is predicted that the effects of AM on business will be diverse and extensive. It will be critical for business owners to observe how AM impacts on conventional supply chains and business networks, plus the effects on customers' value propositions and on value creation. Value creation and value capture are concepts strongly linked to business relations and to stakeholder management. However, the concept of value is inherently complex and multifaceted, and so are the structures within which value potential exists in business networks and business environments. The critical issue for business managers is to identify where and how value is created in business relations. In this study, the primary purpose was to observe how AM technology impacts on company value creation within complex business relations.

Keywords: 3D printing, additive manufacturing, stakeholder theory, value creation

Introduction

Technologies that have been labeled as "disruptive," such as the Internet and additive manufacturing (AM), have challenged conventional business procedures. The Economist business magazine estimated that the digitization of manufacturing would transform the way goods are made, and it referred to AM technology as the third industrial revolution. The effects of AM technology will not only change the way products are manufactured, but will also change how products are designed (The Economist 2012). AM technology accelerates product development cycles, shifts the profit structure of companies (Cohen et al. 2014), reduces the environmental load (Gilpin 2014), and can reshape future professions and jobs (The Economist, 2012). Altogether, AM technologies present an important strategic and competitive use of information technology.

Existing research on AM has provided a good understanding of the technical aspects of AM, and of how AM technology is implemented in various industries (e.g. Chimento et al. 2011; Michaleris 2014; Sanz-Izquierdo and Parker 2013). Nevertheless, the literature has not elaborated AM technology from the point of view of value creation for companies, or of business networks. This is important, as AM provides interesting perspectives for a company's value creation – involving delivery and capture among its current stakeholder groups – and there is a need to discover how AM technology could impact on future business relations and ecosystems. In this regard, one can draw on stakeholder theory (Freeman 1984) and research on value creation and value networks (e.g. Allee 2000; Ojala and Helander 2014), in order to understand how a company creates value for its stakeholders. This paper seeks to contribute to the literature on IS and value creation in the context of AM technology, by examining: 1) where and how value is created in company business relations and, 2) how AM technology impacts on a company's value creation among its primary stakeholders.

Stakeholder Theory

R.E. Freeman (1984) is regarded as the initiator of stakeholder theory. Freeman (1984) suggests that businesses should build their business strategy around relationships with key stakeholders, and that the focus should be on the jointness of the stakeholders' interests. Fundamentally, stakeholder theory is a theory concerning how business works and how it could work best in a turbulent global business environment. The purpose of the theory is to show how business can be described through stakeholder relationships, and how value is created for stakeholders in an effective way (Freeman et al. 2010). The importance of value creation for all stakeholders is underpinned by the assumption that people engaged in value creation will be more responsible to those individuals or groups whom they think they can affect, or whom they may be affected by.

If stakeholder theory provides answers to the problem of value creation, the essential question from a management perspective will be to determine which groups or individuals are stakeholders and which are not (Mitchell et al. 1997). Freeman (1984) defines a stakeholder as "any group or individual who can affect or is affected by the achievement of an organization's purpose" (Freeman 1984, 53). Friedman and Miles (2006) consider the organization itself to be a group of stakeholders; the purpose of the organization thus becomes that of managing the stakeholders' interests, needs, and viewpoints. By identifying a certain focal stakeholder group – such as top-management within an organization – it may be possible to manage other stakeholder groups (Friedman and Miles 2006).

Shareholders, customers, suppliers, distributors, employees, and local communities are considered to be the most common stakeholder groups of an organization (Friedman and Miles 2006). However, Freeman et al. (2010) determine customers, employees, financiers, communities, and suppliers as the primary stakeholder groups of the company (Figure 1). For Clarkson (1995) the primary stakeholders are those individuals or groups whose contribution to the organization is so important that without them the corporation could not survive.

Figure 1. Primary Stakeholder Groups (Freeman et al. 2010)

It is vital for organizations to consider other individuals and groups who can affect or be affected by the organization. Secondary stakeholders, such as the media, government, competitors, consumers and other special interest groups (for example environmental organizations) are examples of the stakeholders who may have an interest towards the organization and should thus not be ignored (Clarkson 1995; Freeman et al. 2010). This means that the stakeholders are multifaceted, forming dynamic cross connections and relationships among each other. The stakeholders thus form interfaces (Figure 1) at which value potential exists. The value potential is actualized when certain business activities occur between the stakeholders. By examining a company's ecosystem and stakeholder activities in the value creation process, it is possible to see where and how value is created and gained (Freeman et al. 2010).

Value Concept and Value Creation

Lepak et al. (2007) express the difficulty among scholars of defining what value creation is, the process in which value is created, and the mechanism that enables value creation in an organization and in business networks. Value originates from the assumption that a human is *a goal-oriented* organism seeking to achieve satisfaction and avoid dissatisfaction. Values are seen as qualitative, via the fact of being excellent, useful, or desirable (Rescher 1969). Values are beliefs and commitments that motivate a person to action to achieve desirable goals (Rescher 1969; Schwartz 2012). In the organizational context, Heinonen (2004, 2006) proposes that customer-perceived value can be conceptualized in four dimensions, involving *technical, functional, temporal*, and *spatial* dimensions in the service and product value context. The technical dimension consists of the technical elements included in the product or service. The functional dimension is related to the functional aspects of the service and product. The temporal dimension of value involves the benefits and sacrifices related to time, and includes the temporal aspects affecting perceptions of the value. The spatial dimension encompasses the benefits and sacrifices related to location (Heinonen 2004, 2006).

Ojala and Tyrväinen (2011) suggested that value occurs not only in customer-seller relationships but also among the other actors in business networks. Business networks may possess certain resources and qualities that the company is lacking. By belonging to the business networks, the company may benefit from the business network's resources and receive value directly or indirectly. Direct value may occur in a monetary form, but also in the form of critical resources. Indirect value may occur, for instance, in the form of improved market and networking potential (Ojala and Helander 2014).

Additive Manufacturing and Three-Dimensional Printing

Rapid manufacturing, rapid prototyping, or three-dimensional printing may be referred to when one is speaking of AM. AM includes materials adding methods such as stereo lithography, laser sintering, and three-dimensional printing. Various materials, including metal, composites, polymers, and ceramics are used in AM processes (Cotteleer et al. 2013). Petric and Simpson (2013) indicate that 3D printing and AM are perceived as synonyms, since both refer to a layer-by-layer production method.

AM technology is based on digital computer-aided design (CAD). It involves the creation of a series of digital images of an object, which are then transferred to an AM machine (Ford 2014). A physical model is formed from the digital image by adding materials cumulatively (Liu and Zhou 2010). The greatest advantages of AM are cost-effectiveness, reduced time to the market, a movement from mass production to more customized or tailor-made products, and environmental benefits. In addition, variety in materials, flexibility in design, and improved accuracy have been mentioned by AM technology users (Ford 2014; Cotteleer et al. 2013; Mertz 2013). Some authors (e.g. Petric and Simpson 2013) have even argued that AM provides the ability to produce almost anything that can be imagined.

During recent years AM machines and materials have improved, as have AM software and digital platforms. AM-compatible 3D scanners and software solutions have been developed for a variety of applications. Platforms such as Autodesk and Spark offer 3D design services that are optimized for AM. Consumer and electronics, automotive, aerospace and medical instrument industries have been the main industries to benefit from 3D printing (Mertz 2013; Petric and Simpson 2013). For instance, the automotive industry has benefited from AM in terms of producing tool prototypes and small customized parts. For it part, the aerospace industry is using AM to produce more light-weight and stronger components, and to print small numbers of geometrically complex parts from materials such as titanium and plastic (Ford 2014). The medical industry has increasingly benefited from AM; thus medical instrument companies can often fabricate unique products and small runs of complex parts (Ford 2014; Mertz 2013; Petric and Simpson 2013).

The Effects of AM on Value Formation

Petric and Simpson (2013) describe AM technology as a disruptive technology. By this they mean that AM has impacts on how products are designed, built, and delivered. The economies of scale of conventional manufacturing are challenged by economies of one, which AM technology makes possible. Petric and Simpson (2013) have estimated and compared the principles of conventional and AM technology in respect of economies of scale and economies of one (Table 1). Traditional manufacturing enables high volumes, which leads to a low unit price. With AM technology it is possible to produce tailor-made products with variable costs. The roles and responsibilities in the traditional supply chain are clear and well-defined. By contrast, AM technology enables local production and collaboration with various stakeholders. There are reductions in product delivery time and in costs to end-user when an AM service provider produces and delivers the product locally (Petric and Simpson 2013). Cotteleer and Joyce (2014) note that AM technology makes it possible to set up small and flexible AM service centers in various places, with lower capital costs. This opens up opportunities for companies to design and produce products more cost effectively, and to create value for existing and new customer segments. AM also impacts on the supply chain process, and on how products are transported in the supply chain.

Conventional/Additive Manufacturing	**Economies of Scale**	**Economies of One**
Competitive advantage	Low cost high volume & variety	Tailor-made products
Supply Chain	Well-defined roles and responsibilities	Non-linear, vague roles & local collaboration
Distribution	High volumes cover transportation costs	Local Customer/producer
Economic model	Fixed & Variable costs	Nearly all costs variable
Design	Standard, with aim of simplicity	Complex and unique
Competition	Precise	Continuous change

Table 1. Economies of Scale and Economies of One (Petric and Simpson 2013)

It is clear that AM technology impacts on supply chain activities, and also on the business partners and stakeholders involved in the supply chain. Companies have started to talk about moving from mass production to mass customization (Ford 2014). In particular, middle and small-sized manufacturers in the supply chain have the opportunity to take advantage of AM technology. Flexibility and cost savings are the aspects mentioned most often, with AM making it possible to respond quickly to changes and to produce (perhaps temporarily) components in house. In addition, AM technology allows production of critical components on demand, or spare parts for final use, reducing the overall risks in the supply chain, for example in terms of materials, tooling, storing, and transportation costs (Ford 2014).

Research Method

This study applied a qualitative research method, as 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 effecting their development in the future. In addition, a qualitative research method examines the study phenomenon with a view to understanding the people operating within a certain social context (Myers and Avison 2007).

The companies selected for this study included six SMEs (small and medium-sized enterprises) and two large companies (see Table 2) from the Finnish machine industry. An SME is defined as a company having less than 250 employees (Statistics Finland 2014). In addition to size, the companies were categorized on the basis of their expertise in AM technology, into those of *beginner*, *experienced*, and *professional* level. A beginner-level company possesses some AM knowledge but lacks knowledge of AM materials, methods, and machines. Experienced-level companies utilize AM in R&D functions and are acquainted with AM design, materials, and methods. Experienced companies do not print AM products themselves, and instead utilize subcontracting. Professional-level companies provide AM end products, and services as subcontracting.

Altogether, eight semi-structured interviews were conducted (one per case company) as the means of data collection. The semi-structured interview procedure is flexible, enabling in-depth data collection and understanding of the research phenomenon (Gillham, 2005.) 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 four themes: 1) a company's background, 2) AM benefits and value-adding elements, 3) a business development, and 4) resources and skills needed to implement AM technology. Finally, all the interviewees were able to make free comments and give feedback. In the SMEs, the interviewee was the owner or business manager, while in large companies the project manager or design engineer took on the role of interviewee. The interviews were recorded by using a voice recorder, and were transcribed verbatim. The average interview length was approximately 60 minutes.

Company	**Business description**	**Knowledge level**	**Company size**	**AM for prototype use**	**AM for final production**	**Own printer/ Subcontracting**
A	3D engineering design for the metal industry	Experienced	SME	Yes	No	Yes/No
B	Machine engineering	Beginner	SME	No	No	No/No
C	Metal processing and life-cycle solution provider	Beginner	SME	No	No	No/No
D	A subcontractor in machine engineering	Beginner	SME	No	No	No/No
E	AM service provider	Professional	SME	Yes	Yes	Yes/No
F	Machine engineering and design services	Experienced	SME	Yes	No	No/Yes
G	Optical devices, maintenance and product life cycle support.	Experienced	Large	Yes	No	No/Yes
H	Agricultural machines	Experienced	Large	Yes	No	No/Yes

Table 2. Overview of the Case Companies

Findings

The empirical study indicated that five companies (A, E, F, G, and H) utilized AM for prototypes and for miniature models production. Company E, an AM service provider, offered AM services for prototype use, but also for printing end-use products. The remaining three companies (B, C, and D) did not benefit from AM in their current business, but indicated an interest in learning more about AM technology and metal 3D printing. Two companies (A and E) owned printers suitable for AM, while three companies (F, G, and H) utilized subcontracting. Companies B, C, and D observed AM benefits between subcontracting and acquiring one's own printer. AM service provider (E) possessed professional-level knowledge, while the companies utilizing AM in prototype and in miniature products (A, F, G, and H) showed experienced-level knowledge. The others (B, C, and D) were regarded as being at beginner-level, with little knowledge of AM technology.

The Benefits of AM Technology, and Value-Adding Elements for a Company

The AM technology benefits noted varied among the case companies. Table 3 shows the benefits that interviewees expressed as being the most valuable for the company. The beginner-level companies (B, C, and D) indicated that AM technology would accelerate the company's development and generation of new products. AM technology might provide the opportunity to acquire a leading position and to achieve a competitive advantage over competitors. In addition, AM would make it possible to design more tailor-made products and to produce end-use products immediately, and further, to produce and deliver spare parts more rapidly, minimizing the stock requirements. Furthermore, one beginner-level company put forward the idea that current low-pressure molds could be replaced by AM molds, or else new stainless steel products could be designed and printed directly for the function required. In general, beginner-level companies assumed that AM technology would allow more flexible and faster service, and a better product offering.

Category	**Company benefits**
Beginner (B,C , and D)	New and tailored products, production to function, spare part delivery, minimizing of stock rate, AM molds, environmental issues
Experienced (A, F, G, and H)	3D designed, realistic prototypes, early human error detection, cost and time savings in product design, accelerating product testing and modification, marketing purposes, environmental issues
Professional (E)	Expanding AM services to new customers

Table 3. AM Company Benefits

The experienced-level companies (A, F, G, and H) benefited from AM in new product design and in all product R&D phases. AM made it possible to produce prototypes and miniatures precisely as they were 3D designed. In addition, human design errors could be detected at the early product design phase, and corrections for the second prototype version could be implemented easily. In particular, if molds are needed for industrial product manufacturing, AM streamlines mold design and production processes. Traditional expensive work phases such as tooling or manual work are absent in AM. This leads to cost and time savings in product design and manufacturing. The cost savings with AM technology were seen as substantial. The Design Engineer of Company H expressed this as follows:

> *Production molds are really expensive. If there is human error in the prototype design, it is preferable to detect and repair the error in an AM printed prototype, which costs around 1000 Euros. That is cheap compared to what happens if the error occurs in the final production mold. To repair the error in the final production mold is expensive and sometimes even impossible.*

Other benefits mentioned by the experienced-level users were related to new product design and product testing. As AM technology makes it possible to produce realistic prototypes and parts quickly and cost-effectively, new forms and structures can be produced. AM also accelerates functional and field tests, making it possible t0 perform modifications in the early phase, and to shorten product development time. This improves product quality. The Product Manager of Company G explained this as follows:

> *It is possible to present AM printed prototypes to customers, since they look like properly made final products. AM printed prototype products stand up to all kinds of scrutiny. In our case, an AM prototype printed with current plastic material stands up to normal product usage, but is not as durable as the final product under extreme conditions.*

Three experienced-level companies (A, G, and H) utilized AM prototypes for marketing purposes. The companies mentioned the ease of demonstrating sketched products to the customer, due to the fact that an AM prototype allows a genuine feeling for the product, including its form, structure, color, and usage. The experienced-level companies were of the opinion that AM technology can reduce the company's pollutant load and address environmental issues. One professional-level company (E) indicated that AM can facilitate new customer segments.

The Benefits of AM for Customers, and Value-Adding Elements

The noted customer benefits of AM and its value creation potential varied between beginner, experienced and professional levels. Table 4 illustrates AM customer benefits according to the companies researched.

Category	**Customer benefits**
Beginner (B, C, D)	New product solutions with savings in energy consumption, improved machine durability and lifetime, accelerated investment payback time.
Experienced (A, F, G, H)	Cost and timesaving in product concept design, realistic prototypes, reduced mold costs, ease of illustrating the final product or solution.
Professional (E)	Materials information and printing for function or prototype use.

Table 4. AM Customer Benefits

The value-adding elements for customers varied individually among the companies studied. The beginner-level companies' (B, C, and D) noted the potential to produce lighter products, leading to savings in the customer's energy consumption, and improving machine durability for the customer. This would accelerate the customer's investment payback time. AM may also widen the product offering, and enable faster spare part delivery, if spare parts are 3D designed and printed.

The experienced-level companies (A, F, G, and H) indicated cost efficiency and time-saving as the most valued advantages of AM. The design time for a new product concept had been reduced from months to a few weeks, since the prototypes and even molds could be produced directly, moving from 3D images to a final prototype or product part. AM technology allows customers to receive a genuine hands-on feeling for the product, as the AM prototype strongly resembles the final product in form, structure, and texture. In addition, AM makes it possible to produce immaculate prototypes prior to the final production mold. Company H also mentioned the ability to observe the entire interior design including ergonomic aspects, when all the parts are 3D printed, finalized, and assembled as in the final outcome. All these elements improve the quality, and reduce the time and costs for new product development. The Design Engineer of company H explained this as follows:

> *By utilizing AM in product design, we are able to examine the various product design aspects simultaneously. Firstly, the prototype can be installed in its final position with the right size, color, and surface structure. Secondly, we are able to explore and test the functionality of the prototype. In my case it means I am able to test how the armrest affects the seat's rotation and the ergonomics in general. Thirdly, we are able to execute collision tests.*

Impacts of AM on Value Creation

The empirical study indicated that the beginner-level companies (B, C, and D) based their business on one or a few long-term customer relationships (usually with large companies) and that they adapted their business to meet the customer's needs. There was less long-term business planning among these companies than among the larger companies (G and H). However the findings showed beginner-level companies to be interested in exploring AM and its impacts on business and customer value creation. For instance, Company C indicated that it would integrate its customers within the AM development and implementation process if AM technology were to become part of the company's service and life cycle management. By integrating customers within the AM process, the aim would be to share and minimize financial risks, and to explore mutual value possibilities with customers.

The beginner-level companies appreciated the fact that AM opens up the potential to design complicated product forms and to develop customer-tailored products in collaboration with the customers. If AM machines and materials were developed sufficiently, tailored materials could be used in certain machine parts, and it would be possible to offer customer-centric maintenance services irrespective of the manufacturer. In addition AM has the potential to improve the manufacturing process, making it possible to produce small product series or spare parts on demand.

The large companies (G and H) estimated that the utilization of the AM technology would increase within the next five years. They took the view that if AM technology allows the manufacture of products that are impossible with current methods and technologies, new value creation opportunities and new business models will arise. Such new products could be more complex in structure, as well as being lighter and extremely small. In addition, totally new product forms could be designed and produced. The Product Manager of Company G expressed this as follows:

> *In optronics, the aim is to have pieces that are as tiny as possible. In business terms it means we are able to design much more complex forms and structures. We can design and produce smaller and lighter pieces. Honeycomb and cavity structures cannot be produced with current methods. With AM technology this can be achievable.*

The interviewees noted that if various materials can be printed simultaneously, the final products could be produced for use immediately. The interviews also indicated that if there are improvements in AM materials and machine capacity, and if prices fall, AM will enable small-scale serial production and on-demand production. For one experienced-level company (A), AM technology has the potential to open up new customer relations at the global level.

Discussion

The findings in this study indicate that in the context of an AM business network, value exists primarily in customer relations, but additionally in supplier and employee relations. The companies indicated that AM increases company value, since AM prototypes realistically show the final product in terms of form, structure and usage. AM makes it possible to detect design errors at the early design phase; hence the product can be modified and AM prototype test cases run, prior to final production. The time saved with an AM prototype is substantial, and the costs are minute compared to conventional prototype methods. It was estimated that company value would emerge with new customer-tailored products, and by producing AM products for actual use. The companies also emphasized that AM widens the product offering to include both existing and new customer segments. The environmental benefits were also highly valued by the interviewees.

As Rescher (1969) emphasized, values originate from the assumption of a goal-oriented organism which attempts to achieve satisfaction. Customer satisfaction and value were improved when companies used an AM prototype to illustrate the final product to the customers. The AM prototype presents the final product in terms of form, structure and colors, and can withstand normal product use under normal conditions. The AM prototype improves trust and customer satisfaction, and it reduces misunderstandings during product development phases. Both time and costs are saved with AM prototypes, and this improves customer-perceived value. It was also estimated that AM reduces the customer's energy consumption and improves the durability and lifetime of the machines.

Heinonen (2004) proposed that customer value is conceptualized in terms of spatial and temporal values, in addition to technical and functional value elements. The large companies in this study emphasized an interest in acquiring AM services from external service providers, due to a reluctance to invest in their own machines and employees. If SMEs take the role of an AM service provider in an AM ecosystem, they may be able to offer local AM services on demand. For instance, an AM supplier could print a critical spare part locally in just a few hours instead of ordering the spare part through conventional channels. By forming joint ventures, SMEs could share their business risks, improve their AM knowledge, and gain benefits from Economies of One, as suggested by Petrick and Simpson (2013).

The study pointed to demands for additional AM materials, machines, and knowledge of processes. There is an essential role here for educational institutions in accelerating AM technology, given that AM requires totally new skills, with personnel such as digital product designers, materials specialists, and AM processing specialists. As Ojala and Tyrväinen (2011) have emphasized, value occurs not only in customer-seller relationships, but also in business networks. By forming and developing an AM ecosystem in the machine industry it may be possible to detect not only direct value but also indirect value, as noted by Ojala and Helander (2014). For SMEs in particular, belonging to AM ecosystem might provide an entry to new customer segments and markets. In this context, one can suggest that business owners in the machine industry have possibilities for redefining, reinterpreting, and re-describing their stakeholders' interests, and for discovering opportunities for direct and indirect value creation.

Conclusions

This study contributes to IS and value creation research in the context of AM technology in a number of ways. Firstly, although previous literature has examined AM from a technical perspective and in the context of a variety of industries, the present study focused on this topic from the perspective of value creation and networks. Secondly, the findings in this study provide detailed knowledge on how AM technology might increase perceived value via time and cost savings. All in all, it appears that AM shortens the time needed for conventional product design and production, enhancing the overall production cycle. Furthermore, AM has the potential for value creation, not only among current suppliers, but broadening outwards to new partners and customers. Here it is worth noting that although there has already been extensive discussion of value creation in the broader sense (Allee 2000; Ojala and Helander 2014; Walter et al. 2001) and of AM technology (Chimento et al. 2011; Michaleris 2014), value creation in the context of AM has been underrepresented in IS literature. Thirdly, this study incorporates stakeholder theory and the literature on value creation, seeking thus to extend IS research by conceptualizing value creation and value networks in the context of AM.

As a limitation, it will be noted that the case companies and the interviewees formed a somewhat heterogeneous group of AM adopters from a single country, i.e. Finland. The study included both SMEs and large companies, with considerable variation in the AM technology adoption and knowledge of those concerned. In addition, the interviewees' roles in the organizations varied, with resulting differences in viewpoints. These aspects should all be taken into the consideration in evaluating the results of this study. In further research, one could aim at more in-depth studies, observing and comparing companies that benefit from AM technology, and possible barriers of AM usage. This would provide fascinating insights on the differences in value creation and boundary spanning role of AM (Carlile 2002). It should also be noted that customers formed the main stakeholder group in this study, and that the role of other possible stakeholders was not so visible. Thus, the findings of this study would usefully be extended to cover the possible role of other stakeholder groups.

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