CUSTOMER ENGAGEMENT AND VALUE CREATION IN AM SUPPLY CHAINS

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Introduction

Recent developments in Additive Manufacturing technology have received increasing attention. Several authors have reported the potential of Additive Manufacturing (AM) in transforming the global supply chains (see e.g. Oettmeier and Hofmann, 2016; Fawcett and Waller, 2014; Despeisse et al. 2016). AM has been characterized as the third industrial revolution which illustrates the potential it is considered to have, not only to the product manufacturing but to the design and supply chain as well (The Economist, 2012). With AM the supply chains have better potential to access and respond to the end value demand by cutting out much of the traditional chain (Laplume et al., 2015). It is thus clear, that AM will change the way we produce value in the supply chains, and in order to capture the potential the technology holds, the roles and structures of the networks have to be reshaped accordingly.

While AM has gained the attention of many scholars and practitioners in different fields, the more recent studies have started to underline the gaps in the AM research. The technical and implementation aspects of the technology have received much of the attention of the previous research, however for example the lack of knowledge in the network and value perspectives of AM has been noticed (see e.g. Hämäläinen and Ojala, 2016; Christopher and Ryals, 2016). This is important especially, as many entrepreneurs are still struggling how to utilise this disruptive innovation technology in their business models and networks (Laplume et al. 2015). In addition, the consumer perspective of value creation has been mostly neglected. Considering the AM technology is estimated to shift the supply chain power to the customers side the perspective is of importance.

One of the most rapid growing trends is personalized manufacturing or desktop 3D printing with privately owned printer (The Economist, 2012; Blua, 2013). This trend has been increasing as the price of the printers have fallen to a fraction of the previous years. Currently a personal 3D printer can be purchased with just few hundred EUR (Laplume et al. 2015). The potential for printing complex and 3D products has become economically and technically viable which has enabled individuals not only to manufacture, but also design the products themselves (DeVor et al. 2012). In addition to this, open access services have enabled different stakeholders to share their design ideas and AM models online. These products include for example toys, tools or different kinds of prototypes (Pearce et al. 2010; Sells et al. 2010). As the manufacturing and designing of different products is available for a vast network online the companies have to find new ways to reach the customer where the understanding of value production is crucial.

Based on above discussion the main aim of this paper is to study the value creation process in open access manufacturing service network. In doing this our main contribution is two-fold: Firstly, we aim to illustrate the formation of value in open access additive manufacturing supply chains by synthesizing the theories from service and value research with supply chain management, and develop a framework which illustrates the customer engagement in creating different natures of value. Secondly, the empirical part of this study provides understanding on what type of products are currently printed with personal 3D printers. The proposed framework is applied to illustrate the different natures of co-created value in case of some representative product examples.

Theoretical Background

By design, the conventional supply chain system is designed to focus and compete mostly in terms of costs and time. With additive manufacturing the principles of mass customization can be utilised where the focus will shift towards the end customer demand and needs. With additive manufacturing the supply chains will become more local and the focus will be more in satisfying the end-user needs through value co-creation.

When considering the additive manufacturing from supply chain perspective, it becomes clear that there is only a sparse literature covering the subject. Overall, the research on AM can be divided into seven different streams of focus (adapted from Oettmeier and Hoffner, 2016): (1) Focus on outlining the current state-of-the-art in AM and its applications (e.g. Bak, 2003; Berman, 2012), (2) focus on developing materials or technologies (e.g. Murr et al., 2012; Janaki Ram et al., 2006), (3) focus on adoption of AM (e.g. Arvanitis and Hollenstein, 2001; Oettmeier and Hofmann, 2016), (4) focus on the costs of AM (e.g. Hopkinson and Dickens, 2003; Ruffo et al., 2006), (5) focus on the implementation of AM and make-or-buy decisions (Mellor et al., 2014; Ruffo et al., 2007), (6) focus on addressing AM in the context of SCM (e.g. Holmström et al., 2010; Khajavi et al., 2014; Nyman and Sarlin, 2014). Where most of the SCM focus has been directed on the impact of AM in spare part supply chain context. While many of the studies mention value of applying AM, only a few of the studies properly address the issue of how value is created through the technology.

By its nature the AM value creation in the supply chain can be considered closer to the nature of service value rather than traditional manufacturing. Overall the service supply chain perspective has been identified and discussed by several scholars, the specifics of their management, and how value is created in the supply chains has been addressed by relatively few (e.g., Vilko and Ritala, 2014; Arlbjørn et al., 2011) and can be considered unexplored in many ways. While the focus on the few existing studies on service supply chains has been in applying the existing traditional manufacturing frameworks in service context the feasibility of those has been considered poor (Vilko and Ritala, 2014; Cook et al., 2002). The benefits that service supply chain management include better coordination of processes, improved performance through process integration, and improvement of the customer interface (Giannakis, 2011) which are essential elements in customer value creation with AM as well, and illustrate the need for research in this area.

Still, several authors have identified the importance of looking at the bigger picture in how AM will impact the supply chain designs (see e.g. Mellor et al. 2014; Khajavi et al. 2014; Vilko et al. 2014; Rogers et al. 2016). Fawcett and Waller (2014) identified four different domains where AM is having an impact: New product development, spare parts management, inventing and customer shopping behavior. This illustrates the wideness of impact that the AM technique has over supply chains. According to Jones Lang Lasalle (2014) there are six major benefits that additive manufacturing provides for the supply chain, namely: Shorter lead times, customized production, better pull effect by the end customer, localized production, lower transportation cost and lower carbon foot print. Still, some professionals have seen AM's ability to transform supply chains in years away still (see e.g. Banker, 2014)

From supply chain management perspective, the implementation of AM will require changes in roles and in value creation philosophies as the supply chains will have to become more aware of the end customer demand and needs and enable the customer involvement in the supply chain from design all the way to the actual manufacturing process. Therefore, the power in the supply chain will shift towards the customer demand side, and the upper stream value actors will have to adjust their offering accordingly (Christopher and Ryels, 2016).

Creating value in customer engaging AM supply chains

By its nature the AM value creation in the supply chain can be considered closer to the nature of service value rather than traditional manufacturing. Therefore, understanding customer value in AM contexts calls for applying a service logic (Grönroos, 2011) or service-dominant logic (Vargo and Lusch, 2004). In supply chain management literature, the perspective accounting for these issues is the service supply chain. This perspective has been identified and discussed by several scholars, the specifics of their management, and how value is created in the supply chains has been addressed by relatively few (e.g., Vilko and Ritala, 2014; Arlbjørn et al., 2011) and can be considered unexplored in many ways. While the focus on the few existing studies on service supply chains has been in applying the existing traditional manufacturing frameworks in service context the feasibility of those has been considered poor (Vilko and Ritala, 2014; Cook et al., 2002). The benefits that service supply chain management include better coordination of processes, improved performance through process integration, and improvement of the customer interface (Giannakis, 2011) which are essential elements in customer value creation with AM as well, and illustrate the need for research in this area.

By their nature customer value and value propositions are very complex phenomena, and there is no broad-based definition available (Anderson et al., 2006). To gain insight into the distinctive features of value in AM supply chain context, we refer to categorization introduced by Rintamäki et al. (2007) and Talonen et al. (2016), where customer value is divided into four categories: 1) economic, 2) functional, 3) emotional (and experimental) and 4) symbolic (and social). Each value proposition pursues to create value to the customer in one or several of these areas. Economic value refers to the financial benefits that can be offered to the customer. Functional value is the actual service, which helps to solve a concrete problem, e.g. moving products to one place to another. Emotional value refers to the feelings such as convenience, entertainment or feeling of safety. Finally, symbolic value refers to social status, respect and identity

Similarly to services, in AM supply chains the value creation process becomes more complex when compared to dyad-level analysis between provider and customer. While the functional and economic value creation has been seen as very difficult issue to handle in complicated, multiparty logistics services, the issue is even more pronounced when it comes to emotional and symbolic value.

Customer engaging value creation in AM networks
Customer engagement in value co-creation refers to the customer provision of resources, that occur in interaction with the focal firm and/or other stakeholders, thereby affecting their respective value creation and outcomes (adapted from Jaakkola and Alexander, 2014). The customer engagement in value creation have been adopted from Jaakkola and Alexander (2014) to four different ways of contribution, namely: 1) Augmental, which refers to the customer contributions of resources such as knowledge, skills, labor, and time, to directly augment and add to the value network's offering beyond the basic level of value. 2) Codeveloping, which means, which refers to the customer contributions of resources such as knowledge, skills, and time, to facilitate the value network's development of its offering. 3) Influental/Defining which refers to customer contributions of resources such as knowledge, experience, and time, to impact other actors' perceptions, preferences, or knowledge regarding the network's offering of value and 4) Mobilizational customer contributions of resources, such as relationships and time, to mobilize other stakeholders' actions toward the network's offering of value.

By synthesising on the previous research we connect the natures of customer value with the natures of customer engagement in the value creation process in supply network context.

		Functional	Economic	Emotional and Experiental	Symbolic and Social
Nature of customer engagement in supply chain value creation	Augmental	Knowledge, skills, labor and/or time augment and add to the networks offering beyond the basic level of functional value	Knowledge, skills, labor and/or time to augment and add to the networks offering beyond the basic level of economic value	Knowledge, skills, labor and/or time to augment and add to the networks offering beyond the basic level of emotional and experiential value	Knowledge, skills, labor and/or time to augment and add to the networks offering beyond the basic level of symbolic and social value
	Codeveloping	Knowledge, skills, and time facilitate the supply networks development of its offering of functional value	Knowledge, skills, and time facilitate the supply networks development of its offering of economic value	Knowledge, skills, and time facilitate the supply networks development of its offering of emotional and experimental value	Knowledge, skills, and time facilitate the supply networks development of its offering of symbolic and social value

	Influential /Defining	Knowledge, experience, and time affect other actors' perceptions, preferences, or knowledge regarding the supply network's offering of functional value	Knowledge, experience, and time affect other actors' perceptions, preferences, or knowledge regarding the supply network's offering of economic value	Knowledge, experience, and time affect other actors' perceptions, preferences, or knowledge regarding the supply network's offering of emotional and Experiential value	Knowledge, experience, and time affect other actors' perceptions, preferences, or knowledge regarding the supply network's offering of Symbolic and Social value
	Mobilizational	Relationships and time mobilize other stakeholders' actions toward the supply network's offering of functional value	Relationships and time mobilize other stakeholders' actions toward the supply network's offering of economic value	Relationships and time mobilize other stakeholders' actions toward the supply network's offering of emotional and experiential value	Relationships and time mobilize other stakeholders' actions toward the supply network's offering of symbolic and social value

Table 1. Customer contributions of different resources to create value in the network

Research Design

The focus of our study was to discover the customer engaging value creation process of the open access additive manufacturing service supply chains. Given the limited amount of research on the subject we chose the explorative case study as our research approach (Yin, 1994). The case study form was seen to work well in serving the information-oriented focus of the research and discovering causalities of the phenomenon (Jensen and Rodgers, 2001; Yin, 1994). The study is based on the integrated literature review of AM, value, service and supply chain perspectives as well as primary data collected from the additive manufacturing service provider Thingiverse data base.

The research was conducted in a four-step research process (see Figure below): Firstly, the identification and forming of the research problem was done based on the experiences of the additive manufacturing technology researchers and a cross-section of the scientific and managerial literature was screened to validate the identified gap both in scholarly discussion and managerial relevance. Secondly, an integrated literature review was conducted and relevant case data was collected from the Thingiverse online open access service. The Thingiverse service provider was contacted to inform about the research interest and to validate the relevancy of the case and information collected. Thirdly, based on the synthesis of relevant sources, a theoretical framework was developed and finally applied in the fourth step to illustrate the customer engaging value creation in open access AM service network.

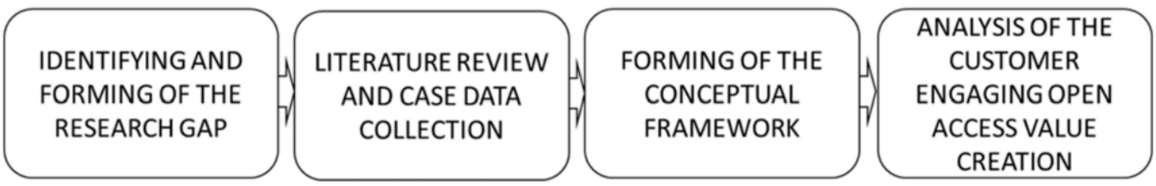

Figure 1. Research process

Case

The empirical case research data component comprises an analysis of metadata collected from design files hosted by Thingiverse, which reveal the content and scale of supply and use of free AM designs. Thingiverse is one of the most well-known file repositories available for the semi-public distribution of files for use in 3D printers. Thingiverse was selected as a case study due to the information value and relevance as a leading position in the field. In addition the service had an application programming interface (API) that allowed to collect the relevant case data.

The leading online service in open access AM is Thingiverse (owned by MakerBot). In a reasonably short time Thingiverse has become the leading repository of user-submitted design files and holds the world's largest online 3D printing community. Unlike in some other platforms serving similar purpose, all designs are free to upload and download. Its commercial function for MakerBot is to add value to printer sales by offering a free and easy way for users to find designs they can print off at home. Moilanen et al. (2014)
Thingiverse offers an application for customizing the designs. If the user uses OpenSCAD program for modelling, the design can be made customizable. Then specified desing parameters, can be selected according to users need. Customizing a Thing takes a couple of minutes, and users can publish their customized objects for other users as new Things. A clear preference for printing 3D printer parts indicates that personal 3D printing is still in its early steps and hobbyists are tuning their printers with printed parts.

The case example of a 3D-printable product, namely a *Customizable 3D printer belt clip (see figure 2)* was selected based on its popularity and tags received. Such belt clip can be used for closing a toothed belt loop e.g. when replacing a broken toothed belt. Typically, toothed belts are used in printers to transmit power to the printer heads. The below Table 2 illustrates the feasibility of the framework combining the perspectives of natures of customer value and engagement.

		Functional	Economic	Emotional and Experiential	Symbolic and Social
Nature of customer engagement in supply chain value creation	Augmental	Customers design adds value of toothed belts by offering an attachment method.	Customers design offers an economic way to produce a special spare part.	A convenient part designed by customer can get positive feedback from other users about the design	The customer increases the visibility of his/her "personal brand" as a designer.
	Codeveloping	Other customers test, comment and thereby help in introducing a new spare part designed by a customer.	Other customers' experience sharing may save time when selecting a replacement method for a printer part.	Customers may feel fellowship when sharing experiences of repair work.	The customer designing the part may gain visibility as a potential co-operator of equipment manufacturers.
	Influential /Defining	Customers design enhances know-how on replacing broken printer parts.	Using a customer-designed belt clip to close a belt instead of using a belt loop may offer economic benefit	Being able to replace a broken belt may cause users feel happy	Availability of spare parts increases the sustainability of products. Sustainability may belong to customers' personal values.

	Mobilizational	Customers design may serve as an inspiration to other users to design and share more spare parts.	Greater selection of 3D-printable accessories provided by customers increases the cost-benefit ratio of a personal 3D printer purchase	The experience sharing of other customers may inspire other users to participate in experience sharing.	The availability of spare parts may inspire customers to prefer sustainable purchasing in general.

Table 2. Case illustrations of customer contributions to create value in open access AM value network

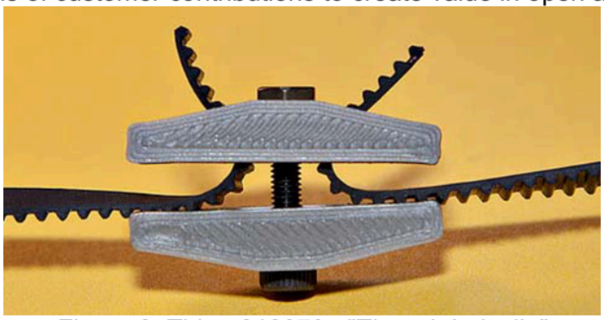
Figure 2: Thing 212873: "Though belt clip"

Discussion and Conclusions

The importance of collaborative service value creation is increasing in importance as additive manufacturing allows more flexible and dynamic supply chain models. Through the additive manufacturing technologies development, customer role in value co-creation is gaining more relevance. To our knowledge this article makes the first attempt to conceptualize the connection between the nature and customer engagement of service value in open access additive manufacturing context. The value of our research is both in instigating discussion of the unexplored research gap and furthermore to propose a framework to illustrate the creation and structure of customer engaging value creation.

Theoretical implications

The current contributions on uncertainty in additive manufacturing value creation are still quite scarce, and only a few scholars have studied the phenomenon. So far the research, the research has concentrated mainly on the technical aspects of AM and only narrow body of scientific literature has taken into account the supply chain side for example. Several authors have identifies the need for further research in this field, and this is the gap at which the core contribution of this study aims. There is, however, some work that comes close to our aims here. For example, in the demand chain context, Christopher and Ryals (2016) underline the need for a better understanding of AM, and approach the issue from demand chain management perspective. Similarly, we analyse the customer perspective in the value management domain from the perspective of the customer engagement, and we concentrate on the different ways of customer contributions to value creation and how those contribute to different natures of value.

In building our argument, we have combined theories of service value and marketing (Jaakkola and Alexander, 2014; Rintamäki et al. 2011; Vilko and Ritala, 2016) in the context of additive manufacturing value network. The ways of customer contribution to value creation presented in the developed framework were augmenting, codeveloping, influencing/defining and mobilizing. The classification presented here facilitates is connected with the different natures of customer value which enables deeper exploration of the concept and its implications.

Our framework for customer engaged value creation contributes to the existing literature in two distinct ways. First, it illustrates the different natures of value and therefore enhances understanding of the structure of the customer value. This could help researchers in the field to better assess the value creation in additive manufacturing service networks, and thus make recommendations in how customer value should be managed. Complementing on the previous literature in additive manufacturing and building on the existing knowledge from the service management and value management fields, our research work takes a step in explicating the customer role in creating value in service network. The illustrated case of open access additive manufacturing service is to our knowledge first contribution in the service value network field. Our study carries implications for decision making in developing value offering in the network and how the roles of creating value will change via additive manufacturing technology.

Practical implications

The results of this study enhance the practitioner's understanding about the different roles and possibilities that the open access additive manufacturing services can bring. In addition, the empirical part of this study identified some fields that are primarily facing the phenomenon of open source AM innovation (e.g. 3D printers, R/C Vehicles, mobile phone accessories). The results imply that open source AM innovation currently concerns mainly special hobbyist groups, but still is inevitably a grooving phenomenon.

Limitations and suggestions for future

The most obvious limitation is in the conceptual nature of the study. There is a need for further empirical studies, as well as for the further refinement of the analysis framework from several viewpoints.

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