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Redefining SME Cooperation to Foster a Value-Creation-Oriented Approach and Propel Forward Cutting-Edge AM Services in the Medical Market

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ABSTRACT

This paper depicts the value-creation-oriented approach of a German SME in the field of additive manufacturing (AM) to find its role and establish itself as reliable and valuable player within new multi-actor alliances with the aim of positioning innovative customized products in the medical market. For this purpose, three different use cases are considered for analysis: 3D-printed phantoms as visual models, realistic organ phantoms for the surgical training of surgeons, and orthoses and prosthetic devices. For the SME, the decision to move into a new market involves a significant effort as well as certain risks. To make a well-founded decision regarding its own positioning, it is therefore important to know the respective value creation systems within new emerging business models. In the following, considerations and findings regarding the potential of these business ideas are outlined, and first steps towards a formal modelling of service-oriented value creation are presented.

Keywords: Service-oriented value creation, Modelling, Additive manufacturing, Cutting-edge innovation, Medical field, 3D-printed phantoms, Orthoses, Prostheses

INTRODUCTION

It has been observed for some time that manufacturing companies are increasingly evolving from product manufacturers to service and solution providers (Baines et al, 2009). This transformation process is driven by the desire of companies to better meet customer needs and at the same time gain a competitive advantage by creating bundles of products and services that are not easily copied (Böhmann et al. 2013, Bruhn & Hadwich, 2019). The growing importance of services corresponds to a general paradigm shift in the service marketing literature, the service-dominant logic, according to which value creation is no longer seen primarily as the result of the production or refinement of material goods, but rather as the co-creation of value that occurs when suppliers and customers integrate their respective resources and which is realized at the moment a good or service is used (Vargo & Lusch, 2004). The move towards service-oriented value creation is accompanied by the fact that service provision is increasingly taking place across industry boundaries. Traditional value chains are being complemented by multi-actor constellations in which loosely connected actors collaborate to fulfill a common value proposition (Vargo, 2012, Lusch & Nambisian, 2015, Vargo & Lusch, 2016). A key driver is the increasing digital interconnectedness of products and processes, which enables new forms of collaboration.

Value creation in networks or ecosystems is complex. It always takes place in an area of tension between cooperation and competition. Cooperation is necessary in order to achieve common goals, while competition arises with regard to performance contributions and the sharing of profits (Bruhn & Hadwich, 2019). Ideally, the actors involved share the same rules and norms and are characterized by a high willingness to contribute their resources in the expected way. Otherwise, the result can be value diminution or value co-destruction (Vafeas et al. 2016, Mustak & Plé, 2020). Aligning and orchestrating the performance contributions of all partners thus becomes a critical success factor (Tombeil & Nägele, 2022).

Against this backdrop, companies looking to reposition themselves in the market face the challenge of understanding existing or emerging ecosystems and finding a role where they can bring their resources and capabilities to bear in the most efficient and profitable way (Müller-Stewens & Lechner 2016, Heuskel, 1999). They face questions such as:

- Who are the players in the ecosystem in question and what is the relationship between them?
- What resources do they bring to the table and what benefits can they derive from the collaboration?
- What do the processes look like and which actors are involved in which process steps?
- Are there customer needs not being adequately addressed by existing players?
- Which products or services can be used to create added value for customers?
- How is the network orchestrated and who needs to be approached to gain access to the network?
- What are the costs and risks associated to the collaboration and market entry?

Answering these questions requires extensive analysis and many discussions with stakeholders. Insights and business ideas must be documented in a comprehensible manner. A common method for the compact representation of value propositions and business models based on them are business model frameworks such as the Business Model Canvas (Osterwalder & Pigneur, 2010), the Lean Canvas (Maurya, 2012) or the Business Model Navigator (Gassmann et al. 2016), to name just a few. These frameworks enable a compact description of business models from the perspective of the main supplier. At their core, they comprise three elements: value proposition, value creation, and value capturing. A few frameworks aim at mapping business models of collaborating partners, such as the Business Model Co-Creator (Schletz &

Tombeil, 2018) or the Service-dominant Business Model Radar (Gilsing et al. 2018). However, what all these frameworks have in common is that they only support a qualitative description of business model elements. An optimization or simulation of different business model alternatives in multi-actor constellations is thus not possible. For this, a formal mathematical modelling of the value creation system is required. Such a method is being developed in the research project from which the following case study originates. However, this work is only in the early stages, so that the modelling method could not yet be applied to the full extent in the use cases described below.

ENTERING THE MEDICAL MARKET WITH CUTTING-EDGE ADDITIVE MANUFACTURING SERVICES

The above-mentioned factors set the foundation for a wider research project in which the SME participates. It aims to explore and exploit new methods and procedures to model and simulate various value creation systems in order to support the strategic and operative decision-making in the context of the SME's reality. This paper shares the early stages of the ongoing research and provides an insight into the approaches and challenges faced by an additive manufacturing SME seeking to enter new service ecosystems in which it has not previously operated.

Additive manufacturing technologies and thus the AM-market keeps continuously developing and is quite dynamic. The spectrum of available printers, printing technologies and materials, as well as its different combinations, is steadily developing enabling a vast range of applications. On the other hand, the AM-production prices have been falling constantly making AM more and more competitive with classic manufacturing technologies. In this context, a growing market resulted in an increasing number of competitors in the AM-service provider field, putting pressure on the margins.

Cirp GmbH is a German SME whose expertise relies on the processing of polymers with diverse additive manufacturing techniques. In order to create a connection between the market demands in the industry and the latest breakthrough technologies, the company has participated in multiple funded research activities addressing diverse areas of application. This enables the SME to push the boundaries of additive manufacturing and improve not just the materials and processes, but also the knowledge on polymer processing and, therefore, its own products.

Motivation of the Company to Explore New Markets

As stated by the Organisation for Economic Co-operation and Development (OECD) in 2008, "in order to stay competitive, SMEs must constantly improve their skills not only in regard to science and technology but also in the management of technology and knowledge of the market and its evolution".

In recent years, cirp has been investigating different market segments within the medical realm. Personalized medicine has gained relevance and that is where AM offers a significant potential: because every human is different, bespoke production seems to be made for this field. The latest industry report has estimated the global healthcare 3D-printing market to grow at a CAGR of 18% in the next five years (Market Data Forecast, 2022:13).

Cirp has increased its expertise in various areas of additive manufacturing through research over the years and does not want to be considered just as an extended workbench for its clients and customers. In this regard, the SME addresses the need to reposition itself driven by an underlying interest of changing the dependence on the existing traditional supply chain structures; and has acknowledged the necessity of collaborating across boundaries with specialist of diverse fields to foster a value-creation-oriented approach. However, expanding the business opportunities in a multi-actor collaboration framework entails certain challenges and risks regarding on the one hand the legal and technical requirements of the industry and the products; and on the other hand, the regulation of the economic claims and roles of the actors involved.

The aim is to create a new value-creation-oriented approach to find its new role and establish itself as valuable player within new multi-actor alliances to position innovative customized products in the medical market: 3D printed organ phantoms, and orthoses and prostheses.

Market Options Analysis and Evaluation

One sector that the SME has been investigating within the medical realm is the use of the cutting-edge organ phantoms as visual models and for the training of surgeons and medical specialists. Of these two options, the latter is a new field of application of additive manufacturing for which there is not yet an established market. Another potential new business area being explored by cirp is the 3D printing of orthoses and prosthetic devices. Figure 1 shows two products of the used cases below described.

3D-Printed Organ Phantoms

Nowadays, the rapid development of medical visualization technologies enables the depiction of bespoke pathologies. The data generated from different medical imaging methods such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), if properly processed, can be used to recreate

Figure 1: Left: realistic liver phantom (hybrid: 3D-printing/collagen cast) with sensor integration (cirp GmbH for VIVATOP project). Right: SLS 3D-printed prosthesis (cirp GmbH, ©Fraunhofer IPA).

patient-specific 3D-printed models of organs to be used as visual aid for the planning of surgical procedures as well as for training purposes.

AM-technology offers a wide range of design possibilities to print organ models in different sizes, colours, and hardness levels. Combined with augmented reality (AR) and virtual reality (VR) tools, for example, 3D-printed organ models provide the haptic feedback these technologies are lacking (Reinschluessel et al., 2019). As Nopper et al. (2022:2) points out, mutual understanding between designers and doctors and comprehending the objective for which the visual phantom will be used is crucial for choosing the proper AM-process and design, as well as to ensure that the 3D-printed model fulfils its purpose.

In discussions with experts from the field regarding possible applications of 3D-printed organ models for surgical training, cirp was able to identify the following advantages of organ phantoms over classic cadaver-based biological models:

- The use of 3D-printed models does not arise ethical concerns and the replacement of cadavers is ethically desirable (3Rs)
- Representation of bespoke pathologies becomes possible
- Standardisation of training leads to comparability and accessibility
- Sensor integration is possible.

The latter renders an integration of the phantoms into an interactive training scenario possible, opening a new paradigm of surgical training. After this initial potential assessment, a new service-oriented form of value creation for surgical trainings was further investigated, since realistic organ phantoms for training find multiple fields of application. Key-customers for realistic training phantoms are university clinics and external surgical training providers. Whereas training within clinics is funded internally, manufacturers of medical devices fund a vast majority of specific surgical training courses. cirp attended diverse surgery training workshops and interviewed surgeons of different specialties and physicians. The key findings are summarized in Figure 2. The graphic deciphers the synergies and co-dependences between actors, and identifies key resources, activities and financial flows involved in the current training scenario. It provides as well insights into the actors' motivational drivers to participate in this specific value-creation system.

Neurosurgery was one of the first options evaluated in detail: about 20% of the 2500 neurosurgeons practicing in Germany are doctors in training (Bundesärtzekammer Ärztestatistik, 2020), meaning that ca. 500 specialists have to participate in surgical training programs in the clinics. The initial research showed that the surgical trainings are divided in 3 different difficulty levels leading up to about 1500 trainings requiring phantoms every year. This number does not consider other training courses conducted by external providers in Germany.

Producing an innovative 3D-printed phantom is one of the strengths of cirp. However, the development towards service-oriented value creation can prosper if the company succeeds in integrating itself into the value chains where relevant key partners incorporate their services and resources

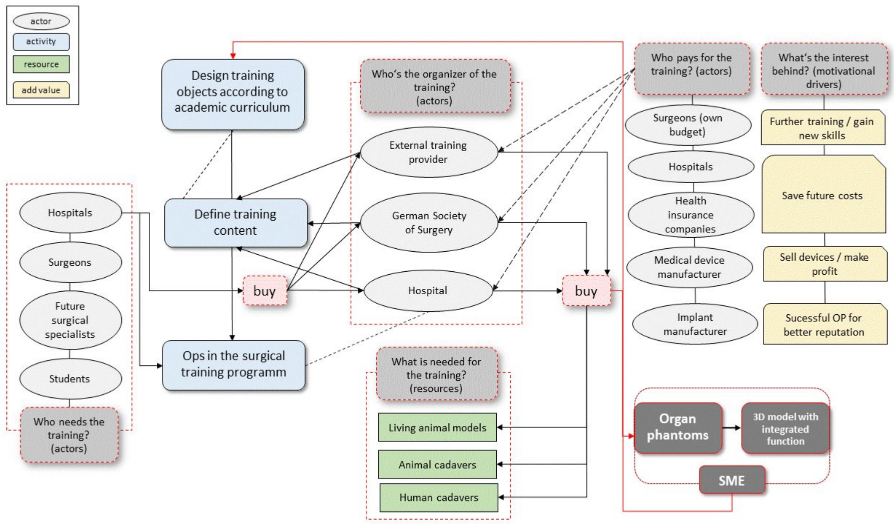

Figure 2: Analysis of the existing training scenario in Germany by cirp GmbH.

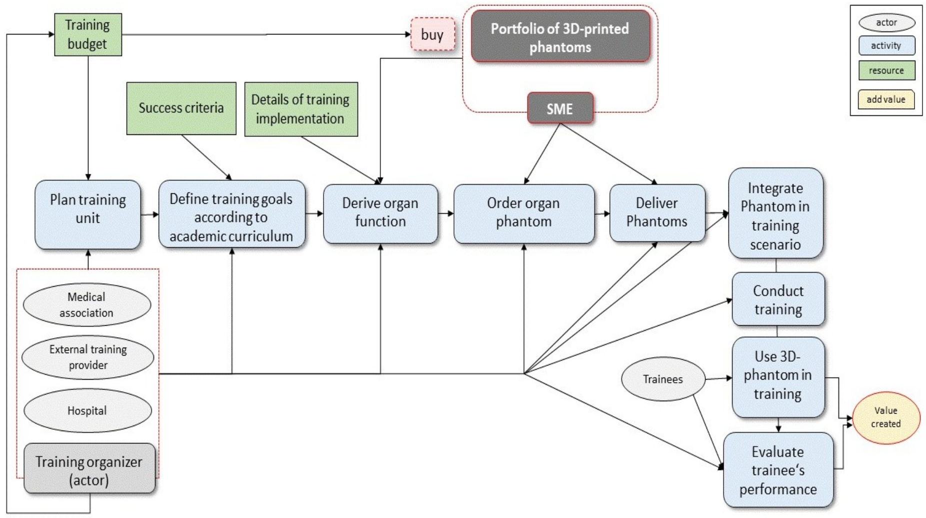

Figure 3: Model of a possible value chain where 3D-printed phantoms are used for value-creation.

in support of the core product (Figure 3). On the other hand, informing and advising the training provider about emerging opportunities in additive manufacturing regarding organ phantoms could become an important new part of the company's services.

The market segment for 3D-printed visual models for surgical planning proved to be challenging in terms of viability at a very early stage. As soon as a medical product deals with personal medical data and has a direct impact on the patient's treatment and, therefore, has a clinical outcome, the legal framework and existing regulations for medical devices set high demanding standards to the processes and certifications. Complying with these regulations result in extensive costs that set high barriers to the market entry. For this reason, the SME focused the research on the 3D-printed models for training purposes. The large dependence on the clinical know-how and the high-cost for a market entry, due to certification issues, are relative to a comparably easy-to-access manufacturing and design know-how for the visual phantom.

3D-Printed Orthoses and Prosthetic Devices

In orthopaedic technology, manufacturing has always been the core of the service and is to a large extent associated with manual labour and skilled craftsmanship. Additive manufacturing technology matches bespoke manufacturing process perfectly, thus experienced herein a huge growth. This is supported by the fact that digital scanning methods are faster and more convenient than classic methods like plaster moulds or similar. The AM-inherent possibilities of function integration further intensify this trend, as complex prostheses integrate more and more complex electronic and mechanical features. This technical tornado rearranged the market, forcing many players like the orthopaedics and health care supply stores to adapt new technologies and to engage into multi-actor alliances.

Within the framework of a market development program of the Federal Ministry for Economic Affairs and Climate Action (BMWi), the Swiss German Chamber of Commerce (2021:02) concluded that “the market for medical technology is a global growth market with a high rate of innovation”. It confirms that the area of orthopaedics is the strongest in the world market for medical technology (12%) followed by the minimally invasive medicine (10.4%). It also estimates that orthopaedics belongs to one of the most innovative research sectors in Germany (2021:5). cirp conducted a first market sounding and talked to experts at various trade fairs to understand not just the roles of the other participants involved, but also the transfer mechanisms within the complex structures of an already established business ecosystem. Figure 4 depicts the key players within in the area of orthoses and prosthetic devices (OT-market) and the processes and technical requirements involved. It also represents potential new partnerships for the SME and the resulting added value.

Mastery of the whole value-creation chain renders practically impossible for smaller players, whereas bigger players try to be in control of the most deciding fractions. Starting from the 3D-printing and scanning hardware and manufacturing know-how to the appropriate software solutions, the value chain is quite fragmented. On the other hand, the design of prostheses itself remains a central part. Nevertheless, the direct contact to the customer remains key, putting orthopaedics in a strategic position and serving those stores with AM-services is the key-objective of cirp. Further goals of the SME to reach a unique selling proposal include positioning itself with a distinctive service in this market landscape and going beyond the status of a pure manufacturing provider. Otherwise, the SME risks to get under margin pressure from the various competitors. In the next steps of the research project, a questionnaire to carry out expert interviews with key market players

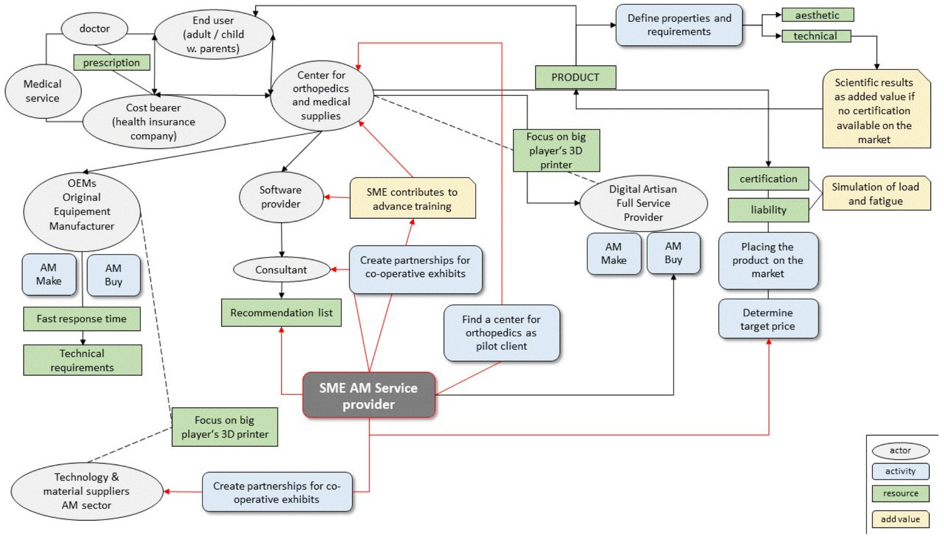

Figure 4: Analysis of the market segment for orthoses and prosthetic devices in Germany by cirp GmbH.

within the sector will be developed in order to find clusters of interest and gather relevant information to build up the multi-actor skills of the SME on the path to reposition itself and establish new forms of value creation. Apart from building up reputation through reliability, quality and service speed, extended consulting services for the stores are being considered. Building up specific unique software-based expertise within the value chain could be here beneficial. Simulation expertise of load and fatigue of AM-lattices gained on another research project conducted by the SME could come into play and add value to its products.

Liability considerations play an important role within the market segment. This is even more, as the main funding body of the products are the assurances, where safety considerations are a major issue within the approval process. Regarding the structure of this market segment, incorporating workshops focusing on the 3D-printing technology for orthopaedic centres as a new service of the SME would represent an added-value to the process.

CONCLUSION

Due to the technological progress and the digital transformation in the last decades, the increased competition in an interconnected, global economy has led to new business ecosystems where service-oriented forms of value creation are gaining ground.

The use of organ phantoms opens a new paradigm of surgical training. Integrated in a broader training scenario, interactive 3D-printed organ models offer unprecedented training possibilities featuring bespoke pathologies and the possibility of creating equitable training units in which all participants have equal opportunities to train their skills. The value of the training is equally quantifiable and would not need to be adapted to the availability of resources, being all trainees equally assessed by identical performance measures. The benefits of this multi-actor collaboration would cover a need that is challenging to address with the given actual resources: training becomes repeatable, comparable and quantifiable. Despite their numerous advantages, elaborate 3D-printed phantoms must justify their higher price against animal cadavers, which are often available at convenient costs. The use of organ phantoms requires a higher investment. Furthermore, the complex the 3D-phantom is, the higher are the time to market and the risk involved.

The SME's examinations lead to think that AM will have an important role within the OT-market in the next years. Whether the added value provided by special software know-how can be a decisive factor for cirp within the multi-actor landscape needs to be modulated in the next steps. New approaches to other key players in this market to discuss possible partnerships and further services to expand the role of the SME need to be examined and discussed.

Understanding how the actors are interconnected in both emerging business ecosystems and their constraints is still challenging. Within the framework of the research project that is being conducted, gaining access to the existing network has proved to be difficult, particularly in the organ phantom market. Further research is needed to find key pillars that could foster and help establishing a solid multi-actor collaboration framework for this emerging market segment. The development of formal models and the simulation of different value creation constellations and processes foreseen in the next stages of the research project will be a valuable contribution to support the strategic and operative decision-making in the context of the SME's reality.

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