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Preliminary communication

Transformation towards Sustainable Business Models in Production: A Case Study of a 3D Printer Manufacturer

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Abstract: A global transformation from Industry 4.0 towards Industry 5.0 will soon take place. Such transformations are intrinsic to human and sustainable value creation. An increasing number of companies, recognising this imminent trend, will need to transform their current classical, solely profit-oriented business models into sustainable business models that also target human, social, and environmental aspects. Various frameworks already exist that support the design of sustainable business models. Practical applications of these frameworks and research on the transformation process in the production domain, which places a special focus on small and medium enterprises, is still scarce. This paper presents the first results from a sustainable business model transformation project on a European SME, which produces 3D printers. The research method applies a single case study design. The study was based on publicly available information and qualitative data, obtained through interviews and workshops carried out on an executive management level.

Keywords: 3D printing; business model; production; SME; sustainability

1 INTRODUCTION

A global transformation from Industry 4.0 towards Industry 5.0 will soon take place. Drivers for this transformation include the rapidly growing and changing digital technologies, the necessity to increase productivity, and the need for sustainable value creation. Pioneers and leaders in the industry are already trying to prepare for this transformation by working on solutions to increase sustainability. [1]

Sustainability includes the creation of social and environmental values, as well as economic values [2]. This transformation is also relevant to small and medium-sized enterprises (SMEs), which play an important role in industry throughout Europe, particularly in Austria, where 99.6% of all companies belong to this category [3]. Many companies have realised this trend and are adapting their strategies accordingly. To support these strategies, enabling companies to achieve more sustainability, this study was conducted to target the business model level, at which the fundamental logic of the company is determined [4, 5]. Companies will need to transform their current classical, solely profit-oriented business model into a sustainable business model, which also targets human, social, and environmental aspects [6].

This paper presents the findings of a study on companies that are still operating using a classic business model, placing a special focus on Austrian SMEs in the production domain. This study explores how a business can be transformed from a classical to a sustainable one. Various frameworks already exist that can be used to support the design of sustainable business models. These include the value mapping tool (VMT) [7], the triple layered business model canvas (TLBMC) [8], the strongly sustainable business model canvas [9], values-based innovation [10, 11], and the sustainable business canvas [12]. Practical applications of these frameworks and research on the development of a sustainable business model (SBM) in the production domain, with a special focus on SMEs, is still scarce [6].

This paper presents results of an explorative study on SBM creation by a European SME. This study was preceded by a preliminary study [13]. The research method applies a single case study design. The study was based on publicly available information and qualitative data obtained through interviews and workshops on an executive management level [14]. This paper includes additional steps needed to develop an SBM, including the procedure, applied tools, and practical insights gained from their application. Feedback in the form of survey responses from our company partner, intermediate results and the final SBM, visualised as a TLBMC [8] are also presented.

The company partner in our case study was HAGE3D [15], a 3D printer manufacturer, that is currently operating using a classical business model. HAGE3D is trying to present their product, with material extrusion technology [16], on the medical industry market. The medical industry represents a completely new market for HAGE3D, requiring them to create a new business model. At the same time, HAGE3D also wants to create a SBM.

This paper is structured as follows. The introduction is followed by a description of the conducted case study, including the applied research method, an overview on selected tools, and the workshop setup. The results section includes a description of the resulting SBM and how the data were generated. Finally, the conclusion, including limitations and an outlook of steps that should be taken in the future, is given.

2 CASE STUDY

Companies face several challenges as they adopt new sustainable business models (SBMs) [6]. To understand this problem more thoroughly, this case study was conducted in cooperation with HAGE3D, which is a family-owned Austrian 3D printer manufacturing SME, initially founded from HAGE Sondermaschinenbau [17]. Both companies are now connected under the HAGE Holding [18], which serves as its parent company. For several years, the company has conducted research on and produced various types of reliable

3D printers for their core customers, including original equipment manufacturers (OEMs), tier 1 suppliers, and SMEs of various industries, such as electronics, chemical, and automotive industries.

Recently, the top management of HAGE3D decided to target the medical industry. Therefore, the need for a new business model arose. The aim was not to introduce major changes into the existing business model, but instead to establish a complete new SBM for the medical industry from the initial business plan and onwards. The case study describes the application of specific tools and provides insights into the resulting SBM. [13]

2.1 Methods

The research method applied a single case holistic design. The study was carried out on the basis of publicly available information and qualitative data, obtained through interviews and workshops conducted on an executive management level [14]. A paradigmatic case of creating a specific SBM type was chosen which integrates the products and services of a 3D printer manufacturing SME [6].

2.2 Applied Tools

Fig. 1 provides an overview of the toolchain and the purpose of the use of each tool. The first two tools were included to emphasise the economic aspects of the business model. This provided a foundation that allowed us to explore the social and environmental aspects of the SBM. The stakeholder map [19] was used as starting point, identifying relevant stakeholders according to the categories defined by the tool. The business model canvas (BMC) [20] was used to identify the economic aspects of the business model. The BMC was very helpful, in that it enabled us to engage the workshop participants from HAGE3D, as they were already familiar with the BMC [20]. To identify social and environmental aspects of the business, the VMT [7] was applied. A VMT guideline published by [21] was used to support the workshop facilitators. Before creating the TLBMC [8], the values that were exchanged by the stakeholders were investigated using a value network analysis (VNA), modified from that presented in [22]. The value network revealed further social aspects of the business. The TLBMC [8] was used to summarize all gained data as SBM.

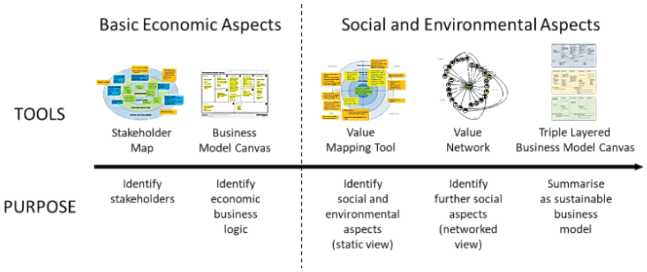

Figure 1 Overview of applied tools and related purpose in order of application. Stakeholder map modified from [19], business model canvas modified from [20], value mapping tool modified from [7], value network modified from [22], and triple layered business model canvas modified from [8]

All tools were introduced to the participants and printed in a large format before being applied in the workshop to foster the engagement of the company partners and allow them to generate the content collaboratively. The detailed workshop setup is described in the next section.

2.3 Workshop Setup

The results of this work are based on data gathered during a preliminary study [13], which included desk research, an interview, and an initial workshop, conducted together with executives from the partner company.

To proceed and gain further detailed information, a second workshop was conducted with the following stakeholders:

- CEO from HAGE3D.
- Head of R&D from HAGE3D.
- Researchers from the Institute of Engineering and Business Informatics, TU Graz.

The second workshop was facilitated by the use of a VNA [22], and feedback was collected through a survey regarding the tools used during the research period. The setup was designed to uncover opportunities for recognising additional sustainable value for the company and their stakeholders over the long run. All practical activity related to the workshop took place in a seminar room at the Graz University of Technology. First, the tools applied in the first workshop, stakeholder map [19], BMC [20], and VMT were revised. During the revision, additional data were collected on the basis of feedback from HAGE3D. To gain further insights, the theoretical background for the value network [22] was introduced to the participants of HAGE3D in terms of its functionality and its usage. In the beginning of the workshop, a simplified version of the VNA [22] was prepared using data from the stakeholder map and printed in a large format for use during the workshop. All identified stakeholders, including their attributes (i.e. names, capabilities, and assets) were connected with lines during the workshop as a result of input from HAGE3D. The aim of this step was to facilitate the creation of a simple, visual way to identify the exchanged values, avoiding the use of predefined generic categories. The executives of HAGE3D were asked to provide free-text answers to the question: What is exchanged between the actors on the chart? After the workshop, the value network was digitalised and, in combination with the results of the previous workshop, the TLBMC [8] was created. This is described in the following section.

3 RESULTS

In this section, an overview of how various tools are used in the process of developing a sustainable business model for a 3D printer manufacturer is provided.

The VMT [7], as shown in the Fig. 2, was used to compare conventional implants with 3D printed implants using material extrusion technology [16] [23]. The activity-generated outcomes for HAGE3D in the form of values

missed, which further supported the process of depicting value opportunities, could be assigned to four dimensions (i.e. environment, society, customers, and network actors) in collaborative conversations about the different aspects.

The use of such a tool helped the researchers and the company executives during the process of identifying the promising social value opportunities, which had been missed when applying conventional manufacturing methods. In addition, an understanding developed that the material extrusion technology [16] has an overall stronger social impact as compared to its environmental impact [24].

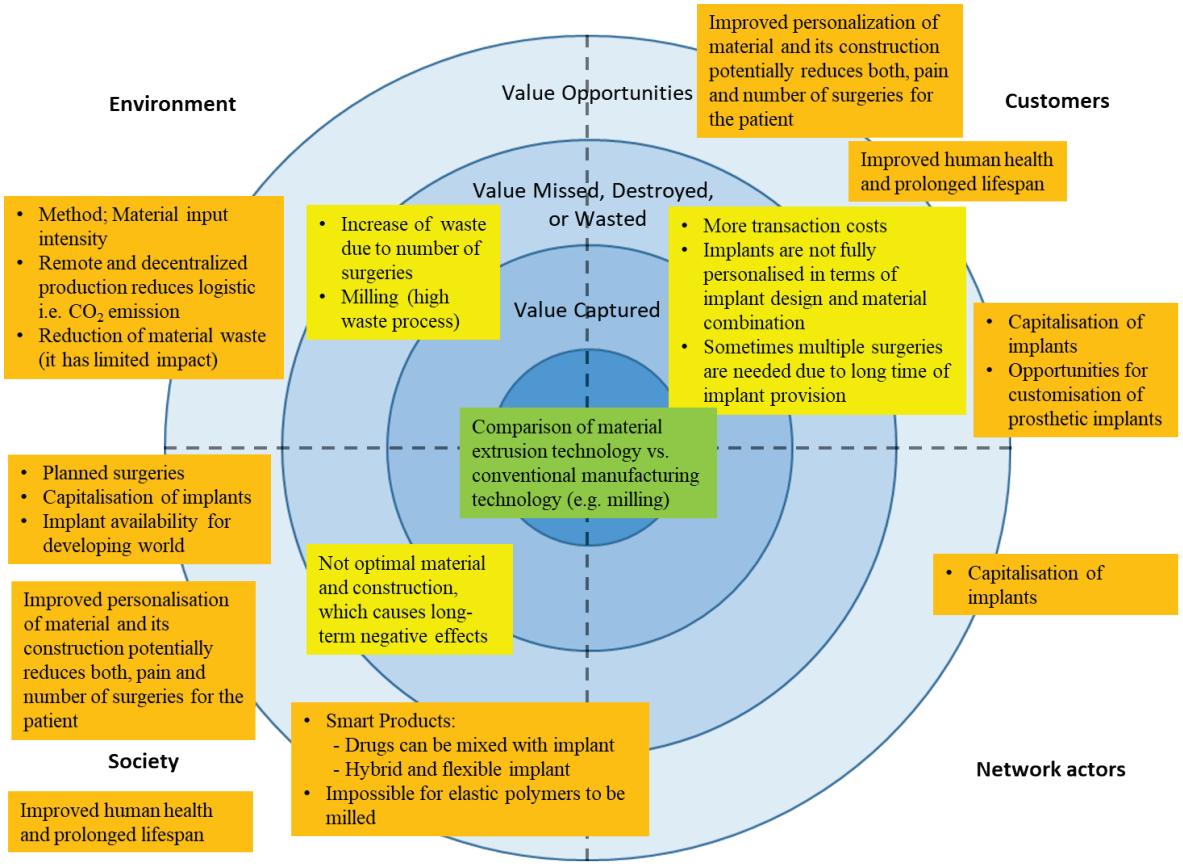

Figure 2 Value mapping tool based on [7] populated with data obtained from a workshop with HAGE3D

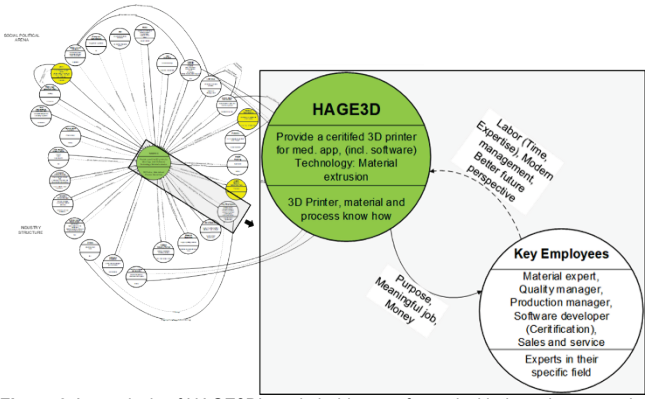

Figure 3 An analysis of HAGE3D's stakeholders performed with the value network. Simplified version, modified from that presented in [22]

In the next step, it was attempted to identify additional long-term stakeholder values by applying the VNA [22] during the second workshop with HAGE3D. Overall, Fig. 3 depicts the values exchanged between the multiple stakeholders present in the company's medical business ecosystem. The exchange of values, for example, between HAGE3D and key employees as two actors, is expanded to provide further illustration. The solid line conveys the information provided by HAGE3D to key employees regarding the purpose of, meaning of, and salary for the offered job. On the other hand, the dotted line represents the values provided by key employees to HAGE3D in terms of services, know-how, modern management, and better perspectives for the future. The resulting value network provides a good overview of the relevant stakeholders and the values they exchange in a networked medical business. The experience gained in this workshop also indicated that creating a stakeholder map [19] early on helped generate actors.

After adopting various tools, as shown in Fig. 1 and Fig. 2, the researchers were finally able to design a new SBM for HAGE3D using TLBMC [8]. The data obtained from the stakeholder map [19], BMC [20], VMT [7], and VNA [22] supported the creative exploration of economic, social, and environmental value for HAGE3D. These could be translated into economic, social, and environmental layers of the TLBMC as a final output [8].

3.1 Economic Layer of the TLBMC

The economic layer provides a systematic and detailed description of key aspects of how the company creates profit and delivers value to its customer via its supply chain in a network-centric manner [25]. The nine components, illustrated in Fig. 4, show the interpretation of the economic layer of the TLBMC [8] of HAGE3D in more detail.

Value proposition: The quest for the creation of economic value begins by providing a certified, flexible 3D printer for medical application. This includes the software needed for production management, which is certified for medical products as well, reselling of reliable material, and includes 3D printer settings (i.e. parameters are set for certain materials, but can also be adapted for other materials). Offering the customer process support engineering and providing the results of an initial feasibility study also contributes to the creation of value. The following 3D system packages are being offered in the medical sector:

- Printer + slicer software
- Printer + modelling + slicer software.

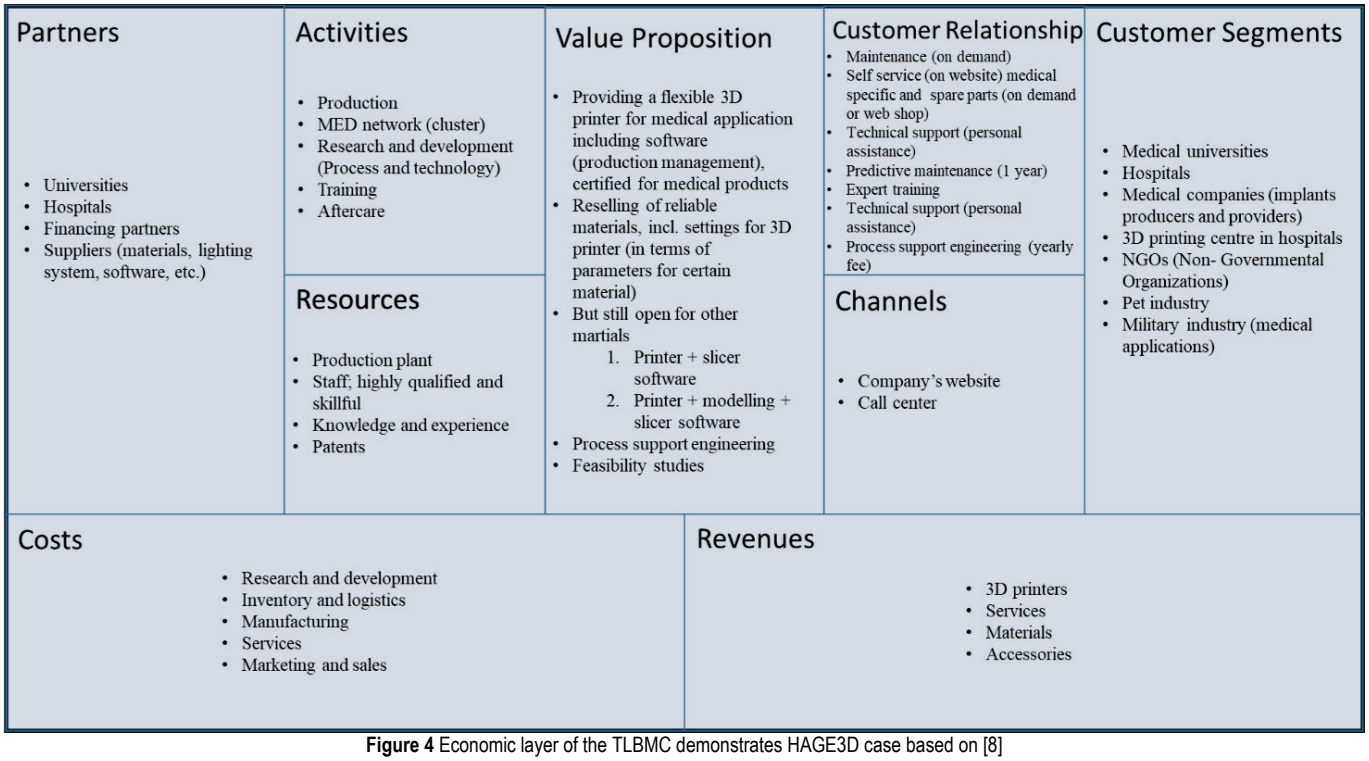

Figure 4 Economic layer of the TLBMC demonstrates HAGE3D case based on [8]

Key partners: The list of the company's key partners includes universities, hospitals, financial partners (e.g. banks), and various core suppliers of software, materials, and lighting systems.

Key activities: The medical cluster of various business stakeholders is vital to HAGE3D in that it offers possibilities to interact, follow new trends, and collaborate. The company's research team focuses on process and technological system development. Training on new developments is provided to staff and customers. After the 3D systems are sold, the company offers a customer care service.

Key resources: Both the company brand and patents are considered to be key resources. This list further includes intangible assets (i.e. the employees' knowledge, skills, and experience). Lastly, the production plant that manufactures the 3DP products is also a crucial company resource.

Customer segments: In general, all medical universities and hospitals are customers at the front layer, including medical implant producers and providers, whereas the 3D centres established in hospitals also use HAGE3D systems for research purposes. Non-governmental organisations (NGOs) and any military partners involved in humanitarian missions in remote parts of the world are also considered potential customers. The demand for customised 3DP products for pets might increase in the future. Therefore, the pet industry in general is also placed in this section.

Customer relationships: Offerings like personal assistance, technical support process engineering with a yearly fee, on demand maintenance, free predictive maintenance for up to one year, and the online or direct availability of medical specific products and spare parts will create a strong customer relationship. Meetings with members of the medical community in various forums and the provision of expert training for the usage of 3DP systems will further strengthen relationships with customers.

Channels: The direct communication channels for customers are the HAGE3D company website and a call centre. Scientific conferences and research projects are also channels which the company can use. Another possibility is face-to-face communication (e.g. for direct sales of their products and services).

Cost: Manufacturing, marketing and sales, research and development, inventory, logistics, and services (e.g. training, personal assistance, and maintenance) contribute to the total cost of the company.

Revenue streams: The company obtains its revenue from the sale of its printers and materials. Accessories contributes a small portion, but services offered by HAGE3D will be of great importance in the future in terms of revenue generation.

3.2 Social Layer of the TLBMC

The usage of the VMT [7] as shown in Fig. 2 proved to be very helpful in creating the social layer of the TLBMC [8]. The nine components of the social layer of the TLBMC [8], as shown in Fig. 5, provides a deep understanding of HAGE3D's role in terms how society generally interprets this.

Social value: The company's social value can be interpreted by considering the fact that it provides an additive manufacturing system that enables the production of smart medical products, which improve the quality of life for its end user. 'Smart' in this sense refers to the fact that the implants are personalised and fabricated with a material extrusion technology, making it possible for drugs to be added to the material during the production process.

Employees: The company has fewer than twenty interdisciplinary employees. The key employees comprise the business head, material expert, quality manager, software developer (certification), and salesperson.

Governance: HAGE3D is a privately-owned for-profit company which performs autonomous decision-making and values transparency towards their shareholders.

Communities: HAGE3D has one local networked community in the province of Styria comprised of various stakeholders, all of whom mutually develop and maintain beneficial business and social relationships. The company is located in two locations (rural and urban) where different business activities take place. The company produces 3D printers in Obdach (rural), while the team in Graz (urban) focuses on operations like business development, research and development, and building a strong network with other stakeholders.

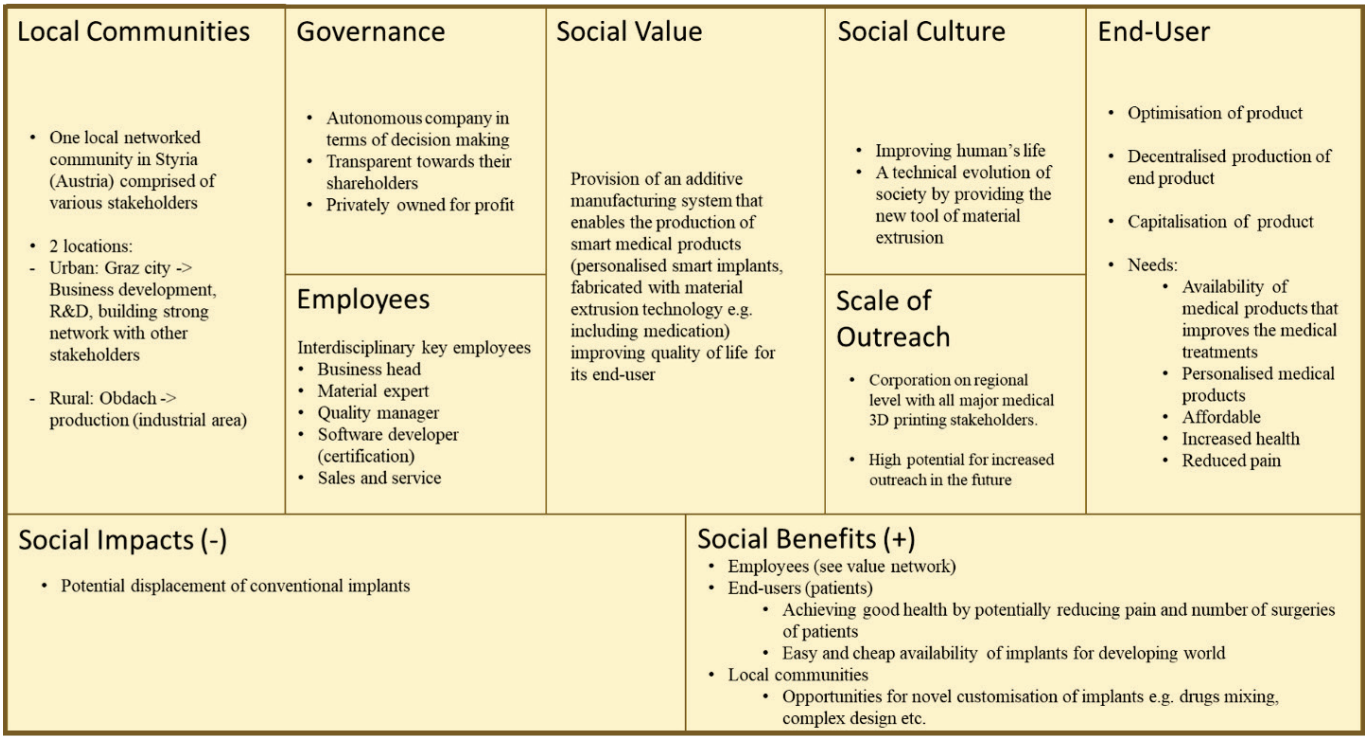

Figure 5 Social layer of the TLBMC demonstrates HAGE3D case based on [8]

Societal culture: HAGE3D has set the improvement of the quality of life of humans as its social agenda. A technical evolution of society by providing the new tool of material extrusion.

Scale of outreach: On a regional level, the company is in strong corporation with all major medical 3D printing stakeholders and possesses a high potential for increased outreach in the future.

End users: HAGE3D seeks to provide value by optimising, personalising, decentralising, and capitalising on medical products, i.e. fulfilling the needs of users by ensuring the availability of medical products which bring improve healthcare treatment by potentially reducing the number of surgeries and pain. In this context, 'capitalisation' means ensuring the affordable and secure availability of medical products in the future in developing countries.

Social impacts: Potential displacement of conventional implants may disrupt many businesses in the medical sector and could contribute to a rise in unemployment.

Social benefits: HAGE3D categorised social benefits as follows:

- Patients can achieve good health by experiencing a reduction in pain and a potential reduction in the number of surgeries by being quickly provided with access to better fitting, optimal end products.
- End users in developing world are provided with easy access to affordable implants for.
- Employees are provided with a sense of purpose, money, and meaningful jobs.
- Local communities can request novel customised forms of implants (e.g. in terms of drugs added to materials, complex designs) and benefit from the creation of new jobs.

3.3 Environmental Layer of the TLBMC

The most challenging part during the creation of the sustainable business model was to fill out the environmental layer of the TLBMC [8], based on the data extracted from using the VMT [7]. The use of the VMT [7] helped workshop participants discuss and identify the basic aspects of this dimension. But to obtain deeper insights into environmental aspects, participants realised that they would require the use of additional methods to completely fill out the environmental layer of the TLBMC [8]. Methods, such as the material input per unit of service (MIPS) [26] or life cycle assessment [27]. These methods support approaches that can be taken to measure the eco-efficiency of a product or service. Therefore, participants realised that it would be very difficult to claim a functional value only by using the tools presented. Nevertheless, environmental layer of the TLBMC [8] could be partially filled in and is presented in Fig. 6, based on data obtained from the use of the VMT [7] (see Fig. 2).

In this study, medical material extrusion technology was considered as the functional value. Although the impact of this technology is still quite low, the following benefits were taken into consideration. The consumption of input materials using material extrusion technology is less than that used by conventional subtractive technologies, and the use of material extrusion technology reduces the waste amount of input material to little or almost nothing during the production phase. The logistics of the process could also be simplified, due to the degree of flexibility and agility possible through the use of material extrusion technology; 3D printed medical products could be rapidly produced in a decentralised location, near the end customer.

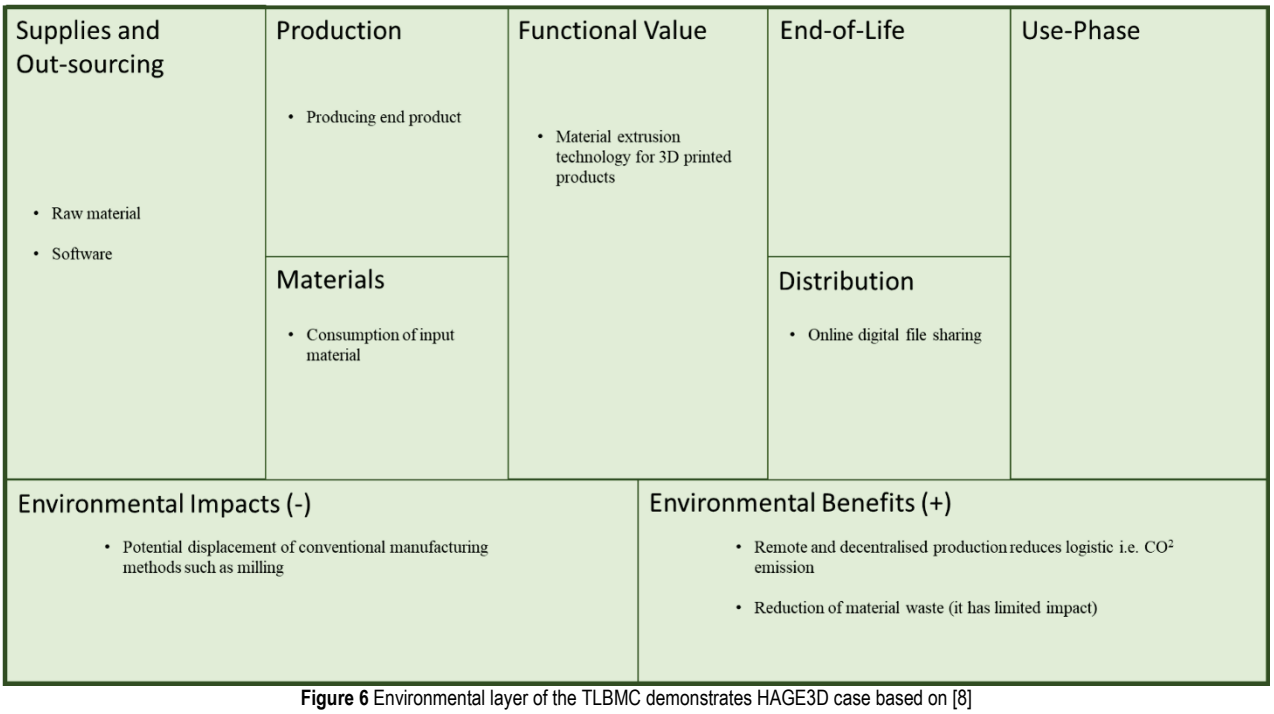

Figure 6 Environmental layer of the TLBMC demonstrates HAGE3D case based on [8]

3.3 Survey Feedback

At the end of the second workshop, a survey was conducted with the participants from HAGE3D to gain insights on the practicability of the tools applied in both workshops. The survey contained questions about all applied tools: their usefulness, ease of use, generated insights, choice of tools in the respective company and for what purpose, and choice of favourite tools and why.

Both participants from HAGE3D rated the value network tool as the most useful tool that had been applied in the workshops. The VMT [7] achieved an average rating in terms of its usefulness. Concerning the ease of use of a tool, the stakeholder map [19] was rated as the most difficult one. The value mapping tool and value network were rated as slightly easier to use than the stakeholder map. One participant rated the BMC [20] as the easiest to use, whereas the other rated it as the most difficult one. This result might

be related to the previous experience participants had had with the tool. Both participants rated the VNA [22] as the best tool in terms of insights gained. One participant stated that he would use the stakeholder map [19] and the VNA [22] again in his company. The stakeholder map [19] was rated as useful for maintaining a general overview, and the value network was considered useful for developing cooperation, for sales-related activities, and for evaluating new business areas. The second participant stated that he would reuse the BMC [20] for business case development and the value network for market research and development.

4 CONCLUSIONS

This paper presents the results of a descriptive study on a process of transformation in an SME, namely, the process of developing a sustainable business model, including defining the procedure, choosing and applying specific tools. Our results indicate that the use of simple and well-known tools, such as a stakeholder map [19] and BMC [20], are beneficial as starting points to engage company partners. The use of the VMT [7] can help company managers during the process of identifying important social and environmental aspects. The creation of a value network [22] provides initial insights regarding the relations between the stakeholders and allows managers to analyse the value exchanges. The results of these steps allow users to explicitly and practically integrate economic, social, and environmental value in a holistic manner using the TLBMC [8] and provide them with an outlook for future steps.

4.1 Limitations

The tools and the procedure could be used by workshop participants to identify social layer aspects for the social layer of the TLBMC [8], but were not as helpful for gaining further insights regarding the environmental layer. A partial or full life cycle assessment [27] of printed medical goods would maybe give more input for this layer. The VNA [22] was applied while only considering the value exchange and resources layer, which places a stronger focus on the economic aspects of the TLBMC [8].

A holistic single case study cannot be generalised to other studies. Therefore, multiple case studies need to be carried out to test the applicability of these findings [28]. The case study is limited to one type of SBM (i.e. product-service system) and one type of sustainable business model innovation (i.e. sustainable business model diversification) [6].

4.2 Outlook

More detailed insights into the social and economic layers can be obtained by applying the VNA as described in [29], including values and needs layer, legal layer, dynamics and motivation layer. Multiple case studies still need to be conducted to explore this topic in depth [28]. Further case studies should also be conducted based on other types of sustainable business model innovation [6].

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Notice

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