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Additive manufacturing innovations: Stakeholders' influence in enhancing sustainability and responsibility

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Abstract: Additive manufacturing (AM) is receiving increasing attention in the manufacturing industry as a collection of novel advanced production technologies, product innovations and innovative supply chains and processes. Companies implementing AM are active in innovation, but successful innovation requires support from other companies in the supply chain and from stakeholders outside of the supply chain. This exploratory study seeks to better understand the mechanism behind stakeholders' involvement in AM innovation activities. The focus is on how stakeholders' involvement enhances the success, sustainability and responsibility of AM innovations. The findings reveal who the stakeholders are and how they influence the innovation processes of companies utilising AM in their manufacturing processes. The study contributes to the field of innovation management in the context of AM by detailing the network complexity in AM innovations and guiding AM companies towards the stakeholders who can improve the success, sustainability and responsibility of AM innovations.

Keywords: additive manufacturing; stakeholder involvement; innovation; sustainable innovation, responsible innovation.

1 Introduction

Additive manufacturing (AM) is a relatively novel manufacturing approach that implies changes in production technologies, the use of digital product designs and a process of joining and adding material, usually layer by layer (ASTM, 2012), to produce innovative goods. The diffusion of AM technologies in the manufacturing industry will require innovations in the business models, supply chains and products and services of the companies involved (Martinsuo and Luomaranta, 2018; Luomaranta and Martinsuo, 2020). There is a growing need for more sustainable and responsible innovations, and AM can become one of the solutions for more sustainable manufacturing (Ford and Despeisse, 2016; Beltagui et al., 2020).

Innovation, in its classical sense, means the introduction of a new product, process or business model for a commercial purpose (Schumpeter, 1934). Creating and introducing new offerings requires a systematic innovation process (Drucker, 1985), and, besides companies operating in the direct AM supply chain, various stakeholders with different interests and demands influence AM innovations. These stakeholders tend to be

important organisations that have the power to influence the innovation process to enhance the sustainability and responsibility of AM innovations (Berger et al., 2004; Pagell and Shevchenko, 2014). This study concentrates on innovations in AM, including both the manufacturing technologies and the new goods being manufactured, and on the stakeholders' influence on the sustainability and responsibility of AM innovations.

There are multiple definitions of stakeholders (Miles, 2017), and these different definitions focus on the relevant stakeholder attributes depending on the context of the analysis situation (Freeman et al., 2010). This study takes stakeholders to be external organisations that have an interest in or contribute to AM but are not key actors in the direct AM supply chain.

Earlier research has identified that research and training organisations have an important role in providing AM-related training and transferring knowledge to companies (Rylands et al., 2016). Standardisation organisations are important stakeholders when standards are created for emerging technologies (Monzón et al., 2015). Before the specific work of standardisation organisations, other stakeholders, such as trade organisations and engineering associations, specify the need for standards and influence the standardisation process (Koch, 2017). Previous research has identified and mentioned such AM stakeholders only briefly, and their input in AM innovations is poorly understood.

The purpose of this study is to explore stakeholders' involvement in the innovation process of AM. The goal is to understand how different stakeholders participate and use power in AM innovation activities in relation to companies in the AM supply chain whose aim is to create sustainable and responsible innovations or at least to try to minimise the negative effects of the AM innovations to meet the requirements of the stakeholders. This paper poses the following research question: "How do different stakeholders influence AM innovation activities in relation to companies in the AM supply chain to enhance the sustainability and responsibility of AM innovations?"

2 Literature review

Defining stakeholders

The term "stakeholders" is frequently used in management studies, which may be the reason why the term has many varying definitions. (Miles, 2017). From the viewpoint of stakeholder theory, stakeholders are assumed to be a part of business and are defined as "groups or individuals that have a stake in the success or failure of a business" (Freeman et al., 2010, p. xv). Often, the definitions of the stakeholders are formed in such a manner that the context and stakeholders' attributes serve the purpose of the study (Freeman et al., 2010), meaning that in the case of a big multinational company, the stakeholders could be the customers, suppliers and employees. In the strategic management literature, the focus is usually on the attempt to define which stakeholders are important from a company's perspective and to which stakeholders the managers should pay attention (Mitchell et al., 1997). In such cases, the stakeholders usually include shareholders, company employees, customers, suppliers and sometimes even competitors and are referred to as primary stakeholders; then, external stakeholders are the organisations

external to the supply chain. External stakeholders are not directly involved in manufacturing and the supply chain but may indirectly influence or affect, for example, the innovation process (Freeman et al., 2010). Such external stakeholders can be, for example, national governmental organisations.

Some of the management frameworks treat companies' business environment changes as external forces (see, for example, the PESTLE analysis, Vlados and Chatzinikolaou, 2019), with legislation, for example, being seen as part of such forces. These external forces are things that companies cannot influence but which have an influence on the company. External forces could, however, quite often be categorised as external stakeholders. Stakeholder theory suggests that the relationship is more complex than one-way forces, to which companies need to adjust, and that while external stakeholders have an effect on a company's actions, companies can also use the relationship with external stakeholders as a two-way relationship (Freeman et al., 2010).

Scholars have noticed that companies are paying relatively little attention to systematically identifying and analysing important stakeholders (Bryson, 2004; Pagell and Shevchenko, 2014; Meixell and Luoma, 2015), which makes this study relevant for managers and practitioners. When studying the involvement of the stakeholders in a company's innovation process, defining the stakeholders too narrowly would most likely lead to ignoring important stakeholders from the perspective of innovation in an emerging technological area. Therefore, when it comes to stakeholders, this study looks beyond the traditional consumeristic management point of view and concentrates on external organisations – external stakeholders – that have an interest in or contribute to AM rather than to the companies, institutions or customers who are directly involved in the AM-product supply chain. An organisation can also have a shifting role between actively participating to the supply chain level processes in one occasion and acting as a stakeholder on other, depending on the specific innovation and the phase of the innovation process.

Stakeholder influence on the innovation processes to enhance sustainability and responsibility

Sustainable innovations and responsible innovations partially overlap in their scientific use, and there is a vivid discussion to clarify the definitions (see Owen and Pansera, 2019). According to common sense, sustainability is often associated with environmental aspects and with responsibility to social issues. One of the most cited sustainable development definitions (where innovation falls under the category of development) comes from the Brundtland Report: "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8). Responsible innovation is defined as "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p. 1570). What is common in these definitions is the consideration of the social and environmental aspects, which can be easily neglected due to focus on short-sighted economic growth (Owen and Pansera, 2019). The notion of collective stewardship increases the need for research studying the innovation network and the stakeholders who have an influence on the sustainability and responsibility aspects of AM innovations.

When looking into the stakeholder involvement in the focal company's innovation process, researchers have noted that the relationships with stakeholders have been increasingly considered as an important way of developing innovations (Haeckel, 2004). One way for stakeholders to participate in the innovation process is to offer knowledge from the network that they represent. For example, the stakeholder could be an organisation representing different customers. Such stakeholders can offer access to a dense network or hub of organisations that are distinct from a company's focal supply chain as well as provide a different view of the marketplace and give early warnings about shifts in public tastes and values (Yaziji, 2004). An example from the biomedical innovations sector involved a firm whose collaborative relationships with partners in a hub enabled by a stakeholder were a key determinant of successful innovation (Powell et al., 1996). Developing relationships with such stakeholders can foster innovation by creating suitable conditions for relevant ideas.

Stakeholders may thus have a general influence on innovation success, but they may also be pursuing other goals. These goals may include enhancing the sustainability and responsibility of innovations. As Ottosson (2009) argues, the different sectors of our society each have their own role in innovation development: companies seek sustainable profits to their innovative products and services, the public sector seeks good and sustainable services for the people in the society, and the idealistic sector (NGOs, for example) aims for responsibility.

In addition to passive involvement, stakeholders can have a more active role in the innovation process. Findings from strategic management shows that organisations are more inclined to protect their existing processes than to develop new ones until they are sure that the development is almost risk free. Therefore, a stakeholder outside of the company can try to force the innovation if a company does not do it voluntarily (Van de Ven, 1986). It has even been argued that especially larger companies do not improve their sustainability (social and environmental) without stakeholder involvement (Pagell and Shevchenko, 2014). Without enough legislative pressure for the larger companies, smaller innovative companies are more likely to drive industrial manufacturing to emphasise responsibility (Shevchenko et al., 2016), but they lack the resources of larger companies, which decreases the chances of success (Minetola and Eyers, 2018). Developing relationships with non-governmental organisations (NGOs) can strengthen any company's social legitimacy. It can be argued that companies need these relationships with NGOs to be perceived as socially and environmentally responsible (Berger et al., 2004). Company-NGO partnerships can address both broad and complex societal issues, and such partnerships can be a source of competitive advantage (Bonfiglioli et al., 2006).

Combining the stakeholder theory and sustainable and responsible innovation make for an interesting research avenue that could identify legitimate stakeholders whose involvement is beneficial (Mitchell et al., 1997). Therefore, from the perspective of responsible and sustainable innovations, it can be argued that certain (often larger) companies need the stakeholder pressure to enhance the sustainability and responsibility of their innovations. On the other hand, certain companies (often smaller and innovative) with an internal emphasis on sustainability and responsibility need the help of stakeholders in order to succeed in their innovation efforts and market diffusion. Thus, this study investigates stakeholder involvement in terms of which stakeholders can foster the sustainability and responsibility aspects of AM innovations as well as which stakeholders can help in the success of sustainable and responsible innovations,

answering directly to the need for future research argued by Pagell and Shevchenko (2014, p. 47): "Future research will have to explicitly recognize the claims of stakeholders without an economic stake in the chain, treat these claims as equally valid to economic claims, and start to focus on ways to deal with situations where synergies cannot be created.".

In the previous studies on AM, stakeholder involvement in the innovation processes was mentioned only briefly. The empirical studies have noted that organised customer groups or associations representing their customers can apply pressure to the AM manufacturing companies already in the design phase of a new product to consider sustainability aspects (Beltagui et al., 2020). Research and training organisations have been found to have an important role in providing AM-related training and transferring knowledge to companies (Rylands et al., 2016) so that the latter could start the AM innovations in the first place. Research organisations can also be of help later in the innovation process – for example, in the testing and development phases. When it comes to emerging technology, standardisation organisations are important stakeholders for the creation of standards (Monzón et al., 2015). Before the specific work of standardisation organisations, other stakeholders, such as trade organisations and engineering associations, specify the need for standards and influence the standardisation process (Koch, 2017). By developing relationships directly with the standardisation organisations, or more likely through engineering associations, companies can influence standardisation – for example, to make sure that it enhances their changes to diffuse their innovations. The focus in these studies has been mainly on a single stakeholder or the general innovation success, and the holistic analysis of the stakeholders' influence on sustainability and responsibility has so far been neglected in the technological area of AM.

3 Research design and method

Data collection

The research design is qualitative and exploratory in nature because of limited previous knowledge on stakeholder involvement in AM innovation activities. The study involved two major industries where AM has shown great potential: car manufacturing and medical implants and devices. Organisations A and F are involved solely in the medical implants and devices industry. Organisation B represents the car manufacturing industry, and the rest of the organisations are involved in the AM industry more extensively and are part of both the car and medical implants industries. The technological background information on the companies that participated in the workshops and survey is presented in Table 1.

Table 1 Background information on organisations that participated in the workshops and survey

Organisation	*Role in AM*	*Stakeholder role*
Organisation A	AM designer, AM producer	
Organisation B	AM designer, customer	
Organisation C	Software developer	
Organisation D	AM designer, AM producer	Research organisation
Organisation E	AM designer, AM producer	Research organisation
Organisation F		Engineering association, training organisation
Organisation G	AM machine manufacturer, AM feedstock provider	
Organisation H		Engineering association, training organisation, research organisation
Organisation I	AM feedstock provider	Research organisation
Organisation J		Non-governmental organisation, research organisation, training organisation
Organisation K		Research organisation, training organisation
Organisation L		Education organisation, training organisation, research organisation
Organisation M		Training organisation, research organisation

During the first workshop, the participants were instructed to map their dedicated supply chain and the actors in it, including all the organisations and institutions inside and outside the supply chain with whom they were developing innovations.

After the listing of the stakeholders, a survey was sent to the company representatives concerning the activities of the stakeholders engaged with the AM companies. The question of the survey was this: "Based on your experience, what inputs or requirements do the external stakeholders bring to the network of companies in the additive manufacturing supply chain?" At this point, the external stakeholders were divided into the following categories: funding and insurance companies; training organisations; regulators and patent authorities; trade associations and customer representing organisations; research organisations; and others. Respondents could offer an open-ended response regarding each identified stakeholder and add the stakeholders they considered as relevant.

Another workshop was organised with the same companies and a group of researchers to identify the stakeholders' interactions and activity inputs and outputs with the companies in the AM network. In this second workshop, the participants were divided into industry-specific teams (car manufacturing and medical implants and devices) to draw up and organise a process map that included the previously identified stakeholders and their inputs and requirements. The data created during the workshop covered the stakeholders' relationships with the companies in the AM supply chain, the requirements of the stakeholders, the benefits to AM companies from the relationships, and the phase of the innovation process in which the stakeholders were involved. Discussions during the workshop were documented using memos and flipcharts.

Analysis

The analysis concentrates first on identifying and defining the stakeholders (see Table 2) and then on mapping the stakeholders' involvement for the three AM innovation process phases (Table 3). Based on the answers about the stakeholders from workshop 1, Table 2 was formed by listing all the relevant stakeholders, removing the statements concerning primary stakeholders, and combining the repeated attributes of the stakeholders into logical descriptions.

Based on these data, a stakeholder matrix mapping analysis was carried out according to the three phases of the innovation process, namely idea generation, idea development and the diffusion of developed concepts (Hansen and Birkinshaw, 2007). One of the most common stakeholder mapping methods is to use a two-by-two matrix with key attributes on both axes. The attributes can include, for example, power and interest, importance and influence, salience and power or support and opposition (Bryson, 2004; Hoejmose et al., 2013). For this study, the power and interest matrix was chosen because it provides the most insight for studying the stakeholders' involvement in innovation.

The interest attribute reveals whether the stakeholder is pro-active in their involvement or passive. It is also important to understand the power that each stakeholder possesses because this enables understanding whether the stakeholder is empowering or controlling the innovation process. Also, the power may lie in the ability to affect innovation in the short term or to affect its success and acceptance in the long-term (Mathur et al., 2007). In addition, to analyse further the stakeholders' influence in enhancing sustainability and responsibility, three different mechanisms were applied. To enhance sustainability and responsibility, the first two mechanisms that stakeholders can use, according to Meixell and Luoma (2015), are to purposefully foster the sustainability and responsibility aspects by giving knowledge or set pressure to them (which might be interpreted as resisting unharmful innovations). The third mechanism used by this study is the stakeholders offering help for already sustainable and responsible enough innovation to become successful. In the analysis, these three mechanisms are referred to as "fosters," "sets pressure" and "innovation help."

Figure 1 illustrates the power/interest matrix and the sustainability and responsibility enhancement mechanisms identified in this study. The data from the survey and the second workshop were used to analyse each phase of the innovation process (idea generation, idea development and diffusion) based on this analytic framework. During the analysis, the interest of the stakeholder was considered to be high if an AM company respondent described a stakeholder's influence as follows: "they brought the idea," "they started the discussion" or "they were very active." Concerning the respondents who were in the stakeholder role themselves, the interest was considered to be high if they claimed to have an active role, for example "we had the idea and then we tried to find a company to collaborate with us." In the analysis of power, strong power was coded if the respondents stated that "we have to comply" or "it is very important to collaborate with them." Weak power was coded if the statements were like the following: "it was not necessary but beneficial to us" or "we collaborated voluntarily." Regarding the sustainability- and responsibility-enhancement mechanisms, innovation help was coded for the stakeholder if there was no specific mention of sustainability and responsibility requirements or knowledge transfer. The fostering mechanism was coded if there were statements such as "they gave new knowledge about new more sustainable materials" or

"we participated in training that covered societal responsibility issues." Sets pressure was coded if the stakeholder used their power to force the company to comply with sustainability and responsibility requirements or if the influence of the stakeholder was mentioned in a negative manner even if the respondent addressed the sustainability- and responsibility-related issues that were criticised.

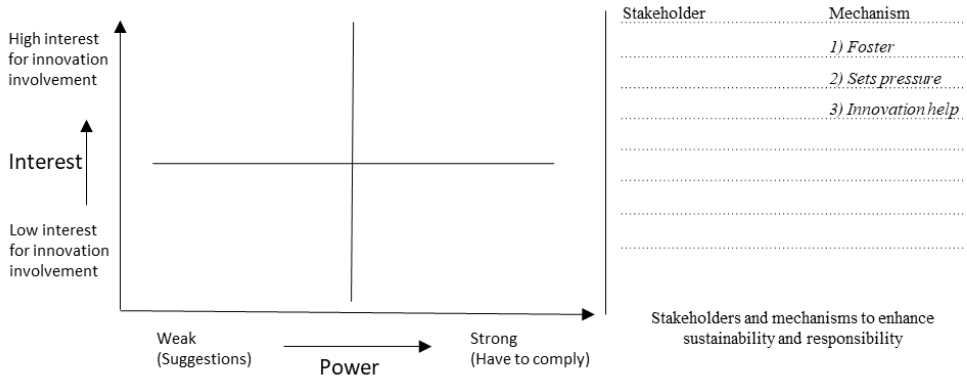

Figure 1 The analytic framework used to evaluate the stakeholders.

4 Findings

Identifying and describing the stakeholders

First, this study identified all the relevant key stakeholders for the AM innovation processes. They were the following: governmental organisations (regulators), NGOs, funding organisations, training organisations, research and technology organisations, standardisation organisations, patent organisations, trade associations, organisations representing customers and end-users and insurance companies. Figure 2 illustrates the research context – that is, the AM supply chain that is presented in the middle and the identified stakeholders. Any company within the manufacturing supply chain can be considered as a focal company, and the other companies are its primary stakeholders. The identified stakeholders are outside the supply chain.

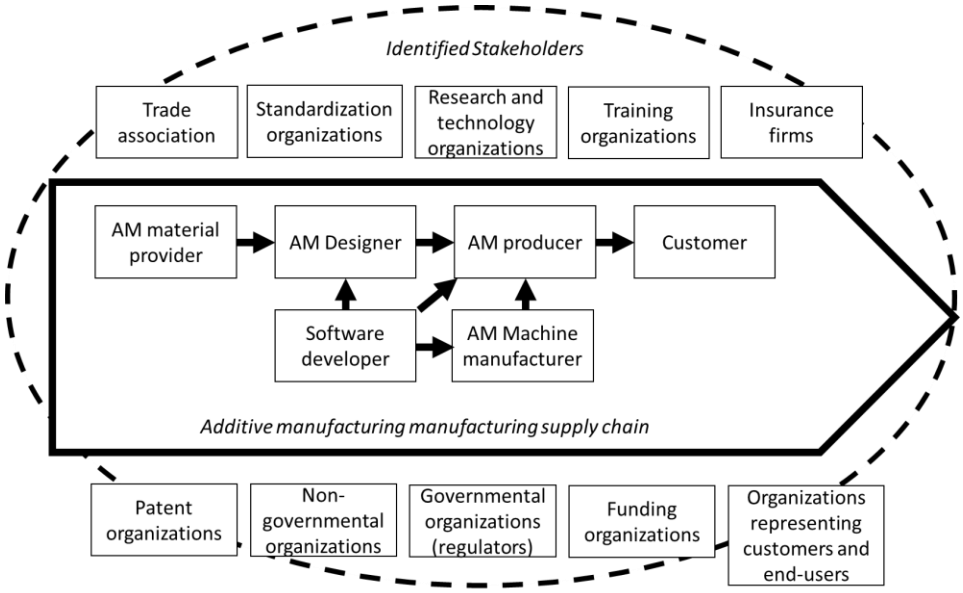

Figure 2 The AM supply chain and stakeholders.

Table 2 further defines the identified stakeholders based on the perspectives of the interviewed organisations. The descriptions are gathered from the answers to the survey and from the interviews. The descriptions reveal stakeholders' participation in and influence on the AM innovations – for example, via technology training and the emphasis of sustainable and responsible innovation or by giving an idea for a socially desirable innovation.

Table 2 Identified stakeholders and their descriptions

Stakeholder	*Description*
Governmental organisations (regulators)	Regulators generate laws and regulations. They also try to secure reliable and sound products for the societies they represent by providing descriptions of what companies should comply with and granting certificates. To create these certificates, laws and regulations, there needs to be collaboration at least with the research and technology organisations, AM machine manufacturers and AM producers. Regulators also set regulations or encourage companies to develop clean and material- and energy-saving technologies, and they set safety regulations and try to create new job opportunities for the society.
Non-governmental organisations (NGOs)	Non-governmental organisations in the context of AM are usually protective of the environment and/or the society. Damage to the environment may seem like a small issue at present, but as time goes on, repairing such damage becomes increasingly costly. Therefore, the information that NGOs can provide about the effects of new technology on the environment and society can be used to enhance the responsibility of the industry and to protect end-users and the wider society from the social consequences of the AM applications.
Funding organisations	Funding organisations can be national or, for example, European-level organisations. Their input, such as funding, enables new product development at quicker pace. They require that the companies provide comprehensive resource allocation and reporting to support the AM innovations in the most efficient way

	by multiplying the effect of funding to develop the innovation systems. Comprehensive reporting means that the sustainability and responsibility aspects of the innovations can be demanded and the implementation can be monitored. Funding can be terminated if the requirements are not met.
Training organisations	Training organisations provide standardised training, provide knowledge as quickly as possible to the organisation in the AM industry and offer different formats of training (e.g. academic, lifelong learning), and they can be universities or commercial organisations. Co-creating a vast knowledge base with research and technology organisations is necessary to achieve state-of-the-art knowledge, that can be used in training of new skills and best-practises. Also, training organisations need to gather funding, analyse the AM market and analyse the training purchasers' current situation. Training with multiple attendees can enhance the connection among different organisations and companies. The sustainable and responsible innovations aspects are embedded into the training. Education is included in this definition because education organisations have similar attributes for the innovations but at a larger scope.
Research and technology organisations	Research and technology organisations include universities, publicly funded organisations and privately funded institutes. Research and technology organisations are, in many cases, the main contributors/starting points for developing innovations in the early phases (idea generation, development), but they need companies to commercialise the innovations (development, diffusion). Research and technology organisations rely on funding organisations and company partners to fund their research and to advance innovations. Research and technology organisations contribute to new regulation–creating processes and to the new standard–making processes. They also transfer knowledge to training organisations. The sustainability and responsibility aspects of innovations are often embedded in the new innovation ideas (as publicly funded research and technology organisations mainly seek socially desirable innovations), and responsibility is also required by the funding organisations.
Standardisation organisations	Standardisation organisations coordinate expert groups to set the standards for the characteristics of AM-produced parts. This includes data formats, reliability, quality requirements and restrictions on software use. Standard compliance can be used to foster some technologies more than others. Standards try to secure the sustainability of different AM technologies and thus enhance responsible innovation activities. To create standards, standardisation organisations need to collaborate with industry experts, research and technology organisations and companies in the AM supply chain. Standards ensure a common understanding among different partners in the supply chain. This is important for communication and innovation purposes.
Patent organisations	Without patents innovations could be freely adopted by any competing company. Since there is a cost associated with innovation, patens serve as a security mechanism to protect the ownership of the innovation so that the owner could make a profit to cover the costs of the innovation. Patent organisations provide help and instructions to the companies seeking to file a patent application. Patents can also serve as a source of knowledge after they expire. Patents become public after a certain period, especially if the patented technology becomes an industry standard. After the patent expires or is licensed by the owner of the patent, companies can access the technology restricted by the patent.
Trade associations	Trade associations provide its members with new knowledge, strengthen the current networks and create and explore new networks. Trade organisations seek to gather information about the markets to provide marketing possibilities to different countries. Trade associations need to collaborate with research institutes and regulators, both within their country and outside, as well as with their member organisations. Professional associations, such as engineering associations, are included in this category of stakeholders.

Organisations representing customers and end-users	Organisations representing customers and end users identify possible applications and thematic areas for AM. They collect the requirements of the customers and the needs of end-user to analyse possibilities for further applications of AM. They have the possibility to influence the market (and, therefore, the whole supply chain) through the feedback of customers and end users. To influence the market, they need to collaborate with communities of interest, informal networks, educators and technology users. Companies in the AM value chain can use the knowledge from organisations representing customers and end users to better understand the potential needs and concerns of customers and end users.
Insurance companies	Especially in the medical sector, insurance companies can foster some technologies more than others through insurance decisions. This is an economic aspect of medical sector, which works as risk management (granting insurance for AM implants vs traditional implants), but insurance companies must follow regulations as well.

Analysing the stakeholders' involvement in the innovation process

The power/interest matrix analysis, together with the sustainability- and responsibility-enhancement analysis, was applied to each phase of the innovation process, respectively, and the results are presented in the Figures 3, 4 and 5. Figure 3 represents the early phase of the innovation process, where the idea for the innovation is generated.

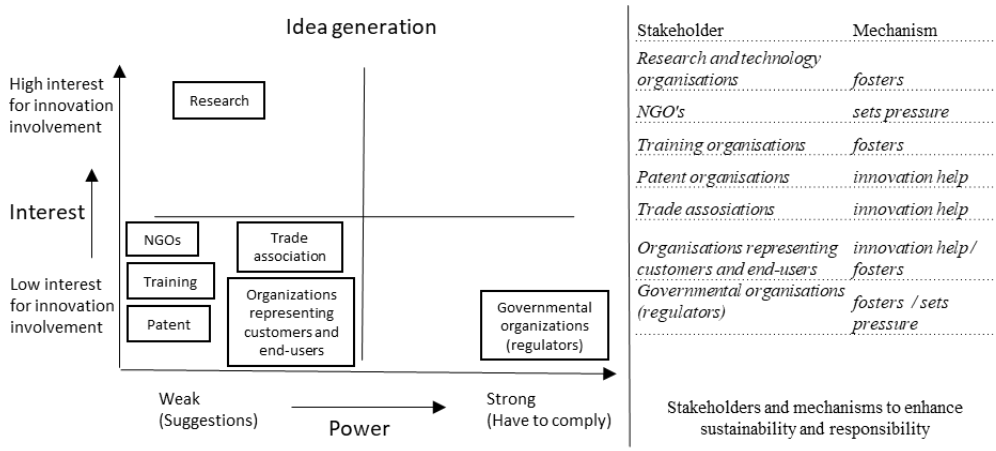

Figure 3 Stakeholder involvement (power/interest) in the idea-generation phase of additive manufacturing innovations, and mechanisms to enhance sustainability and responsibility.

For example, research and technology organisations were considered to be highly involved in the innovation process phases of the idea generation and idea development, as workshop participants discussed this actively. In the car manufacturing sector, research organisations were mentioned as the stakeholders who most often generate and introduce new AM component ideas or AM methods to the car manufacturers' products or

production process. Especially regarding the medical implant innovations, it was mentioned that in the development phase, when the implants go through clinical testing, the research institutes are highly interested in being involved in the innovation process, but ultimately they do not have enough power to go through the whole innovation process by themselves and, therefore, need the company. On the other hand, the focal company does not necessarily need the research institute, but they can benefit from faster development with the involvement of the research institute. Research and technology organisation also often consider the sustainability and responsibility issues extensively, and this knowledge is passed on to the other organisations engaged in the innovation process.

Training organisations are an example of low interest and weak power in the first phase of the innovation process. Innovating companies need the education offered by the training organisations, but the training organisations have weak power to become involved in the innovation process. Of course, training organisations try to market their services, but the respondents saw their interest as lower than that of the research organisations. This was considered to be applicable in both the medical implant and the car manufacturing sector.

In the second phase of the innovation process, the idea is developed further into a viable solution ready to be diffused once this phase is finished. The analysis of stakeholder influence in the second phase of innovation process is presented in Figure 4. The respondents highlighted that, at this point, external funding is often sought from national or European-level funding organisations. If the funding is granted, this means strict reporting policies are required, and societal responsibility issues, such as public dissemination of the created knowledge or a high-enough gender balance of the personnel in the innovation process, are often included within the requirements.

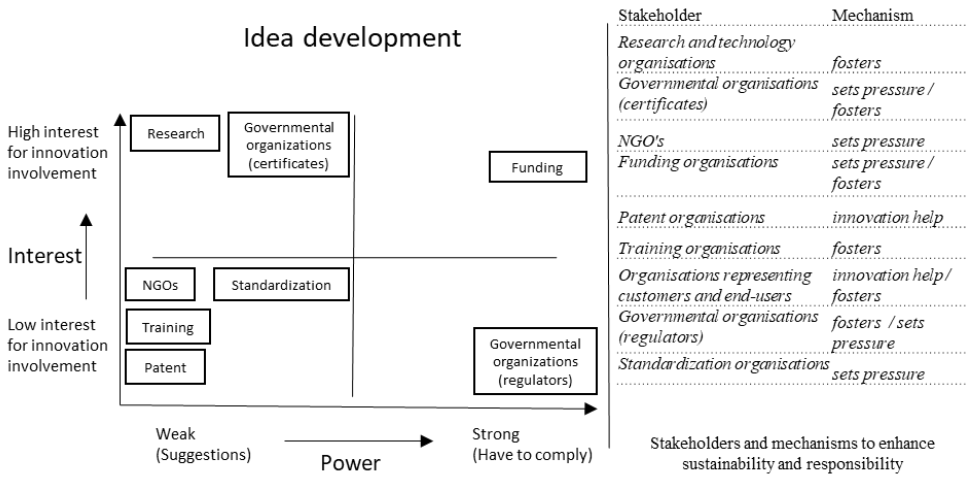

Figure 4 Stakeholder involvement (power/interest) in the idea-development phase of additive manufacturing innovations, and mechanisms to enhance sustainability and responsibility.

In the case of standardising emerging AM technology organisations are involved in order to create the best new standards for the technology. New AM technological solutions and new AM products must also have the relevant certificates to be diffused in the market. For this reason, the governmental organisations which oversee the certificates need to stay up to date by seeking new knowledge about the emerging technologies. The companies at the forefront can benefit from the participation of such organisations by getting their knowledge heard and getting feedback from both the standards and certifications to develop their products accordingly.

The analysis of the diffusion phase of the innovation process is presented in Figure 5. During the diffusion phase, organisations representing customers and end-users have a powerful position, and they are highly interested in being involved in the innovation process. These organisations are advocacy groups that can represent, for example, customers in a certain medical field or, in the car sector, conduct testing and inform the customers about the new innovations and their reliability. According to the workshop participants, such organisations try to provide the best new innovations to the customers they represent. Therefore, their role is important for AM companies trying to diffuse their innovations, meaning that AM companies try to convince and involve organisations representing customers to make sure that innovations are successfully diffused by being socially desirable.

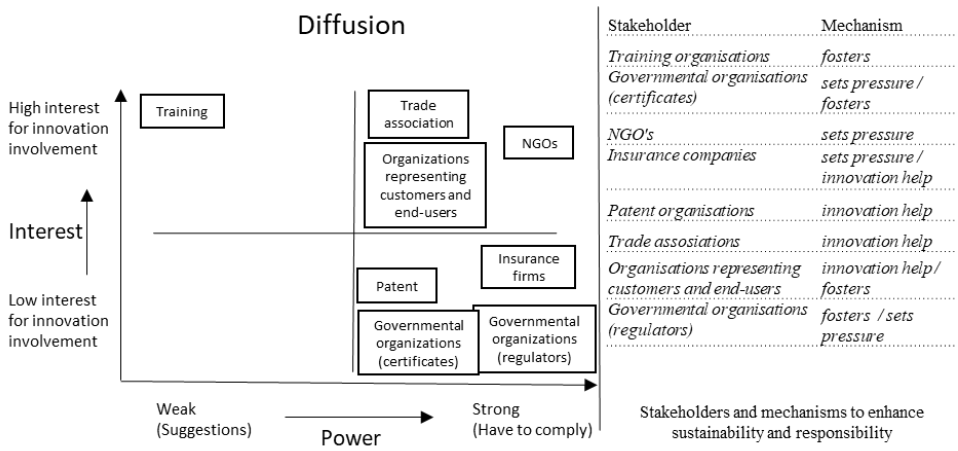

Figure 5 Stakeholder involvement (power/interest) in the diffusion phase of additive manufacturing innovations, and mechanisms to enhance sustainability and responsibility.

Compared to the research institutes, insurance companies are an example of the other end of the spectrum. Based on the answers to the survey and the data from the workshops, it was found that, in the context of this study, insurance companies do not seek to become involved to the innovation process actively; their involvement was only seen in the last phase of the innovation process, during innovation diffusion. Especially in the case of AM medical implants, the innovating companies have to convince the insurance companies that their product, which might be more expensive than traditional implants, are better for patients in the long run. Therefore, insurance companies were considered to have low interest in seeking to become involved in the innovation process,

but they wield great power when it comes to successfully diffusing an innovation, such as a medical implant, in the market. This can, of course, be the case because of the rather novel nature of the AM sector and AM implants, and in the future the role of insurance companies can become more active. The insurance companies were not considered to be very important for the car manufacturing sector.

Discussion and conclusion

This paper started with the premise that AM innovations require the involvement of stakeholders both within and outside the direct supply chains of AM firms for the success of sustainability- and responsibility-oriented innovations. The research question was this: "How do different stakeholders influence AM innovation activities in relation to companies in the AM supply chain to enhance the sustainability and responsibility of AM innovations?" To be answer this question, the stakeholders were first identified and described. Then, their involvement was analysed using stakeholder analysis method of a two-by-two matrix, with interest in taking part in the innovation process as one attribute and the power to influence the company's decisions in the process as the other attribute. In addition, the mechanisms of stakeholder influence to enhance sustainability and responsibility was analysed using three categories: fostering, setting pressure or providing innovation help. This analysis was then conducted three times, once for each of the three innovation process phases – idea generation, development and diffusion – thus combining the method of stakeholder mapping (Bryson, 2004) and influence mechanisms (Meixell and Luoma, 2015) with the framework of the three phases of innovation process (Hansen and Birkinshaw, 2007).

The findings contribute to the limited previous research by adding the perspective of external stakeholders' influence to the AM innovation process to enhance sustainability and responsibility. This study offers new insights on the complex innovation networks in which different stakeholders take part. In these networks, the stakeholders use their power to influence the different companies in the AM supply chain or companies may seek the help of the stakeholders in order to enhance sustainability and responsibility outcomes. The findings contribute to the research need to recognize those stakeholders without an economic stake in the supply chain who can contribute to the sustainability and responsibility of innovations, as requested by Pagell and Shevchenko (2014). If a company's aim is to create possibly harmful innovations from the viewpoint of sustainability and responsibility, the results of this study offer no help, although such companies have to comply when a stakeholder with high power applies pressure.

This study reveals that different stakeholders support the sustainable and responsible AM innovation projects in four different ways: 1) reactively, when AM companies seek external support and stakeholder's power is weak, meaning that their advices or involvement is voluntary from the perspective of the innovating company; 2) stakeholder involvement can be very active but weak in power, meant to help the innovation success or to foster its sustainability or responsibility aspects; 3) the participation of stakeholders can be very active and powerful, meaning that companies need to comply with everything that the stakeholder advises (in this case, lack of compliance would usually greatly endanger the success of the innovations); and 4) the involvement interest of the

stakeholder is low but powerful, and it sets sustainability- and responsibility-related pressure (for example, it would be against the laws and regulations to not comply).

Even though the earlier studies about the stakeholder involvement in AM product innovation processes were limited, it can be argued that the findings of this study are in line with the results by Rylands et al. (2016), namely that training organisations and research institutes are important for the AM innovation process. This study adds to this insight by noting that training can be a good way to educate AM companies in the areas of sustainability and responsibility. This study supports the study by Monzón et al. (2015), which claims that standardisation organisations also influence and can be influenced during the AM innovation process, and by Koch (2017), whose results indicate that engineering associations are important hubs of knowledge and ideas. The findings of this study also support the views of the stakeholder theory (Freeman et al., 2010), namely that innovations are not invented by a single company but that there are other stakeholders, especially external stakeholders, which have influence on the innovation process.

The findings offer practical contributions to managerial decisions by showing external stakeholders' influence in the AM innovation process to enhance sustainability and responsibility. The findings and the analytic framework provide AM companies with a way to identify the central stakeholders, promote the market access of socially desirable products and achieve other benefits during the innovation process. The study creates new knowledge from the perspective of the firms directly involved in the supply chain of AM, acknowledging the complex business network around them. This study provide insight to the companies who want to add sustainability and responsibility aspects to their innovations, by encouraging them to seek cooperation with stakeholders as one possible solution for the concern raised by Beltagui et al. (2020), namely how to increase the innovation success of smaller innovative companies.

This study used an exploratory research design with workshops and a qualitative survey to collect data. Using this kind of research design allowed to achieve a wide understanding of the phenomenon. However, the design does not allow to analyse single stakeholders very deeply. The empirical findings are limited to the medical and car business sectors of the AM industry, albeit the analysis framework might be well transferable to other research context. Each of the respondents also gave their organisation's point of view on the research task, possibly causing a single-respondent bias. In the future, more respondents from each organisation could be involved for a more in-depth study on external stakeholders' involvement. Also, respondents from the relevant stakeholders could be included to compare their intended ways to enhance sustainability and responsibility and the perceived mechanisms by the innovative companies.

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