Stakeholders' involvement in additive manufacturing innovations

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Abstract
Additive manufacturing (AM, 3Dprinting) is gaining increasing attention in the manufacturing industry as a collection of novel advanced technologies, supply chains and processes. Firms implementing AM are active in innovation, but successful innovation requires support from other firms in the supply chain and secondary stakeholders. This exploratory study seeks new knowledge on secondary stakeholders' involvement in AM innovation activities. The findings reveal who the secondary stakeholders are and their scope of involvement in the AM firms' innovation process. The study contributes by characterizing the network complexity in AM innovations and guiding AM firms' actions toward stakeholders.

Keywords: Additive manufacturing, stakeholder involvement, innovation

Introduction
Additive manufacturing (AM) is a relatively novel manufacturing approach that implies changes in manufacturing technologies, the use of digital product designs, and a new process of joining and adding material, usually layer by layer (ASTM, 2012), to produce goods. The diffusion of AM technologies in the manufacturing industry will require innovations in the business models, supply chains for the firms involved, and products and services (Weller et al., 2015; Martinsuo and Luomaranta, 2018), driving AM firms to be very active in their innovation activities. Innovation, in its classical sense, means the introduction of a new product, process, or business model for a commercial purpose (Schumpeter, 1934). We concentrate on innovations in AM-related products, including both the manufacturing technologies and the new goods being manufactured.

Creating and introducing new offerings in the competitive industry requires a systematic innovation process (Drucker, 1985). This innovation process can then be divided into three sequential phases that are idea generation, idea development, and the diffusion of the developed concepts (Hansen and Birkinshaw, 2007). In idea generation stage, an idea for the innovation is generated inside a firm or through external sources. In the idea development stage, the best ideas are chosen and the development work starts internally or with external sources. In the diffusion stage, firms try to commercialize the outcome of the innovation.

In the innovation process, the innovating organization can use the support of external resources. Besides firms operating in the direct supply chain of AM, various stakeholders with different interests and demands have an influence on AM product innovations. There are multiple definitions of stakeholders (Miles, 2017) and these different definitions serve

their dedicated purposes by focusing on the relevant stakeholder attributes in their context (Freeman et al. 2010). This study concentrates on secondary stakeholders - those external organizations with an interest in or contribution to AM product innovations, but who are not the key firms, institutions or customers in the direct AM supply chain.

Previous AM-related research has identified that research and training organizations have an important role in giving training regarding AM and transferring knowledge to firms (Rylands et al., 2016). Standardization organizations are important stakeholders when standards are created in the emerging technology (Monzón et al., 2015). Before the specific work of standardization organizations, other stakeholders such as trade organizations and engineering associations specify the need for standards and influence through the standardization 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 in this study is to explore the involvement of secondary stakeholders in the innovation process of AM products. The goal is to create knowledge on how different secondary stakeholders take part in AM innovation activities with firms in the AM supply chain and, consequently, help firms benefit from their involvement. The primary research question is: *How do different secondary stakeholders participate in AM innovation processes with the firms in the AM supply chain?* The question is approached from the perspective of the innovating firm in the AM supply chain and at the product level in an emerging industry of AM.

Literature review

Defining stakeholders

The term 'stakeholders' has many alternative definitions (Miles, 2017). In stakeholder theory, stakeholders are assumed to be a part 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 stakeholders use the context and stakeholders' attributes to serve the purpose of the study (Freeman et al., 2010), meaning that in a case of a large multinational firm, 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 firm's perspective and to which stakeholders should the managers pay attention (Mitchell et al., 1997). Usually stakeholders in strategic management are categorized into shareholders, firm employees, customers, suppliers and sometimes competitors, which can be referred to as primary stakeholders, and then to the secondary stakeholders who are external organizations with regards to the supply chain, not directly involved in for example manufacturing and delivery, but may indirectly influence the innovation process (Freeman et al., 2010). These secondary stakeholders can be for example national governmental organizations and labor associations.

Some management frameworks handle business environment changes for the firms as external forces (see for example PESTLE analysis), and for example legislation is part of such forces. These external forces are difficult to influence, but they have an influence on the firm, and the organizations in question could well be categorized as secondary stakeholders. Stakeholder theory suggests that the relationship with secondary stakeholders is more complex and despite secondary stakeholders' influence, firms can also use these relationships as two-directional (Freeman et al., 2010).

It has been noticed that firms give relatively little attention to systematically identifying and analyzing important stakeholders (Bryson, 2004), but such relationships can cause uncertainties in the innovation process. Therefore, exploring stakeholders and their relationship with innovating firms in the innovation process is relevant for managers and practitioners. Defining the stakeholders in a too narrow manner would most likely lead to ignore some important stakeholders from the perspective of innovation in an emerging technological area. This study purposely looks *beyond* the manufacturers' customer-oriented core supply chain and concentrates on those external organizations – secondary stakeholders - with an interest in or contribution to AM.

Involvement of secondary stakeholders in the innovation processes

A focal firm's relationships with the secondary stakeholders have increasingly been considered as an important way of developing innovations (Haeckel, 2004). The secondary stakeholders can participate in the innovation process, for instance, by offering knowledge through a network that they represent (possibly including customers). In some cases these secondary stakeholders are non-profit organizations whose interest is not to make profit by conducting business, but to serve a social cause (e.g. environmental protection, or a university offering education). Developing relationships with these secondary stakeholders can foster innovation by creating suitable conditions for discovering relevant ideas. Gaining access to these dense networks that differ from the focal firm's direct supply chain can offer a different view of the marketplace and offer early warning signs about shifts in public tastes and values (Yaziji, 2004). An empirical finding from biomedical innovations shows that a firm's experience of collaborative relationships with partners in a hub provided by secondary stakeholders was a key determinant of innovation (Powell et al., 1996).

In addition to this passive involvement, secondary stakeholders can have a more active role in the innovation process. Findings from strategic management show that organizations are more inclined to protect their existing processes than develop new ones until they are sure that the development is almost risk free. Therefore, a stakeholder (primary or secondary) outside of the firm can try to force the innovation if a firm does not do it voluntarily (Van de Ven 1986). Developing relationships with non-governmental organizations (NGOs) is good for the firm's social legitimacy. Firms may need these relationships with NGOs to be perceived as socially and environmentally responsible (Berger et al., 2004). Firm-NGO partnerships can address both broad and complex societal issues and they can become a source of competitive advantage (Bonfiglioli et al., 2006).

The earlier studies in the context of AM have mentioned secondary stakeholder involvement in innovation processes briefly. For example, research and training organizations have an important role in giving AM-related training and transferring knowledge to firms (Rylands et al., 2016) so that they can start the AM innovations in the first place. They can be of help also later in the innovation process for example in the testing and development phases. In the case of an emerging technology, standardization organizations are important stakeholders when standards are created (Monzón et al., 2015). Before the specific work of standardization organizations, other secondary stakeholders such as trade organizations and engineering associations specify the need for standards and influence through the standardization process (Koch, 2017). By developing relationships directly with the standardization organizations or more likely through associations, firms can influence in standardization for example so that it enhances their chances to diffuse their innovations.

Research design and method

The research design is qualitative and exploratory in nature because of the limited previous knowledge on stakeholder involvement in AM innovation activities. The study was targeted at two major industries where AM has shown great potential: car manufacturing and medical implants. The focus is on secondary stakeholders.

Figure 1 illustrates the research context. The AM supply chain is presented in the middle. Any firm within the supply chain can be considered as a focal firm, and the other firms are its primary stakeholders. Outside of the supply chain are the secondary stakeholders, whose participation in the innovation process of the focal firm is covered in this study.

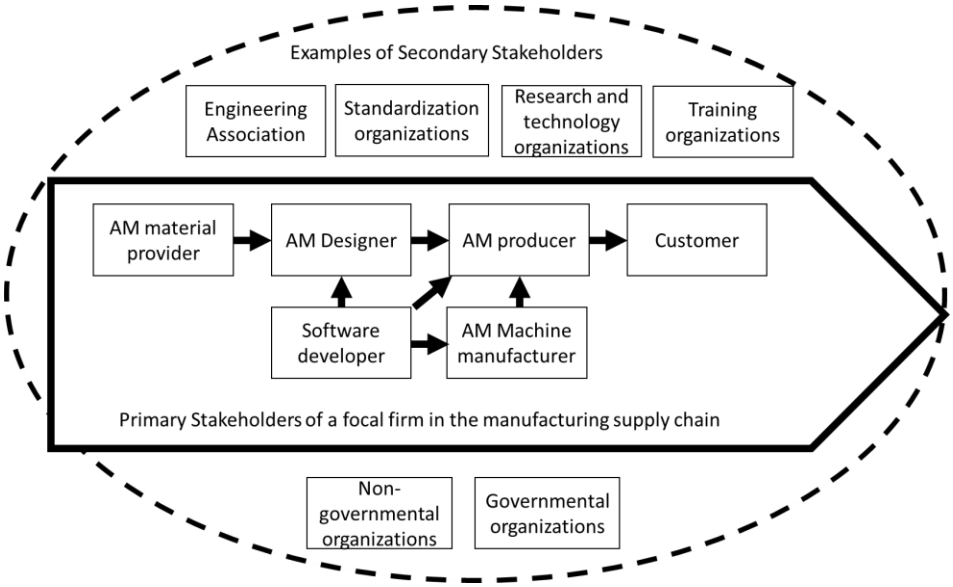

Figure 1 – Illustration of the AM supply chain (primary stakeholders) and secondary stakeholders

Data collection

Data were collected through two workshops and a survey with thirteen AM firm and stakeholder representatives (labeled as organizations A...M). Background information on firms that participated in the workshops and survey is presented in table 1. Organizations A and F are involved solely in the medical implants industry. Organization B represents car manufacturing industry, whereas the rest of the organizations are involved in AM industry more generally, including both – car and medical implants industries.

Table 1 – Background information on firms participated on the workshops and survey

Organization	**AM firm role**	**Secondary stakeholder role**
Organization A	AM designer, AM producer	
Organization B	AM designer, customer	
Organization C	Software developer	
Organization D	AM designer, AM producer	Research organization
Organization E	AM designer, AM producer	Research organization
Organization F		Engineering association, Training organization
Organization G	AM machine manufacturer, AM feedstock provider	
Organization H		Engineering association, Training organization, Research organization
Organization I	AM feedstock provider	Research organization
Organization J		Non-governmental organization, Research organization, Training organization
Organization K		Research organization, Training organization
Organization L		Education organization, Training organization, Research organization
Organization M		Training organization, Research organization

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

After the listing of stakeholders, a survey was sent to the firm representatives concerning the activities that the stakeholders engage in with the AM firms. The question in the survey was: "Based on your experience, what inputs or requirements do the external stakeholders bring to the network of firms in additive manufacturing supply chain?" External stakeholders were divided into: funding and insurance firms; training organizations; regulators and patent authorities; trade associations and customer representing organizations; research organizations; and other. Respondents had a chance to offer an open-ended response systematically to each identified stakeholder, and also add stakeholders they considered as relevant.

Another workshop was organized with the same firms and a group of researchers to recognize the interactions, activity inputs and outputs of stakeholders with the firms in the AM network. In this second workshop, the participants discussed in industry-specific teams (car manufacturing, medical implants) to fill in and organize 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 firms in the AM supply chain, requirements of the secondary stakeholders, benefits to AM firms from the relationships, and phase in the innovation process of the secondary stakeholders' involvement. Discussion during the workshop was documented into memos and flipcharts.

Analysis

The analysis concentrates first on identifying and defining the secondary stakeholders (results in table 2) and then mapping the secondary stakeholders' involvement for three AM innovation process phases (table 3). Based on the answers about secondary stakeholders in workshop 1, table 2 was formed by listing all the relevant stakeholders, removing those expressions that concerned primary stakeholders, and combining the repeating attributes of secondary stakeholders into logical descriptions.

Based on these data, the power/interest matrix analysis was done, according to the three phases of innovation process, i.e., 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. These attributes can be for example power and interest, importance and influence, or support and opposition (Bryson, 2004). For this study, the power and interest matrix was chosen since it offers the most insight for studying the stakeholders' involvement in innovation. The data from the survey and the second workshop were used, to analyze each phase at the time using the power and interest matrix.

Interest attribute reveals if the secondary stakeholder is very pro-active in its involvement or if is more passive. It is also important to understand the power that each stakeholder possesses, because it creates understanding on whether the secondary stakeholder is empowering or controlling the innovation process. Also the power may lie in the ability to affect innovation in the short term or affect its success and acceptance in the long-term (Mathur et al., 2007) Figure 2 illustrates the power/interest matrix used in this study. During the analysis, the interest of the secondary stakeholder was considered as high if an AM firm respondent described a secondary stakeholder's participation for example as follows: "they brought the idea" or "they started the discussion" or "they were very active". Concerning responses by secondary stakeholders themselves, the interest was considered as high if they claimed an active role such as "we had the idea and then we tried to find a firm to collaborate with us". In the analysis of power, strong power was coded if the respondents expressed that: "we have to comply" or "it is very important to collaborate with them". Weak power was coded if the expressions were for example the following: "it was not necessary but beneficial to us" or "we collaborated voluntarily".

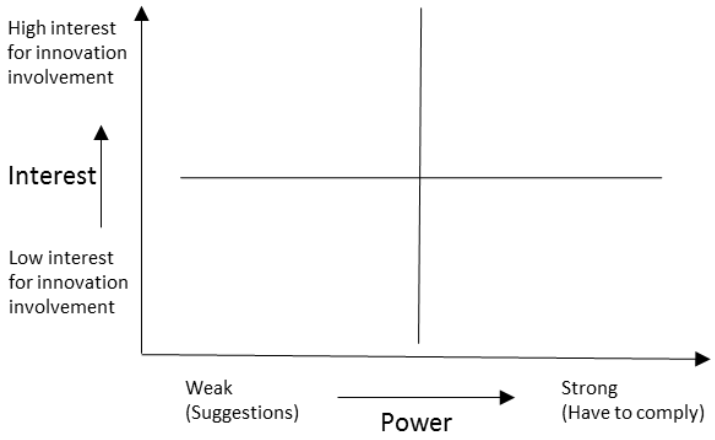

Figure 2 – Analysis framework for the secondary stakeholders

Findings

Identifying and describing secondary stakeholders

This study identified the key secondary stakeholders for AM innovation processes. They are: Regulators, NGOs, funding organizations, training organizations, research institutes, standardization organizations, patent organizations, trade associations, organizations representing customers and end-users and insurance firms. Table 1 shows the identified secondary stakeholders and their description from the perspective of the firms involved in the study, based on their answers to the survey.

Table 2 – Identified secondary stakeholders and their descriptions

Secondary Stakeholder	**Description**
Regulators	Regulators regulate laws such as tax laws. They also try to secure reliable and sound products, by giving regulations for compliance and granting certificates. For these certificates and laws there needs to be collaboration with research institutes, AM machine manufacturers and AM producers. Regulators also set regulations or encourage firms to develop clean, material- and, energy saving technologies, they set safety regulations and try to create new job opportunities.
NGOs	NGOs in the context of AM most often are 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. The information that NGOs can provide about the effects of new technology on 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 AM applications.
Funding organizations	Funding organizations can be national or for example European level organizations. Their input - funding - enables new product development in a quicker pace. They require from firms comprehensive resource allocation and reporting to support the AM innovations in the most efficient way.
Training organizations	Training organizations provide standardized training, give knowledge as quickly as possible to the organization in AM and offer different formats in training (including degree programs and lifelong learning). The training can deal with general AM knowledge as well as best practices. Training organizations need to accumulate the state of art knowledge, gather funding, and analyze firms' current situation and the market. Trainings with multiple attendees can enhance the connections within the AM network.

Secondary Stakeholder	Description
Research organizations	Research organizations are sometimes the main contributor and starting point for developing innovations in the early phase (idea generation, development), but they need firms to commercialize the innovations (development, diffusion). Research organizations rely on funding organizations and firm partners to fund their research and development activities to develop innovations. Research organizations contribute to new regulation creating processes, and new standard making processes. They also transfer knowledge to training organizations.
Standardization organizations	Standardization organizations set the standards for characterization of AM produced parts. This includes data formats, reliability, quality requirements and restrictions on software use. Through the standard compliance, this can foster some technologies more than others. To create standards, standardization organizations need to collaborate with industry experts, research organizations and firms in AM value chain. Standards ensure common understanding among stakeholders, which is important for communication and innovation purposes. Standardization organizations also coordinate the expert groups to develop standards.
Patent organizations	Without patents the innovations would be freely adoptable by any competing firm. Since there is a cost associated with innovation, the patents serve as a securing mechanism to protect the ownership of the innovation and enable the owner to make profits to cover the costs of the innovation. Patent organizations provide help and instructions to the firms seeking to file a patent application. Patents can serve also as source of knowledge after they expire and become public. Especially if the patented technology becomes industry standard, firms have all the knowledge about the technology, after the patent expires or it is licensed by the patent owner.
Trade associations	Trade associations provide new knowledge to their members, strengthen current networks, create, and explore new networks. Trade organizations seek to gather information about the markets to provide marketing possibilities to different countries. Trade associations need to collaborate with research organizations, regulators both within their country on outside as well as with its members. Professional associations such as engineering associations are included in this category.
Organizations representing customers and end-users	Organizations representing customers and end users identify possible applications and thematic areas for AM. They collect requirements of the customers and end-user needs to analyze possibilities for further applications of AM. They have the possibility to influence the market (and in this way, the whole value chain) through the feedback of customers and end users. For this, they need to collaborate with communities of interest, informal networks, educators and technology users. Firms in the AM value chain can use the knowledge from organizations representing customers and end users to help to understand the potential needs and concerns from customers and end user.
Insurance firms	Especially in the medical sector, insurance firms can foster some technologies more than the others through the insurance decisions. This is an economic aspect for the medical sector in terms of risk management (granting insurance for AM implants vs. traditional implants), and has to follow regulations as well. Insurance firms also offer background information about risks that inform AM firms about the possible volumes and needs of certain medical implants.

Analyzing the involvement of the secondary stakeholders in the innovation process

The power/interest matrix analysis was done for each of the innovation process phases respectively and the results are presented in the table 3. For example research organizations had a high involvement in the innovation process phases of idea generation and development, as workshop participants discussed this actively. In the car manufacturing sector, research organizations were mentioned as stakeholders who most often generate and introduce new

AM component ideas or AM methods to car manufacturers' products or production. Especially in the medical implant innovation process, workshop participants mentioned that the research organizations have high interest of being involved in the innovation process in the development phase when the implants go through clinical testing. Ultimately they do not have enough power to go through the whole innovation process by themselves, but they need the AM firms. On the other hand the focal firm does not necessarily need the research organizations, but they can benefit from the faster development through the involvement of research organizations.

An example of low interest and weak power in the first phase of innovations comes from training organizations. According to the workshop participants, innovating firm needs training organizations to supply the education, and they have weak power to involve in the innovation process. Of course training organizations try to market their services, but their interest was seen as lower than research organizations among the respondents. This was considered to be applicable in both the medical implant and car manufacturing sector.

Table 3 – Stakeholder involvement in additive manufacturing innovations

	Idea generation		**Development**		**Diffusion**	
Secondary Stakeholder	**Interest**	**Power**	**Interest**	**Power**	**Interest**	**Power**
Governmental organization (Regulations)	Low	Strong	Low	Strong	Low	Strong
Governmental organization (Certificates)			High	Weak	Low	Strong
NGOs	Low	Weak	Low	Weak	High	Strong
Funding organizations			High	Strong	High	Strong
Training organizations	Low	Weak	Low	Weak	High	Weak
Research organizations	High	Weak	High	Weak		
Standardization organizations			Low	Weak		
Patent organizations	Low	Weak	Low	Weak	Low	Strong
Trade associations	Low	Weak			High	Strong
Organizations representing customers and end-users	Low	Weak			High	Strong
Insurance firms					Low	Strong

In the diffusion phase of the innovation process, organizations representing customers and end-users have a powerful position and they have a high interest in involving in the innovation process. These organizations are advocacy groups that can represent for example customers in a certain medical field, or conduct testing and inform the customers about the new innovations and their reliability in the car sector. According to the workshop participants, such organizations try to provide the best new innovations to the customers they represent. Therefore, their role is important for AM firms trying to diffuse their innovations,

and AM firms try to convince and involve organizations representing customers so that their innovations would be successfully diffused.

Insurance firms are an example of the other extreme of the scale compared to the research organizations. Based on the answers from the survey and data from the workshops, insurance firms do not seek the involvement to the innovation process actively at all and their involvement was only seen in the last phase of the innovation process – innovation diffusion. Especially in the case of medical implants manufactured additively, the innovating firms have to convince the insurance firms that their product, which might be more expensive than traditional implants, is in the long scope better for the patient. Therefore, insurance firms were considered to have a low interest in seeking to involve in the innovation process, but they have a great power whether the innovation – medical implant – can successfully be diffused to the market. This can of course be the case because of the rather emerging sector of AM and AM implants, and in the future their role can be more active. The insurance firms were not considered to be very important for car manufacturing sector.

Discussion and conclusion

This research started with the premise that AM innovations require the involvement of stakeholders both within and outside the direct supply chains of AM firms. The research question was: *"How do different secondary stakeholders participate in AM innovation processes with the firms in the AM supply chain?"* With this study, we draw attention to the complex networks where also the secondary stakeholders have an important role with regards to creating and implementing AM innovations. The focus was on stakeholders' participation in terms of interest and power throughout the innovation process.

This study reveals that secondary stakeholders have different types of involvement over the innovation process, and this involvement varies during the innovation process very differently, depending on the specific stakeholder type. Different secondary stakeholders are involved in the AM innovation process with the firms in AM supply chains in four different ways. 1) Their participation may be reactive only when AM firms seek external support and their power is weak meaning that their advice or involvement is voluntarily from the perspective of the AM firm. 2) Their involvement can be very active but weak in power, potentially reflecting the stakeholders' unique capabilities that are useful in the innovation process. 3) Some stakeholders' involvement can be very active and powerful meaning that AM firms need to comply with everything that the secondary stakeholder advises (usually these kinds of stakeholders would greatly endanger the success of the innovations if AM firms do not comply). 4) Some stakeholders' interest is low but powerful (it would be for example against the laws and regulations for AM firms not to comply).

The findings offer contributions by adding to the limited previous research about secondary stakeholders' involvement and, particularly, by offering a holistic view to the stakeholder landscape of AM. This study adds the perspective and involvement of secondary stakeholders to the AM innovation process, while previous attention has tended to be on company dyads or direct AM supply chains only. The findings provide AM firms a way to identify the central stakeholders, promote market access, 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.

The study also lends support to some studies that have covered certain stakeholder groups separately. For example, the findings are in line with Rylands et al. (2016) concerning training organizations and research organizations as important stakeholders in the AM innovation process, Monzón et al. (2015) regarding standardization organizations influencing and being influenced during the AM innovation process, and Koch (2017) about engineering associations as important hubs of knowledge and ideas. The findings of this study also support the views of stakeholder theory (Freeman et al., 2010) in proposing that AM innovations do not happen in isolation within one firm alone, but there are other stakeholders - especially secondary stakeholders - that have an influence on the innovation process.

This study used an exploratory research design with workshops and a qualitative survey to collect data. This research design allowed to have a wide understanding about the phenomenon of secondary stakeholder involvement in the innovation processes. As a limitation, however, the design does not allow to analyze single secondary stakeholders or single innovations very deeply. The findings are limited to medical and car manufacturing sectors of the AM industry. Each of the respondents also gave their firm's point of view to the research task, possibly causing a single-respondent bias. In the future, more respondents from each firm could be involved for a more in-depth study on secondary stakeholders' involvement.

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