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Webs of Innovation and Value Chains of Additive Manufacturing under Consideration of RRI

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D2.3 Draft on Web of innovation value chains

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Contents

1. Introduction

This report gives an overview on the work which was performed in the first project year on conceptualisation of the web of innovation value chains in AM including the consideration of opening of RRI. This deliverable 2.3 is a document of ongoing work. It starts from the definition of web of innovation value chain in the call and the proposal, derives an understanding on web of innovation value chains a process-oriented construct to the interpretation of the network of actors in AM performing innovation processes together. The outcomes discussed in the D2.3 deliverables build on the literature survey and the investigation on the actor-stakeholder relations in the AM systems.

D2.3 is a draft on the conceptual model and explains more the understanding of web of innovation value chain in the I AM RRI project- D2.4 will give the final conceptual model, D2.3 is an intermediated document for internal project work.

This deliverable D3-2 describes and explains the project's approach to building the underpinning logic and structure for the conceptual model of webs of innovation value chains, in the context of additive manufacturing. D2.1 presented an initial discussion of social performance and Responsible Research innovation (RRI) and gave also a large number and range of factors and indicators that may, according to this wide range of literatures, have a bearing on the outcomes of AM innovation activities. Report D 2.2 has given definitions of selected terms found in the literature reviews. This report will build on these 2 deliverables to explain how the concepts are brought together, developed and, as appropriate, interpreted for additive manufacturing (AM), in order to conceptualise the webs of innovation value chains.

1.1 Starting point – supply chain

The number of publications on additive manufacturing and supply chain showed nearly exponential growth during the last ten years. The articles deal with the structure of the supply chains, how the supply chains evolve, how the supply chains interact with other and how they initiate disruptive innovations. So, the considerations on the supply chain build the starting point for the conceptualisation of the web of innovation value chains. In order to begin to understand the relationship among the factors identified in the literature reviews, it is necessary to develop a conception of the social and industrial system that is the object of investigations in I AM RRI. The intent is to model and simulate these systems as webs of innovation value chains by computer to gain understanding. To arrive at that destination, it is necessary to build more familiar conceptualisations. Key terms such as 'innovation value chain' have been briefly defined in D2.2, but it is necessary to explore them more fully to understand their implications. It is also necessary to distinguish between these conceptualisations and more familiar ones to which they are related. The instinctive way to think about web of innovation value chain is to think about inter-connected firms and organisations being involved in production activities, this is as a supply chain or supply network. These are the inter-connected firms involved in producing materials, components or products (see

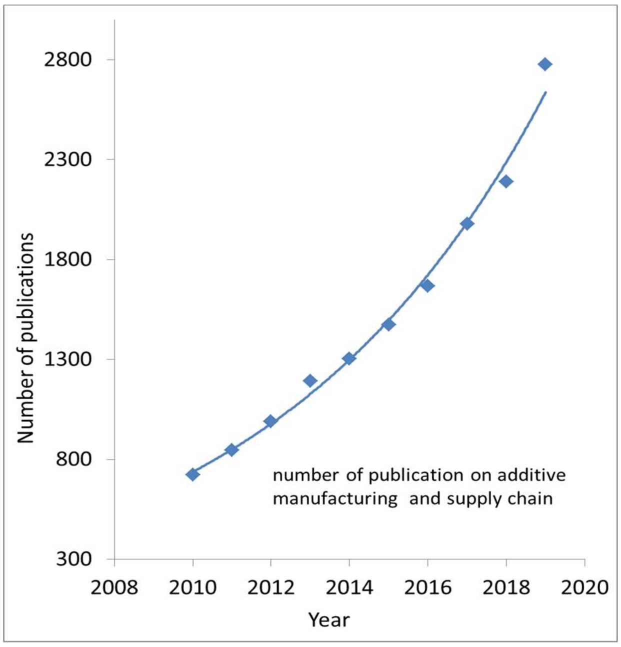

Figure 1: exponential trend of science activity on additive manufacturing and supply chain

D2.2). But our focus is not primarily on production as it has described in the literature of supply chain or supply network. The inclusion of the product development as process step the supply chain (Petersen et al, 2005) brings the understanding on supply chain closer to innovation. The number of publications on additive manufacturing and supply chain showed nearly exponential growth during the last ten years.

In general, a supply chain consists of different processes and may involve some different participants (although some will also be the same). In this report, the terms 'supply chain' and 'supply network' will be used to refer to the interconnected organisations involved in production and distribution. We will see later, that this is also an important part in the innovation process. In contrast, the terms 'innovation value chain' and 'web of innovation value chains' will be used in IAMRRI project to refer to the organisations in innovation processes. Criss-Crossing, which is mentioned as process for broadening innovations in the call can be well understood as interaction of different supply chain, where the crossing points seem to be more individual organisation in the supply network than process steps in the webs of chains.

By starting a supply networks thinking the findings presented in this report produces at least three key contributions to the project:

1. It enhances the understanding of innovation value chains from network perspective where innovation agents use social space to interacts and create value for innovation.
2. Our research follows the current trend on innovation studies, which has moved away from a liner model of innovation to a complex networks model of innovation. As we found during the data collection process, many innovation activities in additive manufacturing happen in parallel as a result of horizontal and vertical partnership among innovation agents such as researchers, manufacturers, customers, etc. The finding also reveals that successful innovation is not determined by a single initiative, but an interactive process facilitated through a number of innovation value chains (Kleine and Rosenberg, 1985).
3. The exercise used in this study help the project to visualise not only the relationships among the agents but also their position within innovation value chains. Moreover, the approach provides new nuances of traditional data collection method in the field of innovation as it was able to capture the complexity of the concept of webs of innovation value chains.

The interactions of organisation lead by co-creation and co-production to products. These products will generate in any organisation of the supply network economic value. Depending on the nature of the product added value for the society will be generated as well. The social values of a product will be described by its contribution to the support of the RRI keys like gender equality in the organisations, public engagement, contribution of the organisation in the supply network to science education, being in line with ethical norms or offering new solution for the grant challenges (strategic value). Even if the starting point was the supply chain/supply network approach, which is dominantly the customer oriented, the perspective to a societal orientation (RRI) gave way to a fundamental change in target group. It turned the customer orientation to the stakeholder orientation and involvement.

2. Applied research method to build up understanding

In order to achieve the objectives of this report, a combined method was applied. This research approach involves workshops with industrial partners, network mapping exercise and interview to capture how agents are interconnected, and how the involved in product development processes, which co-creates value.

In doing so, information on network of relationship were collected from workshops and interviews with industrial partners followed to a deeper exploration on how routines and practices work in real life. The overall data collection process produced the first sign of innovation value chain in the form of what we term 'Actor-Stakeholder Network Maps'. The maps show the key players in these industry sectors, and how they relate to one another, then, drawing on the literature, we set out our understanding and start to define the notion of 'innovation value chains'. This is done in general terms and also for our two application sectors, namely automotive and medical. We then build on this to develop an understanding of what is termed, in the original SwafS call, 'criss-crossing' webs of innovation value chains.

Since we know little about innovation value chains process in the context of AM, we conduct a two-stage research study that views the subject of the study from both a positivist and phenomenological perspective. The first stage is thus an identification of the agents and their roles during innovation process while the second stage develop the concept of web of innovation value chains from the literature. Combining both stages, we develop the framework for webs of innovation value chains.

To achieve the objective, the design science methodology was chosen. The approach is defined as 'an approach aimed primarily at discovery and problem solving… in which problem-solving research and theory-oriented academic research can complement one another… recognizing and building on this complementarity is especially crucial, because problem-solving–oriented research produces the very artefacts (e.g., technologies) that empirical OM [operations management] research subsequently evaluates in an attempt to build explanatory theory.' (Holmström and Ketokivi, 2009, p. 65). Using this method, the I AM RRI project aims to involve AM practitioners or industrial partners to produce and to develop the model of Webs of Innovation Value Chains of Additive Manufacturing.

Literature may offer insights into the innovation process of additive manufacturing. However, in order to address the real-word practical issues and offer solutions, the development of the conceptual model require inputs from practitioner and industrial partners. Developing this model is therefore the central task of this report, in order to combine the theoretical knowledge that already exists with the context-specific practical knowledge of additive manufacturing. The following section will describe the steps in collecting data from practitioners, industrial partners and researchers

2.1 Research on supply chain/networks (actor/stakeholder network)

Step 1. Developing the generic actor-stakeholder network map

The first research task focused on exploring the composition of the AM supply network structure. This was done by inviting the consortium partners to characterize their tasks and involvement in the AM supply network in an interactive workshop (project meeting Leoben, June, 2018). The consortium partners divided into three groups containing both practitioners and researchers. The data collected from the workshops provides the background to define the context and understanding of how additive manufacturing works in two sectors addressed by the IAMRRI project, automotive and medical. This also allows the respondents of this study to associate with their own context. In this step, the industrial partners of I AM RRI consortium were invited to participate in the workshop. The workshop implemented visualisation techniques and build a physical model in the form of network maps. The use of network maps in observing process or strategic options is not new. Scholars such as Mintzberg (1987) and Piaget (1971) argues that the construction of things, such as manipulating objects, build knowledge in the process of understanding an abstract concept. In this workshop, we expanded the technique by asking the industrial partners to not only describe their network but also reflect how idea develops and innovation emerge. The researchers' role was to probe for more in-depth views and summarize the synthesized view to verify its correctness through inquiring the practitioners' feedback.

The workshop resulted in three different diagrams/ flow charts, each representing one group's view to their own innovation value chains. The workshop results were then used as input to a general process mapping technique, to draft version 0 of three actor-stakeholder network maps: a general map, a map for automotive industry, and a map for medical industry. The drafted network maps were presented to the researcher team, to get further information input (researcher meeting Delft, September 2018). Furthermore, the draft process maps were sent to the entire consortium, for reflection and additional feedback. These inputs were used to develop an improved version 1.0 of the generic actor-stakeholder network map (dated 17.10.2018).

Step 2. Identifying stakeholders' activities and mapping the innovation value chain

Literature has been provided some insights into innovation value chains; but in the context of additive manufacturing which is focus of I AM RRI project hardly any literature was found. The actor -stakeholder networks are new, because the development of technology and market basis are still under development. The RRI approach brings society as target group in the centre of innovation, so it opens economic consideration and customer/user orientation to societal orientation. For this reason, we then proceeded to expand and further develop the network map, to cover the stakeholders' activities, to map the phases of the innovation value chain, and to include more comprehensive interactions between actors in a value chain and stakeholders influencing the innovation processes (secondary stakeholder).

Again, consortium partners were invited to identify secondary stakeholders that influence AM innovation processes. Information was first gathered through a survey sent to the partners, asking about the involvement of secondary stakeholders. After the survey data was analysed, the results were used as a starting point for more in-depth knowledge creation. This was done in another interactive workshop (project meeting Düsseldorf, December 2018). Again, the groups included both practitioners and researchers, main content input was inquired from practitioners, and the researchers' role was to probe for more in-depth views and present the synthesized view to verify the findings against the practitioners' experiences. In the workshop, one group discussed the medical implant industry, another group discussed car industry and the third group focused on the stakeholder's activity. The industry-specific groups focused on the progress of innovations and involvement of actors and stakeholders regarding example product innovations, in line with the general framework of innovation value chains. The stakeholder group specified each stakeholder's activities with more detail. The results of these discussions were documented into posters and memos.

These inputs were combined with the previous data and used to map the innovation value chains for automotive industry and medical industry. Also, a version 2.0 of the generic actor-stakeholder network map was developed and this was again shared with the consortium partners. At this point, it became evident that understanding every possible stakeholder's relationships with the innovation network would be extremely complicated and can only be understood by computational modelling. Even the drawing of a single map with all of the connections between organisations preforming the products and services would make the visualisation of the map very difficult. We selected actors that are needed to manufacture a product for customers. Purposely the actor-stakeholder network on automotive and medical networks excluded concerning machine manufacturing, materials or digitalisation and software at this point. This approach leads also to a more generic maps for innovation networks and innovation value chains for production of products by AM technology. But the innovation value chains on materials, AM machines and technologies or digitalisation and software have to be taken into account separately.

2.2 Literature survey

Parallel to the two workshops, a literature review was conducted, to compare the findings from the project work to previous research. Previous literature did not offer a comprehensive illustration of the full AM innovation network that would include the multiple layers where AM innovations operate as well as comprehensive mapping of stakeholders. However, the analysis of the previous literature revealed that combining the results reported in separate previous studies jointly supported the findings of the actor-stakeholder network map descriptions achieved in this study. Most of the studies regarding AM supply chains and firm roles during innovations were from a focal firm perspective or concerned a dyadic relationship (for example Rogers at al., 2016 and Rylands et al., 2016). An illustration of AM supply chain processes is presented in FoFAM (2016) report, it covers the AM product manufacturing process and lends support to findings in this study. Different stakeholders and their involvement for AM innovations are covered for example by Koch (2017) and Monzón et al. (2015) who note that standardization organizations, regulators and engineering associations are important stakeholders for the AM companies' innovation activities.

2.3 Combining literature survey and research on actor-stakeholder networks

Actors' and stakeholders' properties were then specified based on the data collected through the survey, discussions in the workshops and short interviews with the practitioners. These properties as well as actor-stakeholder relationships and interactions were then described in an excel file. In the excel file, every relevant interaction of a specific actor with other actors and stakeholders was marked together with the nature of the interaction (cooperation, customer-supplier, regulator etc.). The objects of exchange (knowledge, physical objects, digital objects etc.) during the interaction were also added to the description of the relationships.

The list of factors including their characteristics were generated through an extensive literature review focusing on the innovation success in terms of market, strategic and social impact of additive manufacturing. In total, 117 factors were identified covering wide spectrum of analysis from organization, business model, project and social dimensions. Further analysis was conducted to evaluate the aptness of those factors in the context of AM. Further input was collected again from the consortium through additional discussions and workshops (project meeting Metz, March 2019). The developed table was iterated several times with the researcher group, to agree on the terms used and to develop the innovation value chain description further.

2.4 Identifying the factors and indicators relevant in the innovation value chains

In this stage, more refined factors and indicators were selected from the factors list. The purpose of this exercise was to identify the connection between the factors and the elements within the webs of innovation value chains. This includes the definition of the relationship between each individual factor and actors' or stakeholders' properties. This process is considered as a continuous process as a part of learning and understanding the behaviour of the system. Since literature offers only partial information on the linkages between actors/stakeholders, factors, and indicators specific to AM innovation value chains, we had to plan for additional reviews on other literature domains and accept that the result at this stage is partial and incomplete. Further empirical study will be conducted to enhance and complete this knowledge later in the project.

2.5 Transition to the webs of innovation value chains and innovation networks

To support the modelling of the webs of innovation value chains, two case examples were selected to illustrate the real-life contexts and circumstances of innovation value chains. The purpose of the selection is to entangle the complexity in the innovation process by examining innovation activities during the development of a new AM product. Two industrial contexts in automotive and medical sector were selected, as both sectors have potentially different types of innovation activities. In the medical sector, innovation can be triggered by a very specific need of users which may be strongly influenced by user-led design approach. In contrast, car manufacturer and OEM companies work together in orchestrating and introducing a new innovation as a part of their product development process. The examples in this report are used for illustrative purposes, and different aspects of their IVCs will be covered with further depth in D2.4.

3. The actor-stakeholder network maps

This section presents the findings in the form of maps from the workshops. The first map was to focus on identifying the agents, the content of exchange and the roles played by each agent during innovation value chains. It started with a simple diagram focusing on the product and how the agents are interconnected. Those agents are categorised into (1) additive manufacturing agents, (2) design agents and (3) demand and use agents. The additive manufacturing agents are the key player in industry containing machine operator, feedstock provider, integrator, quality assurance, post processing and distributor. In the design category, agents are represented by product designer, product designer for AM, software and scanner while the demand and use category includes the end users such as patient, surgeons, hospital and car manufacturer, and buyers. This project selected two applications of additive manufacturing as a context of this study, namely automotive and medical sectors. In both sectors, the adoption of AM technology is relative premature. There have been several developments, but the overall acceptance is still waiting for a momentum. I AM RRI selected both sector as they represent different market characteristics. In the automotive sector, the potential application of AM will be produced for mass production while the medical sector offers a relatively narrow and bespoke production process. The potential application of AM in automotive sector seems to be the production of certain parts in the car assembly or help to make tooling for certain manufacturing task. The use of AM in the sector will help the industry to benefit from faster development cycles, part assembly, lightweight material and custom product. In the medical sector, the application can be developed according to the need. AM offers economic benefit to produce medical devices or medical part in a low volume. Often the implant is designed and produced to the need of an individual patient. Figure 2 and 3 shows the initial network maps in automotive and medical sectors.

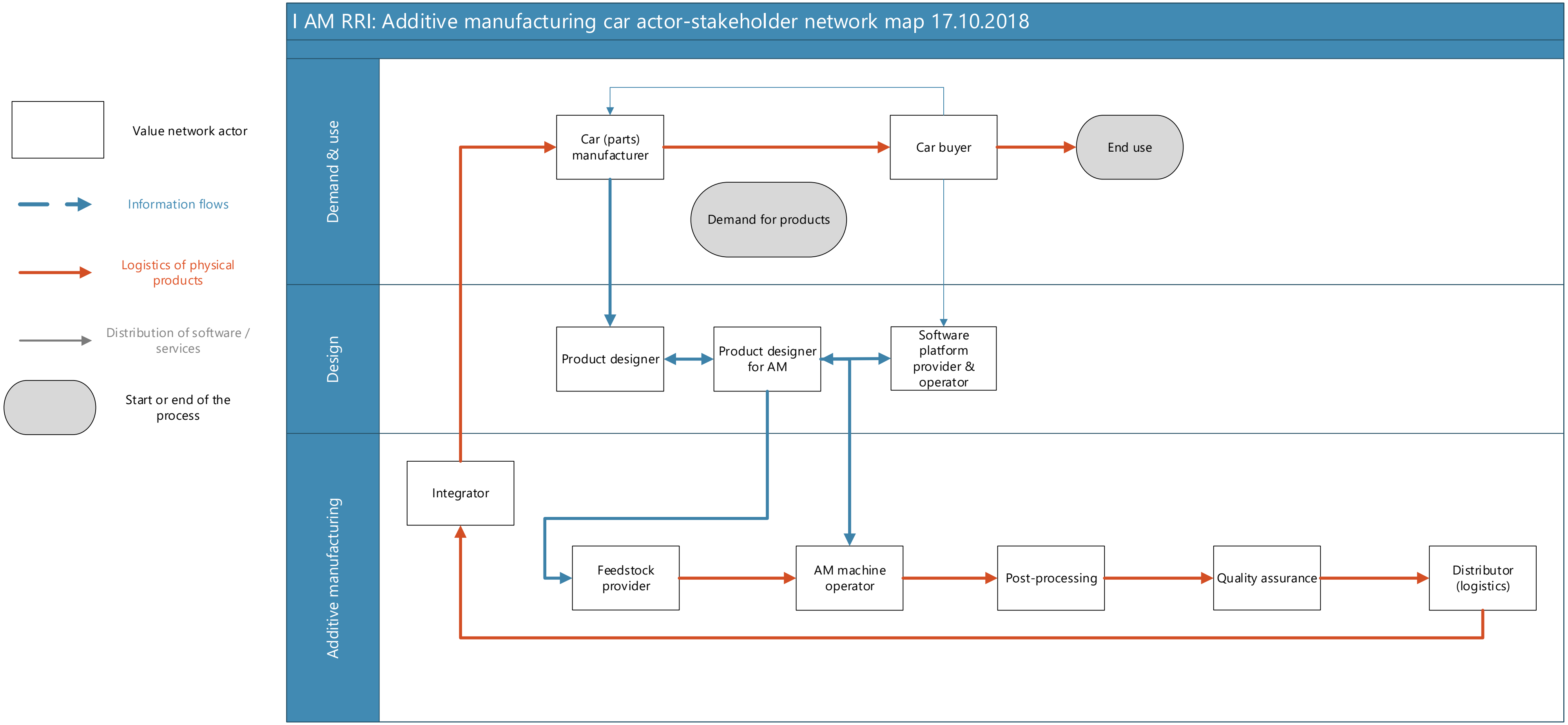

Figure 2: The initial network map in AM automotive sector – the result of the first version of actor-stake holder network shows more a supply chain network, which starts at the demand side of customer. The need for a product arrives from the customers demand (market pull), research or stakeholder involvement is excluded. The supply chain/network follows the process line of AM process chain. This network resembles the situation, when AM technologies and machines are in a mature development stadium, materials or software are available

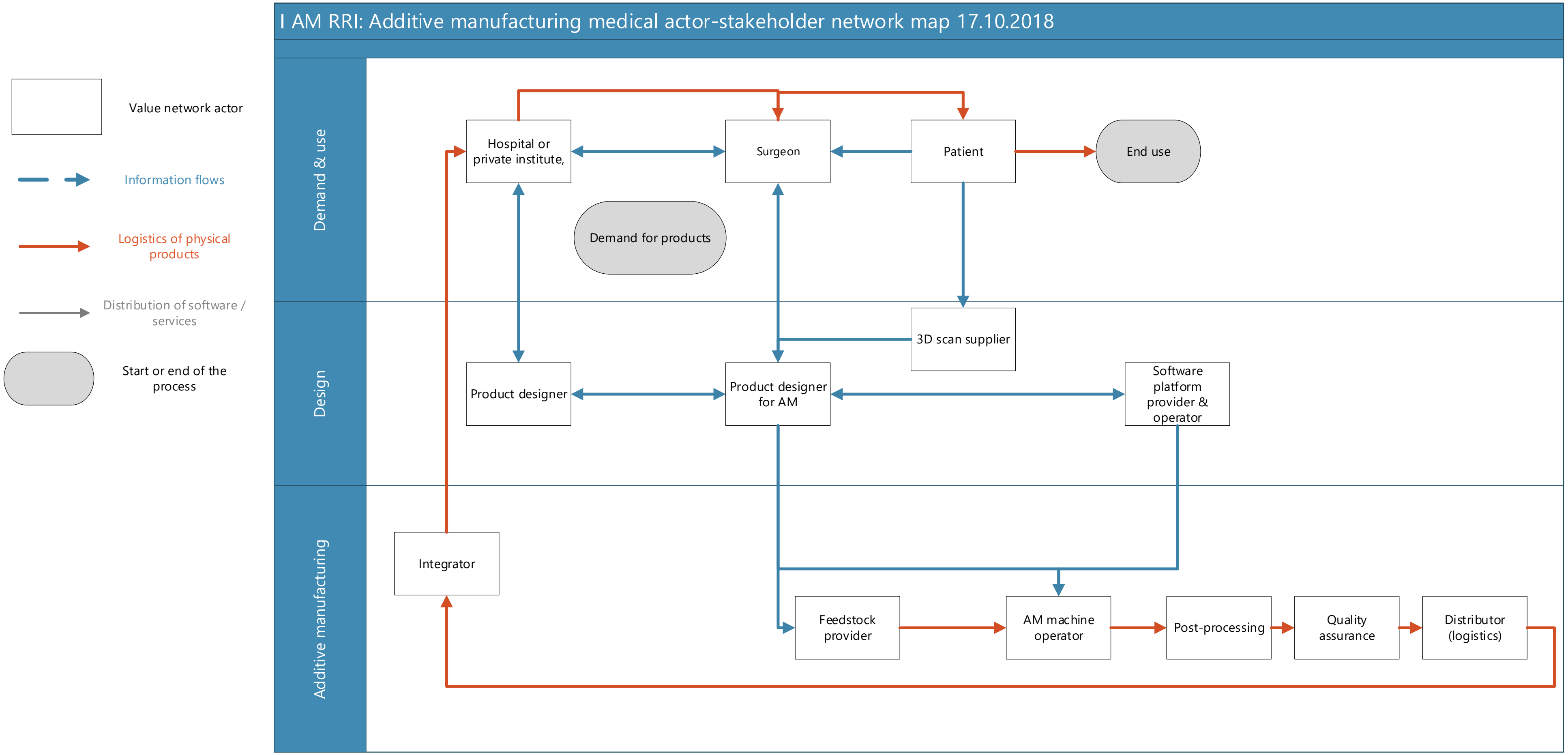

Figure 3 The initial network map in AM medical sector - the initial network map in AM medical sector is similar to that as show for automotive. Big difference is that the end users patient (representative of society) come more in focus, the customer are still hospitals or even health insurances. In the case of medical application, the perspective of the stakeholder involvement starts to change the view of a customer-oriented supply chain to a stakeholder-oriented supply chain.

4. Transformation from supply chain to innovation value chain (stakeholder- and product development orientation)

Since the initial maps did not show the opening for RRI, in the workshops and the interview discussion on the involvement of stakeholder were asked for. AM in both automotive and medical sectors it turned out that there are higher number of stakeholders involved than assumed. Stakeholders are individual or organisation that can influence or be influenced by the organization or the services, products in relation with AM, machines and technology are included as well.

Literature often defines them as external or internal stakeholder. Internal stakeholders refer to internal individual or organisation to the organisation while the external stakeholder includes actors who play a role in supporting organisation's activities. In this case, they are governments, competitors, consumers, media, university and special interest group. Research organisation are often seen as stakeholders because they are seen as a passive source for continuous knowledge production when the production process is targeted only. The role or research organisation will change if it comes to the innovation considerations.

Those stakeholders do not involve directly in the production of products or service. However, they may play a role in the innovation value chains. Based on the findings from the workshop, the stakeholders are:

- Insurance firms
- Research institute
- Regulators
- Patent services
- Trade associations
- NGOs
- Educational providers (university, colleges)
- Banks or other financial institutions (funding organisation play also a minor role when it come only the production of products is seen because of EC competitions law)

The next map focuses merely on the key actors and stakeholders in the actor-stakeholder network map of both automotive and medical sectors. By doing this, we identify common actors, practice and generalisation of relationship at both sectors. The map is important in the project as it will provide a justification for actors or agent selection. Figure 4 show the actor stakeholders network map for additive manufacturing.

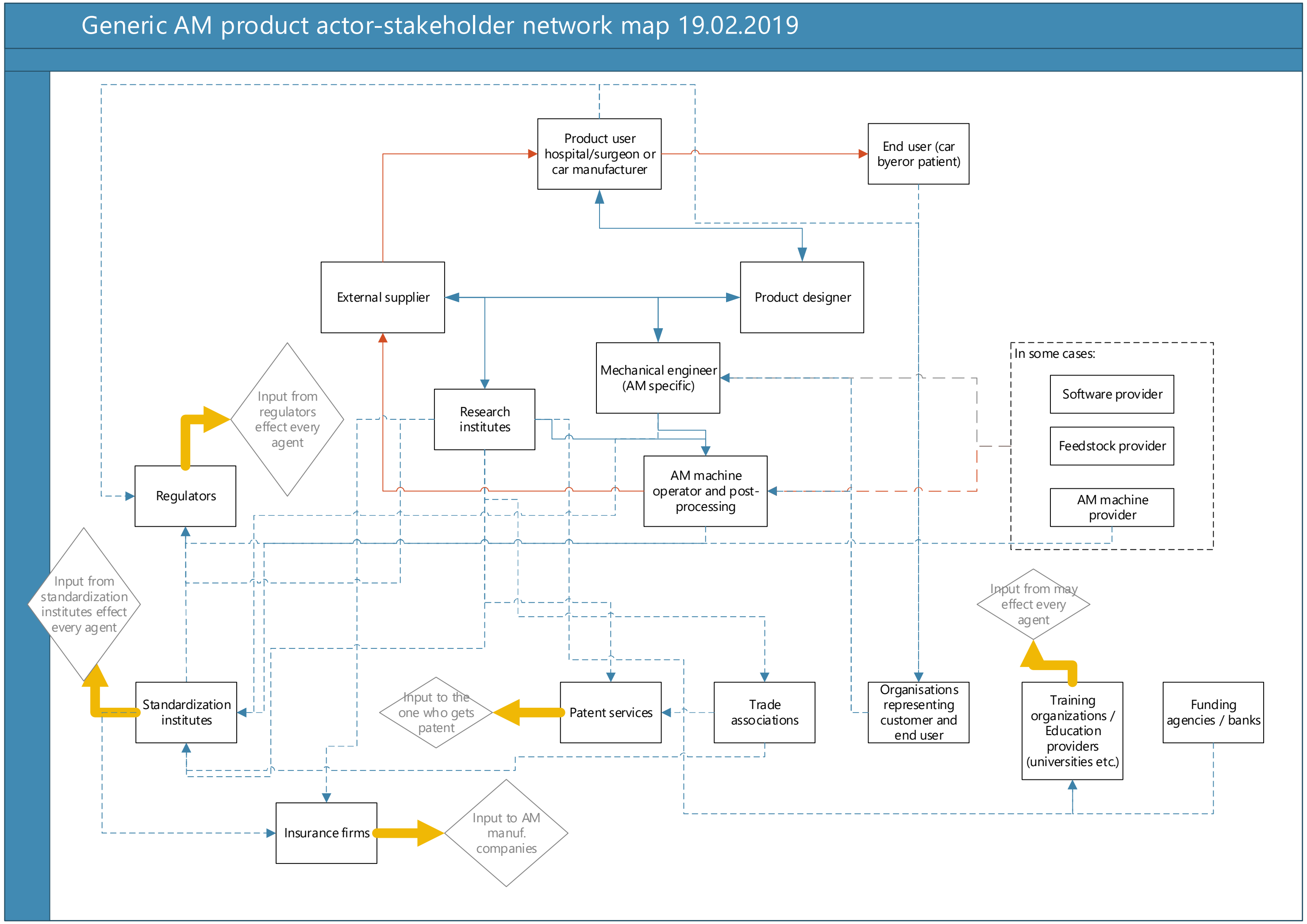

Figure 4. Actor-stakeholder network map for AM, including the interaction of the most important stakeholders in the production process show an even more complex network (stakeholder-oriented supply network) – typical stakeholders are standardisation organisation, financing organisations, insurance companies, trade associations or research institutions

Combining maps and information from previous steps, the next map starts to develop to the concept of stakeholder involvement in supply networks. In other words, the figure shows the original actor-stakeholder network map that includes the central actors in the supply network and their main relationships dealing with value creation (material flow, information flow, software and service flow), as well as the relevant (secondary) stakeholders. Actors participating in the innovation value chains were divided into four layers each representing distinctive tasks, this follows in principle the production process in AM:

The first layer is **demand and use** and it includes the actors that use the AM products or are the customers (buyers) for AM products. The customers may be multiple different organizations (actors), due to the common need to integrate multiple components into a full final product. The demand and use layer is directed to the market perspective, addressing more the needs of customer the society as whole. Orientation in product development of the AM produced parts offer solution of the grant challenges of society, so light weight design leads to a reduction of resources, and a reduction of energy consumption in use phase.

The second layer is **design**, which at this point of the emerging technology of AM is very important both for the supply chain and for the innovations. Both product design and software design are acknowledged. Again, multiple different organizations may be needed, depending on their scope of business. The layer design offers the full potential for addressing the need of society. Since AM offers the engineers and designer nearly any freedom in developing new generation of new functional products and solution, several solutions can be offered to the society as a whole. The third layer is AM production, beginning from the AM feedstock manufacturing until the finished AM product and its distribution. Sometimes a single firm may cover a large part of the production process and only outsource material supply and transport, but sometimes also the production tasks are divided across different organizations. Since the AM production chain is characterised by less complex logistic production and relative low investment in machines, it offers many opportunities for SME to enter the market. Challenge is to have high qualified employees which understand the technology and has the capability to transfer their knowledge in new generation of products within a short time. This is often a barrier for SME coming from classical production because the engineers and designers stuck to the conventional construction thinking. The fourth layer in supply chain is **AM machine manufacturing,** and it includes software development for the AM machines and for AM design. AM machines are a critical resource for AM production, and as the technology is currently evolving and non-standardized, its position in the AM innovations is quite relevant. Today AM technology is characterised by a rapid development of technologies and machines. Gradually machine producer from all parts of the world enter the market, so that the competition is no longer on the technologies itself, it becomes a competition of several machine producers within on technology leading to reduction of machine costs (see Wohlers Report, 2019)

The fifth layer shows the identified **secondary stakeholders** for AM supply networks. Secondary stakeholders are the external organizations with an interest in or contribution to AM industry trough different kind of mechanism, but these secondary stakeholders are not the firms or customers in the direct AM supply chain. University, research institute, insurance companies, financial institution and government body such patent offices are belong to this layer. Although these organisations are not directly related to the production of AM, they may trigger and critical for the entire innovation process. For instance, **research on new AM material is often conducted at university. University also play a critical role in commercialising AM-related technology through patent, licensing and spin-offs creation.** Acting as a driver of innovation, university is known to be the central actor in innovation studies such as in the concept of technology push or national innovation system. Government may also play a role as they may direct the development of technology and market by allocating funding and investment to certain sector or application. Insurance companies may force AM firms to adapt their business model, build a new project and deal with different ranges of businesses. What was recognized at this point was that besides having interested to the industry from the manufacturing point of view, they have an interest to contribute to the innovation phases as well.

<u>From a production oriented to a product development-oriented supply network</u>

In figure 5 the relationship with the actors their interaction was shown as flows of information and knowledge (blue), moving of physical products (red) and distributing of software (grey). This graph goes already more in the direction of a "product development included" supply network. It is still the material flow which is relevant for the interaction but also the information flow. AM technologies are known for the process characteristics that products can be produced very flexible (just in time demand) in small number. AM offers the advantage of a production that does not need tooling, as a result the production process is faster than the conventional process. In addition, the relationship between actors involve many different types of exchange. It includes intangibles such as information or knowledge, software or tangibles like the product itself. However, the frequency of exchanging information is higher for agents in the medical sector compared to their counterparts in the automotive sector. Which needs in consequence that the product development has to be made more efficient and even more rapid. In the supply chain network many processes have to run parallel, which affords that all organisation in the network have the relevant information for development and production simultaneously. Software supported development processes or simulation of the whole AM production process helps to speed up the product development and production process. This makes the interaction of AM with new arising technologies like artificial intelligence or digitalisation very as motor for innovation very important. **This highlights the importance of the filth innovation value chain like digitalisation and software.**

This actor-stakeholder network map (figure 5) provided the foundation for our understanding of the AM industrial system, both in general and in the two target sectors, automotive and medical, since they share the central features. It helps to identify the key supply network actors and external stakeholder that most likely are relevant for the innovation value chains.

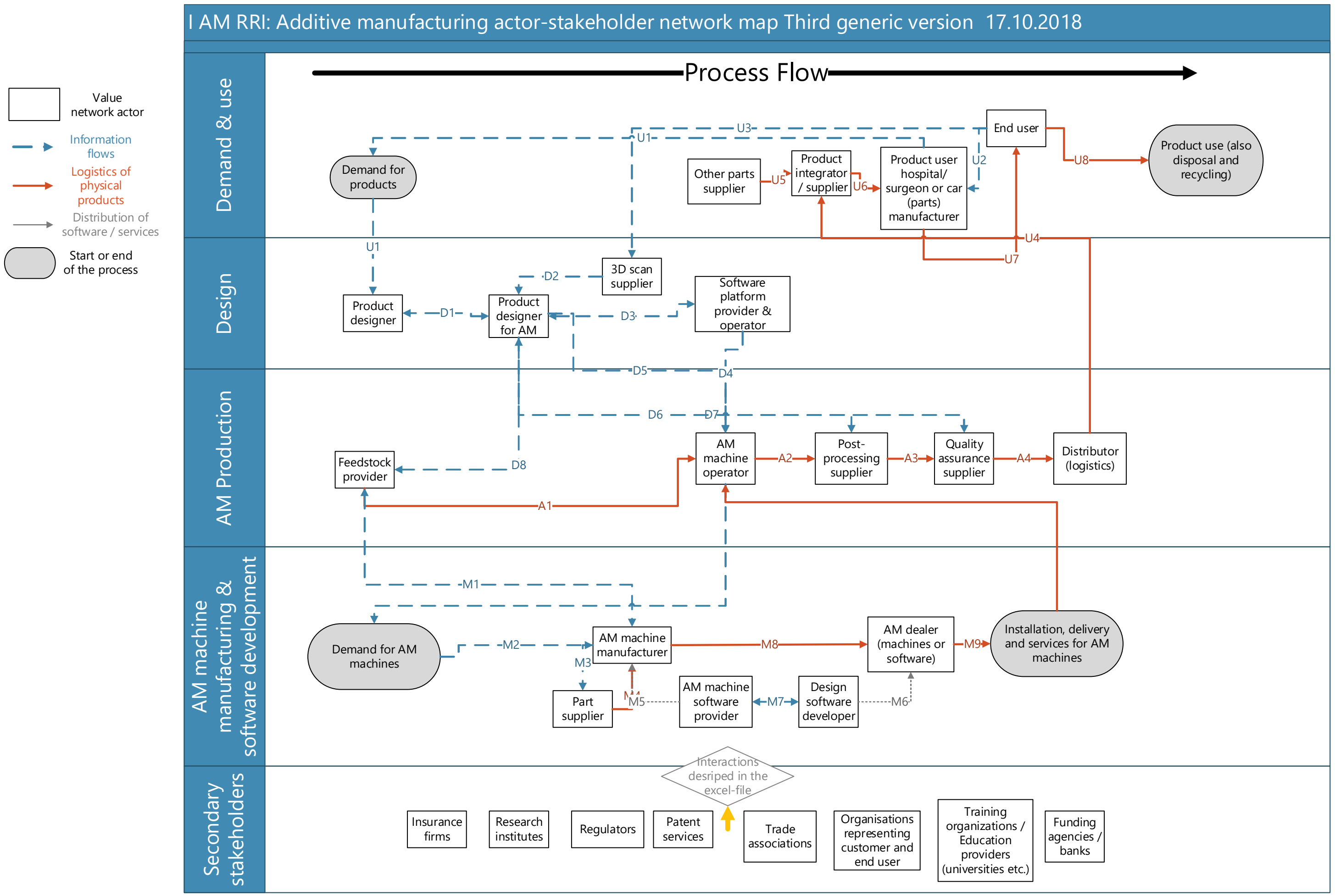

Figure 5. AM generic maps (real world based of AM community) change a lot, while in the previous maps only material flow determines the interaction. In an AM supply networks were products are produced in small number the flows of information become remarkable important. The relevant of information flow of product development become more important, because product development time and effort has to be reduced, which is only possible if process steps are running parallel and not sequential.

5. Literature on innovation value chains and innovation networks

The previous sections concentrated on supply chain/network orientation, which include the perspective of product development and production in the AM system. This section reviews the notion of innovation value chains within the SwafS call. So, it turns from supply chain thinking to the innovation value chain thinking. Basis for that consideration are the existing work in the academic literature. We then combine the logic of IVCs with the mapping approach described in previous sections, to present tentative IVCs for our two target sectors, automotive and medical.

5.1 Innovation value chains in the context of SwafS and I AM RRI

Innovation value chains (IVCs) are the central structural entity within our project. It is useful to refer back to the conception of IVCs in the SwafS call:

“The challenge is to model and better understand the dynamics of the **complex webs of innovation value chains and the openings they offer for RRI.** The key idea is that of crisscrossing 'innovation value chains'. Innovations and prototypes, business-to-business products and final products move from one organization (entity) to another and are transformed in the process; value is added in the transactions and appropriated. Third-party actors are involved, such as standardization bodies and insurance companies but also and increasingly, NGOs. While there is a direction to the eventual product flows, initiatives may emerge anywhere: there is no simple linearity (cf. the chain-link model of innovation) and, even more, no beginning nor end (cf. circular economy). Chains can change, split, be re-arranged, crisscross and co-evolve with changing business models. In general, industry and service structures consist of webs of crisscrossing chains, forming broader structures consisting of more than the traditional economic actors. There are uncertainties involved in the evolution of these webs e.g. with the promise of large-area polymeric semi-conducting materials that can be printed. Will the key driver of the eventual chains in this domain be the materials manufacturers, the printing companies, or the various application sectors?” (European Commission, 2017)[1].

This introduces a number of important issues.

1. First, IVCs should be seen as inter-organisational, which asks for an actor bases model understanding as well.
2. Second, they are seen as encompassing actors outside the typical scope of production supply chains (external stakeholder).
3. Third they are seen as innovation value chain, which turn away from the view or transformation of material to products, to the transformation of knowledge to products.
4. Fourth, the webs of innovation value chains are seen as potentially multi-directional rather than uni-directional (linear innovation), and dynamic (change with time). Typical mechanisms for changing the web are ‘criss-crossing’ of the value chains, which means they are splitting, intersecting and interacting in new configurations.
5. Fifthly, it points not only to a network of innovation value process but also to a network of actors.
6. Finally, this passage suggests that part of the policy agenda is to identify, within these webs of interdependent IVCs, where the most likely points of influence may be for RRI.

[1] SwafS call page https://cordis.europa.eu/programme/rcn/701861/en

5.2 From supply chains to webs of innovation value chains

In order to shed a light on the understanding of innovation value chain, we first look on the existing literature on innovation and innovation process. There has been a wide range of models about innovation where innovation activities can broadly be described as a process again. Some scholars propose a stage gate approach of innovation (Cooper, 2011). The stage gate reflects the phases of development such as emergence, growth and maturity (Mitrova et al, 2015; Perani and Sirilli, 2008) or invention, development and distribution (Maidique, 1980). Stage gate approach is a well-known concept in innovation management, and it is originally derived from literature on new product development. According to the stage-gate approach, innovation follows in steps namely, discovery (invention), development or design and use (Niosi, 1999; Missner, 2015). Often this is seen as linear, but stage gating can also lead to an iterative process in innovation. Not passing a gate can lead to a rejection of the "innovation", to an improvement by undergoing the previous step again. In relation with RRI (Owen et al, 2013) proposed a "stage gating innovation governance model", which should give opportunity for adaptive governance. In general, in the beginning of the RRI, innovation was seen as a result of process steps that lead to a final innovation (see eg. Lee et al 2013; von Schomberg et al 2013).

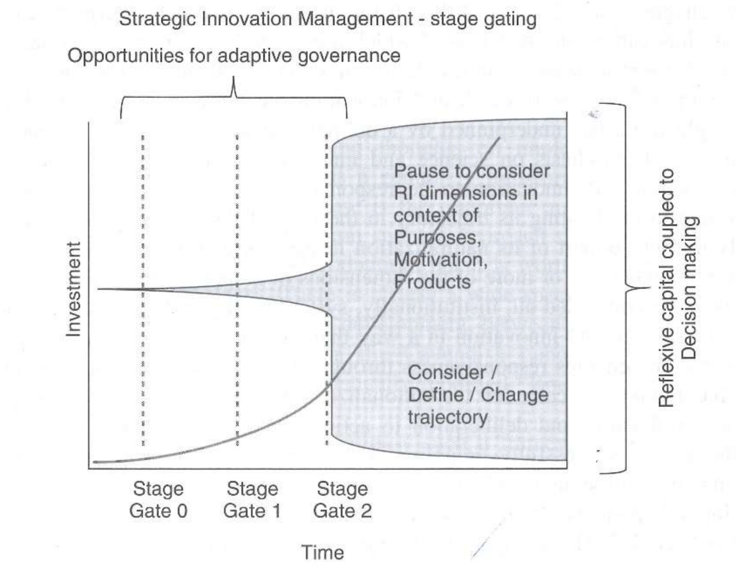

Figure 6 Embedding dimensions of responsible innovation within a stage gating innovation governance model according to Owen 2013

Stage gate approach is still used until today especially as decision making tool during the R&D process. It helps organisations to decide whether to commit and to invest based on technical, managerial and market considerations in each gate.

In other stream of research, scholars developed what is called the first-generation theory of innovation where science push the creation and development of innovation. It then followed with the second-generation theory where the demand or market pulls the innovation process. However, according to Meissner and Kotsemir (2016): "although innovation is commonly regarded the outcome of a process of activities, these are by no means always successing in linear shape but involve several feedback loops". Scholars such as Stokes (1997) argue the presence of dynamic interaction where science and technological development have a parallel trajectory. However, during the process of idea diffusion, ideas evolve substantially as a result of interaction with other sources or social actors. While typical activities and steps which are common in a linear model is still applied, but sometimes organisation need to return to the previous activity due problems and uncertainty in fine tuning the final product. These phenomena show that scholars have started to recognise the complexity in innovation process.

As it indicated from the previous discussion, literature on innovation has argued that innovation is not a simple linear process. The development of idea that is happening during innovation process may have several iterations before finally reach the final stage, the same is for product development. In other occasion, idea in its on trajectory can meet with other trajectories resulting a creation of a new trajectory. Another insight from literature that is important in our effort to develop the concept of innovation value chains comes from the concept of value networks (Carter et al., 2002). Value networks describe as organisation and individual that are or could be involved in the development, marketing and the application of a technology. Originally the concept is derived from the value chain concept where a new idea is developed and brought into market as it is quoted from Botkin and Matthews (1992), 'the value chain is a sequence of activities during which value is added to a new product or service as it makes its way from invention to final distribution. When a commercially valuable ideas takes forever to get from concept to market place – or never arrives – the problem is often a week or missing link (p.26)'. The innovation value chain consists of three stages:

- Stage 1: research and idea generation
- Stage 2: development, design, production
- Stage 3: marketing, sales, distribution, and commercialisation

By including the step 1 – idea generation and research as process step the supply or even development-oriented supply chains transforms to the innovation value chain. The process of innovation is the transformation of gained knowledge to a physical product or a service.

Compared to the older concept of value chains or innovation process in general, the concept of value network emphasis the important role of network and partnership in value creation. The idea is that companies need to work with other organisations in order to move from one stage of value chain to another. For instance, several small firms develop partnership to jointly bring ideas into market or a large corporation acquire small firms to help them to launch a product quickly. Some of these effects can already be seen in AM, like EOS invests in small science-oriented start-up (see Ltihoz). For innovation value chain not only, the innovation process becomes important but also the cooperation management and partner networks.

Hansen and Birkinshaw's (2007) **Harvard Business Review** paper is the most widely cited. It identifies three main stages in innovation process ***within a firm*** (and this is important): **idea generation, conversion, and diffusion**. It then offers a diagnostic tool by which firms can evaluate their performance in each (and they are broken down into subs-stages), and proposes ways to improve performance in weaker areas, which can include using external partners, especially for the idea generation stage.

Hansen and Birkinshaw (2007)'s definition is widely used and offers the closest proximity to a formal definition of IVC: "The innovation value chain view presents innovation as a sequential, three-phase process that involves idea generation, idea development, and the diffusion of developed concepts. Across all the phases, managers must perform six critical tasks – internal sourcing, cross-unit sourcing, external sourcing, selection, development, and company-wide spread of the idea. Each is a link in the chain' (Hansen and Birkinshaw, 2007: 122). The chain, in this case, **is a chain of management tasks, within the firm**. The conceptualisation of value is fairly weak – the model suggests that firms need to make sure that they are good at all the stages, implicitly in order to realise the value of their innovations. The core assumption which will be used in the I AM RRI project is that innovation has to pass these stages, but not in a linear way or only within a firm. Various number of organisations outside the firm can contribute to the innovation (open innovation). Combination with the stage gate process as introduced even if can be an iterative process as discusses in chapter 6.3. Value that can be economic or societal values are generated by the transformation of build-up knowledge (intangibles) to the final product or services (tangibles). Value of knowledge is often described in terms of licences of patents.

The other main source is a series of papers by Steve Roper and colleagues (Roper et al., 2008; Ganotakis et al., 2012; Roper et al., 2012). These also conceptualise the IVC as sequence of intra-firm activities: **Knowledge sourcing, knowledge transformation, and knowledge exploitation**. These are represented in **Figure 7**. Note that this interpretation sees the IVC as a **chain of firm activities:** similar to the conception of Hansen and Birkinshaw (2007), but with less emphasis on managerial action.

The three papers use panel data on manufacturing plants in Ireland and Northern Ireland, to examine the relationship between the characteristics of innovation processes, innovation outcomes, firm resources and firm performance, in terms of productivity and sales and employment growth. Although the various papers emphasise different aspects, the basic argument is about the effect on performance of the complementarity between elements of the IVC. Here, the first two stages are strongly conceptualised as firm activities, but the third is not: knowledge exploitation is not really treated as a process that is managed in the way that Hansen and Birkinshaw (2007) think about diffusion - performance outcomes 'just happen'. However, in focussing on the financial performance outcomes, especially productivity, the Roper et al. work has a much stronger focus on the value aspect of IVCs. It is the assumption of the IAMRRI project that different actors from different organisation interact in innovation value chain. This is self-evident when the consortium of H2020 project are analysed (D6.1). It is also supported by the observation of the actor-stakeholder interaction. In the different stages of the innovation value chain a multi- actor interaction is taking place so that they also build innovation networks. Innovation value chain can run parallel or sequential. Nodes of interactions are built by the actors in the different stage of the innovation value chains. The stage-gate approach and the interaction of different actors in various innovation value chains lead to a none linear innovation action, even if the core model of innovation value chain is understood as a linear approach.

5.3 Discussing and developing the concept of innovation value chains

For the I AM RRI purposes, it is notable that the IVC literature is concerned with activities that take place within one firm, whereas the SwafS concept is almost entirely about inter-firm or inter-organisational processes. I AM RRI sees the IVC as activities between different actors or organisations.

In some respects, that doesn't make any difference – for innovation to happen, the same series of activities have to take place. However, one important difference is that the SwafS conceptualisation mentions value being added 'and appropriated': this raises the question, as posed lucidly by Jacobides et al (2006a), '**Who does what? and Who gets what?**' (see also Jacobides et al., 2006b). In the same way, the business model literature, as reviewed in D2.1, is centrally concerned with value capture (e.g. Teece, 2010).

More generally and importantly, this presents one of the critical issues for this project, and for our modelling process: **how do the IVCs map onto the Actor-Stakeholder network?** To reiterate, the IVCs are chains of ***activities*** **and focuses on** ***innovations***; the Actor-Stakeholder networks show inter-connected ***actors*** **and focuses on** ***production (figure 2-5)***. Multiple actors that take part in production may be involved together in a certain innovation activity, and the interactions during innovation may be very different from the interactions during production. **The innovation activities can be distributed in a multitude of ways across the various actors and stakeholders: there is not a simple one-to-one mapping between innovation tasks and particular actors, and the relationship is dynamic.**

IVCs in the literature are all defined relative to a product. Innovation is about bringing an idea to commercial realisation, so it makes sense that an IVC should be understood in that way. (Some would argue that an IVC could also be used to develop and bring a service to market e.g. see Sampson and Spring (2012) for a parallel argument regarding service supply chains). A research lab's activities is part of an IVC unless if some of its output eventually is transformed into a commercial product/service. Of course, there can be IVCs for intermediate as well as consumer products/services. In our case, that might be a series of activities that lead to the development and commercialisation of an AM machine. But the overall point is that we, as analysts, and other actors (e.g. managers) construct IVCs through convention and for a purpose: they are not simply ‘out there’, but socially constructed (see New, 2004, for a similar argument regarding supply chains). Furthermore, in the IVC literature, IVCs are understood relative to a particular innovation that is commercialised i.e. resulting in a product/service that can be sold and thereby allow value to be captured. In the same way, recent conceptualisations of supply chains have argued that a supply chain is understood relative to a particular product (Carter et al., 2015). This is important when we come to discuss ‘crisscrossing’ IVCs, as the way that IVCs related to different products share certain innovation activity stages may prove crucial in identifying openings for RRI.

For I AM RRI project, it emerges that IVC is not described through separate stages of innovation but rather through non-linear ‘stages’ of IVC separated by critical junctures. It is important for the agents to overcome critical juncture in order to progress towards the next stage of innovation process. In this case, the innovation process can stay in one stage as long as there is no pressure or support to move the innovation to the next stages. Borrowing the definition for Hansen and Birkinshaw (2007), figure 7 illustrates the IVC model for our project.

There are three stages

1. Stage 1: idea generation;
2. Stage 2: product development;
3. Stage 3: innovation diffusion.

A key activity in the innovation process started from stage 1, where ideas are emerging, conceived and presented. In some cases, innovation can start from basic or applied research at universities or research institutes or sometimes innovation can also start from user or market. It then moves to stage 2 and if successful, it can move to stage 3. However, in reality, the process involves critical juncture and feedback loop. The former refers to the idea that is not able to move to stage 2 due to lack of funding or collaboration with key players in the industry. In other case, prototype has been developed by the technology change or market turn their preferences. The later – feedback loop, refers to the process where the outcomes of the stages needs to be returned to the initial stage. For instance, the product has been developed in stage 2 but for some reason, it needs to be brought back to drawing table. If data gather in product development is not sufficient meaning the design of idea is not feasible due to lack of parameter or mathematical model of the product, the process has generally return to stage 1. An example when the result of stage 3 need to return to stage 2 is when product is rejected by the market. More work is still needing to develop a better product or even it is needed to redesign the idea. In this case, the project has to return to stage 1. In principle the innovation can stop after the stages.

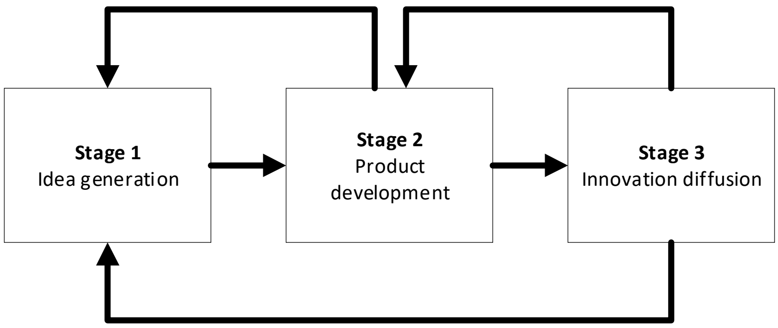

Figure 7. Innovation value chain with feedback loops, in any stage different organisation can be involved, if needed actors are changed from one iteration to another in the same stage (formation of networks).

5.4 Innovation value chain – actor networks

Innovation is increasingly being created in collaboration with a number of actors (Tsai et al., 2009; Powell et al., 1996) (as show inf figure 8 and 9). Innovation as a collaborative phenomenon has led to the development of the concept of innovation networks (Dhanaraj and Parkhe, 2006; Von Hippel, 2007), where actors interact to develop innovations of a different and unique nature (Ahuja, 2000; Westerlund and Rajala, 2010). Knowledge creation is the primarily motivation for collaboration (Cohen and Levinthal, 1990; De Clercq and Dimov, 2008).

The innovation value chain consists of actors. Such actors coordinate day-to-day activities with various partners to create value for customers (Håkansson et al., 2009). In each stage of three stages in the innovation value chain (the stage of idea generation, the stage of product development, and the stage of innovation diffusion) the collaboration activities can be illustrated via actor networks, where knowledge creation takes place. These networks in each stage are connected to the "whole innovation network". The network inside the three stages differ mainly in the type of organisation. The first stage (idea generation) is dominated by scientific and research organisations such as universities in collaboration with high tech firms, not excluding organisation which supports with services or included for stakeholder dialogues. In the second stage (product development) the created knowledge in the first stage in transferred into a product, where mainly production companies are engaged. In the third stage (innovation diffusion) other business firms are active. There are, of course, other organisation types in each stage, however, the dominating once are mentioned here.

5.5 Tentative innovation value chains for two AM segments

To reiterate, it is important to be clear that IVCs are not the same as supply chains, because they include the idea generation phase as well. When the phases of idea generation and product development are passed and the knowledge transformed to a product takes place than stage 3 starts. The task of a supply chain is to sustain the production if the products. Both of the latter can be conceived of as adding value through sequences of production, storage, distribution and transaction.

IVCs are concerned with sequences of innovation activities that add value to the innovation through the innovation process. This also means that different organisations or actors may be involved, and/or the same actors may be connected and interact in different ways. To understand how this would apply to AM, and to the project context in particular, tentative innovation value chains descriptions were developed for the two industries included in I AM RRI project: car manufacturing, and medical implants. We identified the actors and relationships relevant to each of the phases in the innovation process, for both. The I AM RRI project began with the Hansen and Birkinshaw (2007) terminology for the phases (idea generation, idea conversion, and diffusion); our participants preferred 'product development' and 'industrialization' for the latter two.

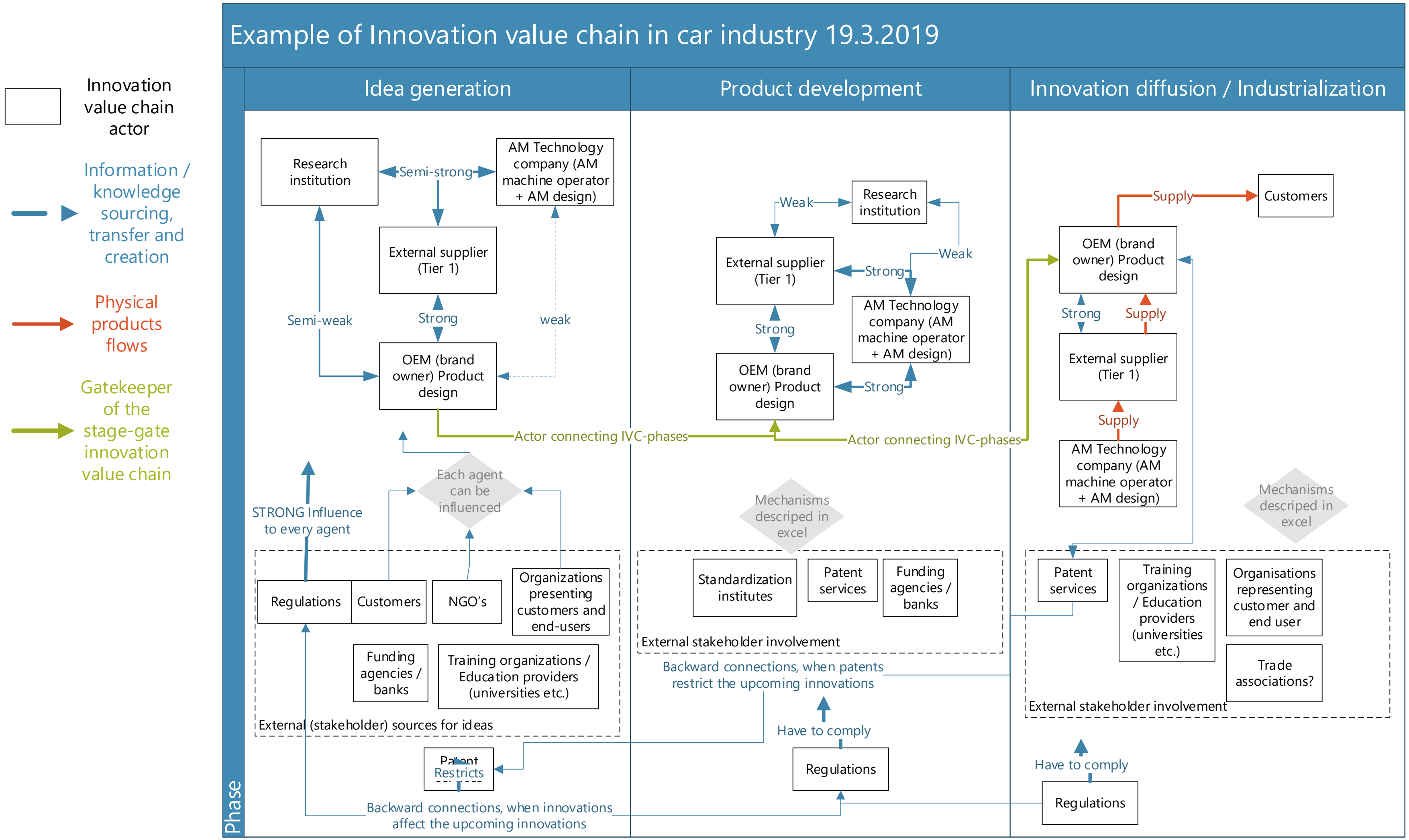

Figure 8. Innovation value chain for AM innovations in the car manufacturing industry, the supply chain model turned into the innovation chain model, knowledge which transfers to product is also shown, the map shows the different actors in the 3 stages, the role and the involvement of stakeholder are also changed within the stages

The example innovation value chain from car industry is presented in Figure 8. In the **idea generation** phase, the stakeholder 'regulators' is one of the main sources of new ideas, as new regulations force car manufacturers to comply and develop new ideas to meet the criteria of the new regulations. Ideas can be sourced from other stakeholders, also, such as research institutes and AM technology companies. These ideas are then iterated through feedback loops within car OEM, Tier 1 supplier, research institutes and AM technology companies. This information and knowledge sourcing, exchanging and creation was coded as a blue colour in the figure 8. The thickness of the blue lines represents the importance of this connection (as it is also labelled).

It was considered that the car OEM (original equipment manufacturer) is the actor that connects the innovation phases as they have the ultimate power to choose what ideas to choose to further development. Therefore, they act as a gatekeeper during the stage-gate type of innovation process and this is coded as a green colour in the figure 8. In the **idea conversion or product development** phase, there are mainly the same actors as in idea generation, but research institutes' influence is weaker than earlier. At this point, patent organizations and standardization institutes become quite important in the context of AM as an emerging new technology. In the **idea diffusion or industrialization** phase, car OEM and Tier 1 (level 1) supplier are the most important actors for the success of the innovation diffusion, together with several stakeholders that can have a large influence on the customers. In this phase it is evident that product innovation has some physical products that flow from actor to actor. This is coded in red colour in figure 8. What can be noted is that the physical products or objects can flow in earlier part of the innovation process as well, but at that time they conceive the knowledge aspect more than actual sellable product.

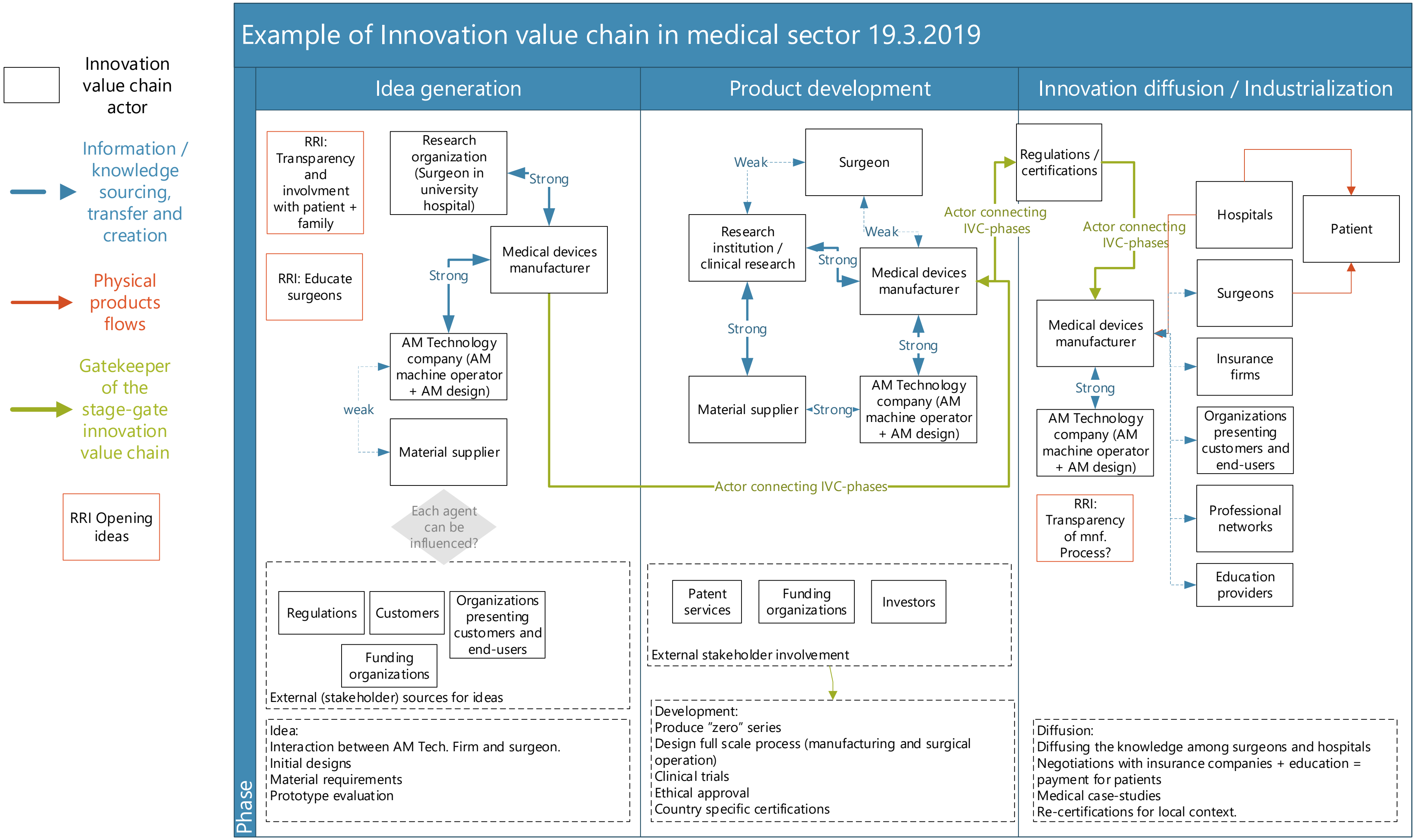

Figure 9. Innovation value chain for AM innovations in the medical implants industry, research institutions are not seen as actor in the AM system, AM is characterised by engineering experience, surgeon are often from medical research organisation (universities) as well

The example of the innovation value chain concerning the medical implants industry is presented in **Figure 9.** The medical devices manufacturer works as the main hub contributor for the **idea generation**. Ideas may come from the medical device's manufacturer, and they then iterate with the surgeons and the AM technology company to develop the idea. Ideas may come also from several stakeholders that are presented in **Figure 9**. The information and knowledge sourcing, exchanging and creation needed for idea generation was coded as a blue colour in the figure 8. The thickness of the blue lines represents the importance of this connection (as it is also labelled).

The medical devices manufacturer is then the actor that connects the phases of idea generation and idea development. Therefore, they act as a gatekeeper during the stage-gate type of innovation process and this is coded as a green colour in the figure 7. In the **idea conversion or product development** phase, research institutes are important actors as they conduct the medical and clinical testing for the implants. The AM material supplier, the AM technology company, the medical devices manufacturer and research institutes form a strong feedback cycle where the innovation is developed. Stakeholders at this point are mainly involved by their ability to fund or protect the innovation. What can be noted is that the physical products or objects flow in this part of the innovation process as well, but at that time they conceive the knowledge aspect more than actual sellable product, and hence they are coded as blue colour in the figure 8.

In the **idea diffusion or industrialization** phase, the medical devices manufacturer tries to promote the innovation in the surgeon community and sell the implants to hospitals. Certificates from the governmental organizations are one major enabler for the diffusion since, without them, the commercialization process is interrupted. In this phase the product innovation has some physical products that flow from actor to actor. This is coded in red colour in figure 9.

Figures 8 and 9 seemingly show a linear process where innovations would flow through the three phases in a sequential order. In reality, however, these phases have also feedback loops within them as well as between each other. The feedback loops within-phase and across-phases are visible in the lower parts of figure 6 and 9 coded as blue where cumulating experience from the current innovation phase affects the future innovation phases or when a past innovation has created knowledge that has an effect on the present innovation.

5.6 Value chains in AM innovation system

From workshops with research and industry partner today 5 principle types of value chains are seen:

- Value chain on materials (metal, metal powder, polymers, filaments, composites, ceramics)
- Value chain on technologies and machines (many technologies, technology are often typical for materials)
- Value chain on digitalisation and software (digital product development, design, process simulation and optimisation, digital twin of AM production)
- Value chain on products produced by AM (automotive, medical, mechanical engineering parts, aerospace)
- Value chain on services (maintenance for machines, consulting, training, teaching)

This agrees with the observations of (Robinson, 2019), who detected 3 core value chains in AM production process and pointed out the strong interaction of the innovation value chain on materials, machines and software. Since these three value chains are the basic of production of products it become self-evident that the value chains on production of products are also strongly interconnected.

5.7 Conceptualising Webs of Innovation Value Chains

The central notion of the SwafS conceptualisation is that it is not just individual IVCs, but webs of innovation value chains that present opportunities for opening for RRI and must, therefore, be understood. Webs of IVCs do not figure in the academic literature at all. As such, it is worth returning to the SwafS text:

"In general, industry and service structures consist of webs of crisscrossing chains, forming broader structures consisting of more than the traditional economic actors. Will the key driver of the eventual chains in this domain be the materials manufacturers, the printing companies, or the various application sectors?" (European Commission, 2017)

Based on this, an interest exists in understanding, from a policy perspective, which organisations, or groupings of organisations ('sectors'), are the most important influences on the way the technology develops. In other words, we need to understand how the way the various IVCs – **which are chains of activities**, **linked to particular product/service outputs – relate to interconnected organisations**.

Webs of innovation value chains (WIVCs), then, are inter-dependent chains of innovation activities that span multiple organisations. Recall that IVCs are defined relative to a particular product or service, which can include an intermediate product such as a machine tool. Note also that the IVC as conceived by Ganotakis et al. (2012) is underpinned by the firm's resource base. From this, we can infer that 'criss-crossing' or inter-dependent IVCs are interdependent because at some point they draw on the same resources and are carried out by the same actors, although not necessarily at the same time. Consistent with the Industrial Marketing and Purchasing (IMP) or industrial networks perspective (e.g. Håkansson and Snehota, 1995), we can say that actors, resources and activities are mutually-defining and to some extent mutually determining: **actors use resources to carry out activities**. On that basis, if an actor uses certain resources to undertake an innovation activity as part of one IVC, the resources will be affected by the activity e.g. learning might take place, or physical resources might be adapted. This would affect the way those resources can be used for subsequent innovation activity as part of a different IVC. In that sense, **the two IVCs are inter-dependent**.

It is useful to note that IVCs are fundamentally different to supply chains, because innovation is non-rivalrous in use: use of an innovation by one actor does not reduce its availability for use by another actor.

IVCS are defined relative to a particular product or service. IVCs for different end products might intersect and be interdependent because of a common innovation activity within, say, the idea conversion or product development phase. For example, a new way of modelling stresses within an AM component might be developed, suitable for use in both automotive and medical end-products. The actors involved in the development of the method might be influenced by both eventual applications, and that would determine their innovation activity, i.e. the two IVCs would be interdependent. Alternatively, IVCs for intermediate products such as machine tools or software might intersect with and be interdependent with IVCs for end-products. In AM, there are IVCs for materials, for machines & production technology, for digitalisation & software, as well as for end products.

While the above model might represent the general process of innovation value chain in certain product or service. The real process can be described as complex system where the interaction between elements of IVC can go beyond their own IVC. In this case, the idea of crisscrossing is identified where the element or layer within individual IVC influence or is influenced by another element from external IVC.

<u>An example, based on stylised facts</u>

An example may be useful. This is loosely based on the situation of one of the project partners, which we will call AM-Co (Additive company) here, and uses the three activity stages used in **Figures 8 and 9**. Two years ago, AM-Co was doing the KT **idea conversion or product development** activity in the IVC for a mould tool to be used in the automotive industry. Now it is generating revenue from making the mould tools for forging – this is the **idea diffusion or industrialization** activity. Let's say they now undertake **idea conversion or product development** activity in relation to mould tools for the medical industry, using the same knowledge (i.e. same **idea generation** activity) – this is a different IVC. The fact that they did the **idea conversion or product development** for the automotive product has an effect on how they undertake this activity for the medical product. This is an effect of the 'criss-crossing' or interdependent IVCs. Both examples so far are intermediate products (i.e. mould tools) to be used in making end products. Let's say AM-Co now start **idea conversion or product development** related to customised medical end- products (e.g. some kind of implant for individual patients). This requires them to source knowledge from completely different sources (i.e. a different **idea generation** activity) and is therefore another different IVC. Their established **idea conversion or product development** activities and related resources and innovation processes will doubtless shape how they carry out the new **idea conversion or product development** activity, for better or worse: in other words, these IVCs are also interdependent. From an RRI perspective, if, in taking part in the medical IVC they are required or choose to consider more and different aspects of RRI (e.g.ethics).

Another example is illustrated from the following case. For instance, a project initiated by EU has allow industrial actors to learn and gain knowledge about RRI. While the project may provide opportunity for those industrial actors to pursue their own product idea by exploiting existing idea, a new IVC might be created. In this case, new actors will be invited, and the network form a new IVC to adapt for the new requirement. The process of creating a new trajectory for IVCs leads to non-linearity of innovation process, a new network is created and the dissemination of RRI approach is achieved. If the network initiates another project, again a new trajectory can be created as a result of their collaboration.

6. The development of framework for describing webs of innovation value chains

As we have concluded and defined the webs of innovation value chain for I AM RRI project, we then need to connect the concept to others elements of the model. The purpose of this section is to provide a framework for modelling purposes. The framework is concerned with the way factors concerning actors and processes determine outcomes in terms of economic performance, social performance and strategic impact in the sense of the EC's strategic agenda smart growth). It might be possible to treat the AM industrial system as a "black box" and measure the effect of certain input factors (e.g. training or education) on the global outcomes. However, to stand any chance of intervening effectively, it is necessary to understand **how certain factors influence outcomes**, as **they work through and are mediated by the specific industry structures and processes with which we are concerned**. In other words, it is necessary to 'open up' the black box, and understand the specific actors, specific innovation processes, and how they interrelate, in order to understand how to influence specific outcomes, and where openings for RRI exist as part of that process. In particular, it is important at this stage to understand the structures and processes inherent within innovation value chains the interconnection with other IVCs within the webs of innovation value chains that these actors and stakeholders constitute.

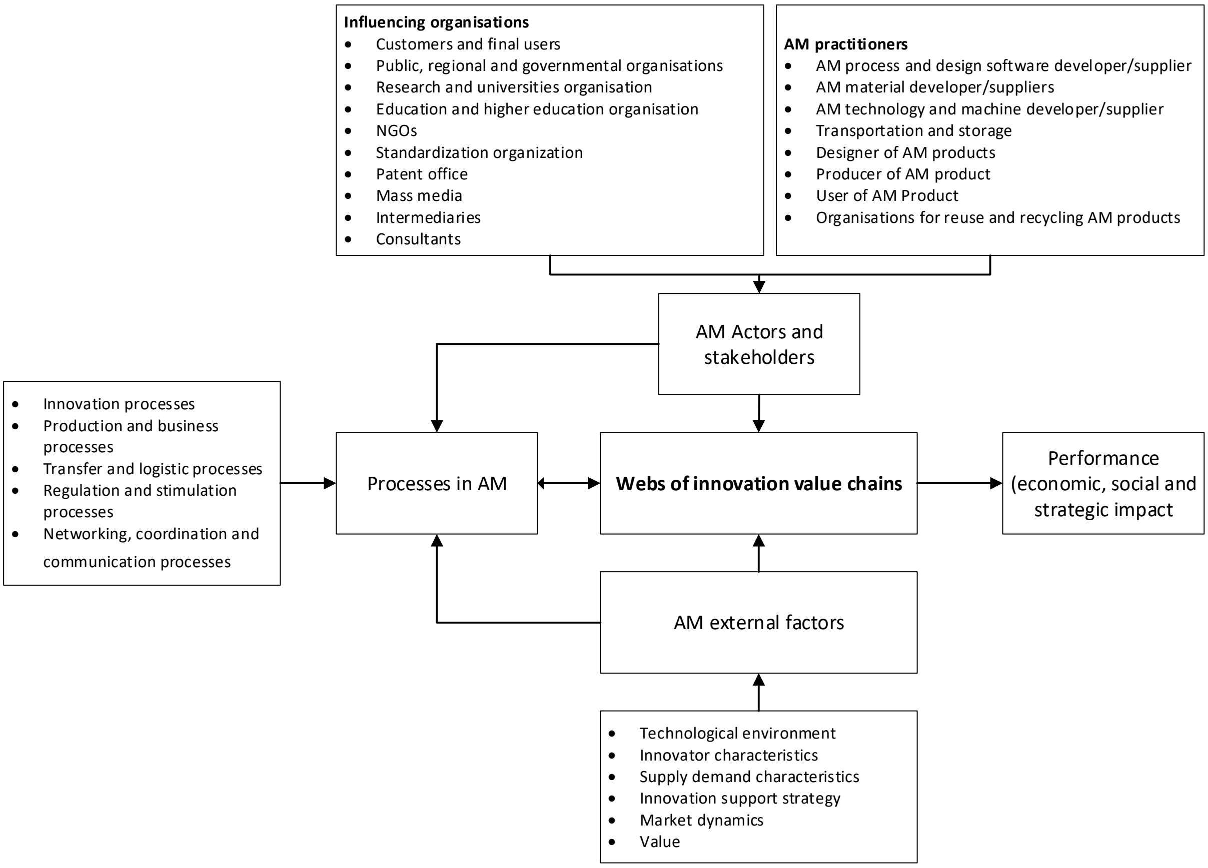

Figure 10. The framework for defining processes, performance, factors and actors of webs of innovation value chains

As figure 10 has shown, the framework consists of four main elements that may influence webs of innovation value chain. These elements are performance, external factors, actors and stakeholders and processes. The performance refers to the outcomes of the sectors and in relation to our programme, the performance will measure the impact of RRI on economy, social and strategic impacts. The external factors need to be considered as they have direct and indirect influence on webs of innovation value chain. Among other, those factors include technological development, characteristics of the innovators and business, supply chain, innovation strategy, market dynamic and institutional value. Actors and stakeholders discuss the role, practices of actors and stakeholders in AM while the processes provide the context of activities which is also useful for our modelling. The actors build the group of organisations which interact in a stage in innovation process, actors can be changed and actors have the opportunity to be in cooperation with other innovation value chains. **This build the innovation networks. Knowledge can go from one web of innovation value chain to another (open access).**

6.1 The role of factors in IVC modelling

The complete list of factors explaining strategic, market and social impacts was introduced in the report D2.1. A prioritized list of factors and indicators were defined with more detail in the report D2.2. In the webs of innovation value chains, those factors may play a significant role in influencing the outcomes at market, strategic and social level. For instance, the 'compatibility' factor, which is often referred to as an innovation's compatibility with the existing technology or system, is a necessary condition in fostering technological diffusion. In many situations, a new technological system will not replace the entire system, but it is likely that certain technologies will be retained and must be integrated with the new technology. The more compatible the new technology to the retained system, the greater possibility that the new technology will be successfully integrated and diffused into the system.

Another factor such as 'network formation and coordination strategy' is also important in relation to innovation activities for additive manufacturing. It is related to the learning process among the organisations and actors in the industry. All organisational learning is path dependent and accordingly, learning is considered to be local. As scholars argue that knowledge is 'sticky', the ability of organisations/actors to acquire knowledge by expanding their networks will determine the success of their innovation activities. In many cases of a new technological development such as in additive manufacturing, organisations or actors work in the context of intense international competition and rapid product cycles. Demand for exploring knowledge and looking for opportunities means that organisations must use networks to learn quicker as well as to gather information and resources. The more organisations or actors are involved in the network, the higher chances and possibilities of crisscrossing activities.

6.2 Organisation, project and business model perspectives on factors

The main aim is to try to positively influence economic performance (in terms of e.g. first profits), social performance (in terms of e.g. user acceptance of innovations) and strategic performance (in terms of contribution to the grant challenges of EU like e.g. generation of jobs) in Europe focusing on AM. In part this is determined by actors and their relations. The actors/stakeholders and their relations play a role at different stages of the innovation value chain and therefore both actors and processes form the input for the AM actors-stakeholder network map.

Factors refer to what these actors can do, their resources, the characteristics of the technology, etc., in order to increase economic performance, social performance and strategic impact. These factors are mentioned in deliverable 2.1 and defined in deliverable 2.2. For example, an AM manufacturer may decrease prices for its products which decreases profits, or it may change its technology so as to increase the level of privacy that they guarantee. It can be assumed that this has a positive effect on user acceptance of innovations.

It will be clear by now that IVCs cut across organisations. Furthermore, the 'Knowledge Exploitation' stage of formalised IVCs is closely related to business models, which are concerned with how value is captured, and by whom – not just the value of innovation, but also the value created by the creation and delivery of more established products and services. Projects are ways of focussing our attention on a particular, bounded set of innovation activities (associated with a particular product or intermediate outcome, perhaps), but they too can span more than one organisation.

Our literature review (D2.1) began by seeking to understand factors operating at the organisational, project and business model levels in the AM context. While some of the factors that we identify are clearly linked to one of these levels of analysis, there are many that cannot be definitively associated only with one. What is more, as has been signalled already in D2.1, and for the reasons just outlined, the organisational, project and business model perspectives do not fit into a neat hierarchical or nested relationship with one another.

6.3 Factors and openings for RRI

Factors

Regarding RRI factors, the roles of those factors on the webs of innovation value chains can be described as the antecedent and the outcomes of the system. For instance, a factor such as **open access** may create more opportunity in the development of AM product. If the open access is defined as the idea of making research activities freely available and accessible, it facilitates a more efficient knowledge diffusion and commercialisation of innovation. As university or commercial R&D provides an open access to their research findings if they public funded or financed, technological development will be more transparent and efficient. Collaboration and knowledge exchange among organisations and actors across national borders can also be facilitated, which later will strengthen the development of a knowledge-based economy. The input or constraints, especially relevant for industry will be given by the RRI keys (gender equality, public engagement, science education, ethics, governance, open access) will be discussed more in detail in D4.2. Other RRI relevant factors (keys) which will be encounter are gender equality, public engagement, science education, ethic consideration in innovation process and impact of innovation as well in supply chain and governance issues like structural change of organisations (institutional change).

<u>Openings</u>

The identification of the openings for RRI and their take up in the numerical model as well as in the value systems of the participating organizations is a major challenge in the development of the work process of all WPs. After analysing the available literature and obtaining insights from the consortium partners, two key definitions of possible RRI openings have emerged:

1. Openings as a failure to address sufficiently any of the six key areas. In a strict sense, RRI is a defined "contract" between science and society on different intersection areas: Open access, Gender, Governance, Ethics, Science Education, Public Engagement;
2. Openings in a prospective responsibility towards society, where stakeholders have the opportunity to undertake an honest effort to achieve the "right" social impact. In a broad sense, RRI promotes responsibility towards society and its beliefs, structures, norms, and values.

The first and stricter categorization is drawn from the proper framework of the RRI concept and is assessed in the project through conduction of interviews and surveys based on previously created RRI Indicators:

- Report on "Indicators for promoting and monitoring Responsible Research and Innovation" (2015)
- Deliverables of the MoRRI Project" Monitoring the evolution and benefits of responsible research and innovation" (2014-2018)

An online survey on RRI indicators was conducted within the consortium mid-March 2019 and revealed first insights about where possible "strict" RRI openings may be identified. The second and broader category is inspired by the need to conduct R&I in a transparent, inclusive, just and responsive way and thus lead to more quality of life and "better society". There are no fixed indicators for this definition, as the scope of the assessment is context-based and beyond the six main keys. This definition is also grounded in the topic in which the proposal was funded: *"This action will show, and induce, relevant change, without having to go through definitional exercises about RRI first, because the thrust is to go for 'openings to do better'. Rather than 'growth' per se, often defined in terms of competition only, the result will be higher quality outcomes and better jobs ('better technology in a better society')." (*European Commission, 2017).

To tackle both categories, a RRI workshop for consortium members was organized in Dusseldorf, Dec 14th with the following objectives:

- Deepen the knowledge of RRI and its five dimensions as defined by EC now
- Realize the need for responsibility in the context of R&I in AM

Create and test ideas for institutional change

Detailed information about RRI and previous paradigms such as TA (Technology Assessment), ELSA (Ethical, Legal and Social Aspects of Technology) were put into context. In addition, the six keys of the vision of the EC were explained to facilitate the identification of RRI challenges in AM industry.

The session triggered reflection and debate about socio-ethical aspects of technology and innovation in a very generic way. Examples of these kinds of statements are:

- "SME´s are much more responsible that the big ones"
- *"In a world where we are spending a lot of millions of euros on corporate image, RRI can be also a point of help"*
- *"What is special of AM in RRI?"*
- *"AM is a very important technology for the future of humanity. It will reshape the whole chains of many industries"*
- *"Entire industries can be destroyed with AM. Where is the responsibility for that?"*

Participants were invited to develop concrete ideas about how to promote the uptake of RRI by designing concrete actions and defining agents and objectives in their concrete field of work. Despite the honest engagement of the assistants in the different exercises questions about how to implement RRI in AM and also about the utility of the concept for the industry remained unsolved. However, there was strong consensus that AM will redefine many industries and this will create significant social needs in terms of anticipation and reflection.

7. Conclusions

This report has begun to develop a conceptualisation and application of the concept of webs of innovation value chains, which provides the basis for the project's approach to developing openings for RRI. It started with consideration and actor-network in a supply chain and derived the concept of web of innovation value chain targeting the role and impact of actors on the web or innovation networks.

It shows, in particular, the importance of distinguishing between, on the one hand, sets of interconnected actors and, on the other, chains of inter-connected innovation activities, i.e. innovation value chains. Understanding how the chains of innovation activities are distributed across multiple actors is crucial to understanding how openings for RRI can be identified and nurtured. Furthermore, understanding the intersection of innovation value chains in 'webs' provides an additional layer of insight into the most propitious points of intervention for policies seeking to promote RRI in AM.

Of course, it is evident that the AM industrial system under consideration is extremely complex. This presents a major challenge for computational modelling as well. As with any modelling exercise, it requires the striking of a balance between a realistic complex model.

8. References

Ahuja, G. (2000), “Collaboration networks, structural holes, and innovation: a longitudinal study”, Administrative Science Quarterly, Vol. 45 No. 3, pp. 425-455.

Botkin, J. W., & Matthews, J. B. (1992). Winning combinations: The coming wave of entrepreneurial partnerships between large and small companies. John Wiley & Sons Inc.

Carter, C.R., Rogers, D.S. and Choi, T.Y.,(2015). Toward the theory of the supply chain. Journal of Supply Chain Management, 51(2), pp.89-97

Carter, L, Graettinger, C, Patrick, M., Wemyss, G, Zasadni, S. (2002) The Road to CMMISM: Results of the First Technology Transition Workshop, STI – Carnegie Melon.

Chesbrough, H. W. (2003a). Open innovation: the new imperative for creating and profiting from technology. Boston: Harvard Business School Press

Cohen, W.M. and Levinthal, D.A. (1990), “Absorptive capacity: a new perspective of learning and innovation”, Administrative Science Quarterly, Vol. 35 No. 1, pp. 128-152.

Cooper, R.G. (2011) Winning at New Products: Creating Value Through Innovation, 4th edition. New York, NY: Basic Books, Perseus Books Group.

De Clercq, D. and Dimov, D. (2008), “Internal knowledge development and external knowledge access in venture capital investment performance”, Journal of Management Studies, Vol. 45 No. 3, pp. 585-612.

Dhanaraj, C. and Parkhe, A. (2006), “Orchestrating innovation networks”, Academy of Management Review, Vol. 31 No. 3, pp. 659-669.

European Commission (2017). Horizon 2020 Work Programme 2016 -2017 - 16. Science with and for Society. https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-swfs_en.pdf

Ellram, L. M., & Cooper, M. C. (1993). The relationship between supply chain management and keiretsu. *The International Journal of Logistics Management*, *4*(1), 1-12.

FoFAM (2016), “Additive manufacturing roadmap: gaps and actions on market driven value chains”, Industrial and regional valorization of FoF Additive Manufacturing projects. p. 52

Ganotakis, Panagiotis, and James H. Love. (2012) "The innovation value chain in new technology-based firms: Evidence from the UK." Journal of Product Innovation Management 29.5: 839-860

Håkansson, H., Ford, D., Gadde, L.E., Snehota, I. and Waluszewski, A. (2009), Business in Networks, Wiley, Chichester.

Håkansson, H. and I. Snehota (1995). Developing Relationships in Business Networks. London, Routledge

Hansen, M.T., Birkinshaw, J., (2007) The innovation value chain. Harvard Business Review, 85 (July), 121-130

Holmström, J. and Ketokivi, M. (2009) "Bridging Practice and Theory: A Design Science Approach", Decision Sciences Vol. 40, No. 1, pp. 65-87.

Jacobides, M.G., Knudsen, T. and Augier, M., (2006a). 'Who does what' and 'who gets what'. Capturing the value from innovation. In Executive Briefing, the Advanced Institute of Management Research (aim) (pp. 1-27). Advanced Institute of Management Research (AIM).

Jacobides, M.G., Knudsen, T. and Augier, M., (2006b). Benefiting from innovation: Value creation, value appropriation and the role of industry architectures. Research Policy, 35(8), pp.1200-1221

Koch, C. (2017), "Standardization in emerging technologies: The case of additive manufacturing", ITU Kaleidoscope: Challenges for a Data-Driven Society (ITU K), Nanjing, 2017, pp. 1-8.

Lee R. G, Petts J (2013)., Adaptive Governance for Responsible Innovation, Responsible Innovation, ed. R. Owen, J.Bessant, M. Heintz, Wiley 2013, 143

Owen R., Stilgoe J, Macnaghten, Gorman M., Fisher E., Guston D. (2013), Responsible Innovation, ed. R. Owen, J.Bessant, M. Heintz, Wiley 2013, 43

Maidique, M. (1980). Entrepreneurs, champions, and technological innovation. Sloan Management Review, 21(2), 59–76.

Meissner, D. (2015). Public-private partnership models for science, technology, and innovation cooperation. Journal of the Knowledge Economy. doi:10.1007/s13132-015-0310-3.

Meissner, D and Kotsemir, M. (2016) Conceptualising the innovation process towards the ‚active innovation paradigm trend and outlook, Journal of innovation and entrepreneurship 5,14.

Mitrova, T., Kulagin, V., Grushevenko, D., & Grushevenko, E. (2015). Technology innovation as a factor of demand for energy sources in automotive industry. Foresight and STI Governance, 9(4), 18–31. doi:10.17323/1995-459x.2015.4.18.31

Mintzberg, H. (1987). *Crafting strategy* (pp. 66-75). Boston: Harvard Business Review.

Monzón, M.D., Ortega, Z., Martínez, A. (2015), “Standardization in additive manufacturing: activities carried out by international organizations and projects”, International Journal of Advanced Manufacturing Technology, Vol. 76, Iss. 5–8, pp 1111–1121.

Morgan, J.P. (1997) ‘Integrated supply chains: how to make them work!’, Purchasing, Vol. 122, No. 8, pp.32–37.

Mowery, D., & Rosenberg, N. (1979). Influence of market demand upon innovation—critical-review of some recent empirical studies. Research Policy, 8(2), 102–153.

Myers, S., & Marquis, D. G. (1969a). Successful industrial innovations: a study of factors underlying innovation in selected firms. In NSF 69–17. Washington: National Science Foundation.

Myers, S., & Marquis, D. G. (1969b). Successful industrial innovations: a study of factors underlying innovation in selected firms. In NSF 69–17. Washington: National Science Foundation

New, S., 2004. Supply chains: construction and legitimation. Understanding Supply Chains: Concepts, Critiques & Futures, pp.69-108

Niosi, J. (1999). Fourth-generation R&D: from linear models to flexible innovation. Journal of Business Research, 45(2), 111–117.

Owen R., Stilgoe J.,Machnagthen P,. Gorman M, Fischer E., Guston D. (2013), Responsible Innovation, Managing the Responsible Emergence of Sciene and Innovation on Science,ed. R. Owen, J.Bessant, M. Heintz, Wiley, 2013, ISBN 978-1-119-96636-4, p43

Petersen K.J., Handfield R.B, Ragatz G.L, Supplier integration into the new product development; co-ordinating product, process and supply chain design, J. of Operations Management, 23 (2005), 371-388

Piaget, J. (1971). Biology and knowledge: An essay on the relations between organic regulations and cognitive processes.

Robinson D.K.R., Langau A., Wouter P.C. B. Technological Forecasting Social Changes 146 (2019), p 733

Rogers, H., Baricz, N. and Pawar, R.S. (2016),"3D printing services: classification, supply chain implications and research agenda ", International Journal of Physical Distribution & Logistics Management, Vol. 46 Iss 10 pp. 886 - 907

Roper, Stephen, Jun Du, and James H. Love (2008), "Modelling the innovation value chain." Research Policy 37.6-7: 961-977

Roper, Stephen, and Spyros Arvanitis (2012). "From knowledge to added value: A comparative, panel-data analysis of the innovation value chain in Irish and Swiss manufacturing firms." Research Policy 41.6: 1093-1106

Rothwell, R., & Zegveld, W. (1985). Reindustrialization and technology. Harlow: Longman.

Rothwell, R., (1994). Towards the fifth-generation innovation process. International Marketing Review, 11(1), 7–31

Rylands, B., Böhme, T., Gorkin III, R., Fan, J. and Birtchnell, T. , (2016), "The adoption process and impact of additive manufacturing on manufacturing systems", Journal of Manufacturing Technology Management, Vol. 27, No. 7, pp. 969 – 989.

Sampson, S.E. and Spring, M., (2012), Customer roles in service supply chains and opportunities for innovation. Journal of Supply Chain Management, 48(4), pp.30-50

Stokes, D. E., (2011). *Pasteur's quadrant: Basic science and technological innovation*. Brookings Institution Press.

MORRI Final Report,(2018) "Monitoring the evolution and benefits of responsible research and innovation in Europe", V. Peter, F.Maier (editors) (Technopolis Group), N.Mejlgaard, C. E.B. Madsen (Aarhus Uni-versity), E Griessler, M Wutekich (IHS), I. Meijer (CWTS, Leiden University), R.Wolley (Ingenio CSIC-UPV), R.Lindner, S. Bührer, A. Jäger (Fraunhofer ISI), L. Tsipouri (University of Athens), J.Stilgoe (UCL), RTD-PUBLICATIONS@ec.europa.eu European Commission, BE-1049 Brussels, May 2018, see http://www.technopolis-group.com/report/final-report-summarising-insights-from-the-morri-project-d13/

D2.1: LITERATURE REVIEW, Geerten van de Kaa, Vladimir C.M. Sobota, Roland Ortt, Cees van Beers (Delft University of Technology), Danny Soetanto, Martin Spring (Lancaster University), Miia Martinsuo, Toni Luomaranta (Tampere University of Technology), Antonia Bierwirth (Tecnalia), Idendifier IAMRRI_D2_1_V2_Final, (2019) Powell, W.W., Koput, K.W. and Smith-Doerr, L., (1996), “Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology”, Administrative Science Quarterly, Vol. 41 No. 2, pp. 116-145.

Quinn, F. J, (1997). Team up for supply-chain success. *Logistics Management*.

Tsai, F.-S., Hsieh, L., Fang, S.C. and Lin, J.L, (2009), “The co-evolution of business incubation and national innovation systems in Taiwan”, Technological Forecasting and Social Change, Vol. 76, pp. 629-643.

Usher, A. P., (1955). Technical change and capital formation, in national bureau of economic research, capital formation and economic growth (pp. 523–550). Princeton: Princeton University Press.

Von Schompeter Rene, (2013), Responsible Innovation, Managing the Responsible Emergence of Sciene and Innovation on Science, ed. R. Owen, J.Bessant, M. Heintz, Wiley, 2013, ISBN 978-1-119-96636-4, p51

Von Hippel, E., (2007), “Horizontal innovation networks by and for users”, Industrial and Corporate Change, Vol. 16 No. 2, pp. 293-315.

Westerlund, M. and Rajala, R., (2010), “Learning and innovation in inter-organizational network collaboration”, Journal of Business and Industrial Marketing, Vol. 25 No. 6, pp. 435-442.

Wohlers Report, (2019), Wohlers Report 2019 (ISBN 978-0-9913332-5-7), Wohler Association