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

www.IAMRRI.eu

The IAMRRI Booklet

Future Talk on Innovation in Additive Manufacturing & Openings for Responsible Research and Innovation

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under grant agreement No. 788361.

The IAMRRI Booklet

Proceeding of the IAMRRI Future Talk –Innovation
in Additive Manufacturing & Openings
for Responsible Research and Innovation
September 8th and 9th 2021

Publisher Montanuniversitaet
Franz-Josefstraße 18
A 8700 Leoben
September 2021

DOI https://doi.org/10.34901/mul.pub.2021.4

Picture scoure istoke: Page 11, 17,18.20, 23,34, 44)

Contents

IAMRRI - a European project to explore networks of innovation value chains and incorporate the approach on "Responsible Research and Innovation (RRI)" in additive manufacturing (AM)
Brigitte Kriszt
Montanuniversitaet — 1

The Prospect of Responsible Research and Innovation
René von Schomberg
European Commission, Guest-Professor,
Technical University Darmstadt, Germany — 2

Web of Innovation Value Chain – the IAMRRI conceptual model

Introduction to the conceptual model
Geerten van de Kaa
Delft University of Technology — 4

Factors for Additive Manufacturing Innovation Success
Vladimir C.M. Sobota, Geerten van de Kaa
Delft University of Technology — 5

Additive manufacturing actor-stakeholder mapping
Toni Luomaranta
Tampere University — 6

Future discussion on webs of innovation value chains (WIVC)
Vladimir C. M. Sobota, Geerten van de Kaa
Delft University of Technology — 8

Additive manufacturing in automotive and medical application: trends, challenges, opportunities and the role of RRI

Introduction to the use cases of IAMRRI
Danny Soetanto
Lancaster University — 10

Participant observations of the use cases
Elena Sischarenco
Lancaster University — 11

Automotive use case – industrial report
Giulia Servoli, Centro Ricerche Fiat
Christopher Wiednig, voestalpine AM — 12

Medical application use case – industrial report
Martin Schwentenwein, Lithoz
Ignas Gudas, Orthobaldic
Igor Drstvensek, Interessansa
Tanja Lube, Montanuniversitaet — 13

RRI Outcomes related to the two use cases
Danny Soetanto
Lancaster University — 15

Analysis of innovation cooperation in the IAMRRI use cases
Toni Luomaranta, Tampere University
Elena Sischarenco, Lancaster University **16**

Future discussion on innovation networks in additive manufacturing considering RRI
Danny Soetanto
Lancaster University 18

From model to simulation: transforming theory and data into the IAMRRI agent-based model (ABM)

Introduction to agent--based modelling (ABM) in IAMRRI
Nhien Nguyen
Nordland Research Institute **20**

History of SKIN model and its application
Nigel Gilbert
Centre for Research in Social Simulation
University of Surrey **21**

Designing the IAMRRI-SKIN model
Are Jensen
Nordland Research Institute **23**

Implementation of the IAMRRI SKIN model
Cristina Ponsiglione, Carmine Passavanti
University of Naples Federico II **24**

Simulation results on webs of innovation value chains in AM
Enrico Cozzoni
Grado Zero Espace **26**

Future discussion on the IAMRRI agent based model and future research
Nhien Nguyen
Nordland Research Institute **27**

Responsible research and innovation (RRI) in the innovation system of AM

Introduction to RRI understanding in IAMRRI
Ana Arroyo, Izaskun Jimenez
Tecnalia Research and Innovation **29**

RRI in web of innovation value chain: The case in IAMRRI
Ana Arroyo, Izaskun Jimenez
Tecnalia Research and Innovation **31**

Views of different actors of additive manufacturing innovation system on RRI
Alexi Perrino
Materalia **32**

Summary on future discussion on RRI in the AM Innovation System
Izaskun Jiménez Tecnalia **33**

IAMRRI Foresight

Foresight in IAMRRI
Marianne Hörlesberger
AIT Austrian Institute of Technology **35**

2040 – Four future scenarios
Andrea Kasztler
AIT Austrian Institute of Technology **36**

Innovation phases of the scenarios and modelling
Enrico Cozzoni, Grado Zero Espace
Andrea Kasztler, Marianne Hörlesberger
AIT Austrian Institute of Technology **37**

Future discussion about foresight
Marianne Hörlesberger
Austrian Institute of Technology **38**

Future discussion on "How could RRI gain a competitive advantage in AM for Europe?"
Brigitte Kriszt
Montanuniversitaet **40**

IAMRRI - a European project to explore networks of innovation value chains and incorporate the approach on "Responsible Research and Innovation (RRI)" in additive manufacturing (AM)

Dr. Brigitte Kriszt
IAMRRI project coordinator
Montanuniversitaet Leoben

This project has received funding from the European Union`s Horizon 2020 research and innovation program under grant agreement No. 788361. IAMRRI belongs to the group of projects under the priority "Science with and for Society" and addresses the question of how innovation systems consisting of networks of innovation value chains will develop in future when RRI objectives guide their actions and innovations. This research question was studied on the case of additive manufacturing.

Additive manufacturing (AM) is a group of production technologies that are developing and are applied to manufacture novel products. Due to the layer-by-layer building manufacturing technologies, there are design freedoms which are not feasible in classical manufacturing. This opens up new scenarios for innovations. In connection with this, innovation value chains are emerging in the areas of materials, software, manufacturing technology and processes and the applications of AM to create new products.

The research work started with the analysis of the real world of the innovation system of additive manufacturing and describes it in a conceptual model. From the multitude indicators of innovation success and failure, the appropriate ones were determined. This model was transformed into a description with an agent-based mathematical model in

order to be able to carry out simulations that allow new insights into the development of innovation systems. The booklet at hand highlight the outcome of the project and give short summaries on the research outcome in conceptual modelling and indicators, building of a IAMRR SKIN agent base model and simulations, the learnings from the performed use cases in automotive application and medical implant manufacturing. The knowledge which was gained on the implementation of RRI in a web of innovation value chains and the introduction to scenarios and future shapes of the European Society who deal intensively with AM are introduced.

The booklet contains all presentations of project members held at the IAMRRI Future Talk and the summaries on the panel discussion on future topics in the focus of the IAMRRI project, September 8th/9th 2021, Web-event. The videos of the IAMRRI Future Talk can be seen under www.IAMRRI.eu.

Thanks to all project members of the following partners to contribute in this IAMRRI project:

Austrian Institute of Technology
Lancaster University
Centro Richerce Fiat
DeskArtes Oy
Orthobaltic
Tecnalia
Grado Zero Espace
Interessansa
Lithoz
Delft University of Technology
Materalia
Nordlandsforskning
Tampere University
voestalpine Additive Manufacturing Centre Düsseldorf
Montanuniversitaet

Preface

The Prospect of Responsible Research and Innovation[1]

René von Schomberg
European Commission
Guest-Professor, Technical University Darmstadt, Germany

[1] Key messages base on: Von Schomberg, R (2019) 'Why Responsible Innovation' in: *International Handbook on Responsible Innovation. A Global Resource,* Cheltenham: Edward Edgar Publishing*, p 12-35*

Why Responsible Innovation?

RRI requires a form of governance that will direct or redirect innovation toward socially desirable outcomes. The initial definition that I provided in 2011 captures the commonalities of the field:

'Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)'

This definition was not proposed as an end-result but as a starting point for an ever-growing field of research and innovation actions. Responsible Innovation is a normative response to the current major deficits of the global research and innovation system. The deficits are the following:

- Need for governance mechanisms for outcomes of Science, Technology and Innovation
- Address market failures in order to deliver on societally desirable innovations
- Align Science. Technology and innovation policy with broadly shared public values.
- Shift focus from technological potentials to societally desirable objectives
- Shift to open scholarship in order to make science better by improved reproducibility of data, efficiency and more responsiveness to societal challenges
- Implement anticipatory governance mechanisms in the policy making process by using a combination of Foresight, technology assessment and normative (participatory) design.

I will address these points below, be it in a very brief manner. The matter is discussed in detail in the article on which this presentation is based.

The definition was put forward, first, to highlight that dominant public policies only negatively select science and technology-related options, notably by the management of their risks. According to the still dominant ideology, all innovation will contribute to common prosperity regardless of its nature. The notion of responsible innovation makes a radical break with such ideology. Furthermore, this ideology tells us that innovations cannot be managed or given a particular direction. Also on this front, the notion of responsible innovation breaks with this ideology and puts the power for a socially desirable change through innovations into the hands of stakeholders and engaged citizens. However, these stakeholders have to become, or be incentivized or even enforced to become, mutually responsive to each other in terms of social commitments to such change. Notably, the current ''green deal'' the EU has embarked on, can be seen as (maybe the soft version of) such a social commitment and makes directional innovation possible. This also implies the institutionalization of a form of collective co-responsibility, going beyond the traditional evaluative forms of ethics, which have concentrated on the negative constraints of new technologies (e.g., what we ''should not do'') rather than engage with a constructive form of technology development (e.g., which direction we ought to go). Finally, we see major market failures in the areas what matters most to people: the provision of effective drugs for major diseases and for emerging public health issues. The market does not deliver on many technologies necessary for sustainable development. Hence, RRI requires a stronger role for public authorities and public governance of the economy.

Open Scholarship

Open scholarship should also be seen as a necessary, yet insufficient condition for RRI. The Covid 19 pandemic was a game changer to some degree for advancing RRI and bringing it to the epicentre of the public policy space. We have witnessed a necessary change in the modus operandi of doing science: Open research and scholarship by which researchers share data and knowledge with all relevant knowledge actors as early as possible in the research process made it possible to deliver swiftly on vaccines. Without open science, the market introduction of these vaccines would have taken, under the usual circumstances of competitive research and intellectual property right constraints, minimally a decade.

Anticipatory Governance

We still have institutions that only indirectly govern emerging technologies, notably through its risk management. Therefore, our institutions have only the capacity to respond to all kinds of crisis when unanticipated risks materialize, for example, when risks of genetic or nano-engineering are identified. We must establish institutions that are not only able to anticipate risks, but also desirable outcomes. Hence, public authorities need to make use of extended forms of Technology Assessment (TA) and Science and Technology Foresight. Notably the employment of Foresight, can help to assess plausible and desirable alternative futures and be employed for determining characteristics of new technologies. It is important to stress TA and Foresight should be embedded in deliberative processes with stakeholder and citizen engagement. Furthermore, research and innovation have to become value driven, rather than only seen as means for fostering future economic prosperity. We possibly have reached now a point that research funding all over the world will feature a focus, at a minimum, which addresses the sustainable development goals. The research and innovation system may, therefore, zero in on a more value-driven system. Yet, this would require more than simply funding, let us say any type of climate change research. It will have to include a research process that allows for a critically informed democratic deliberation of those values in course of the application of these values to local and regional circumstances. After all, a climate change with a 2 degree C rise has different implications for Canada than for Bangladesh. Research and Innovation priority setting, and the shaping of research agendas have to become more open and co-created with stakeholders. Finally, we need to strengthen the public governance of the economy to address early on market deficits. To enable the transition toward a fossil-free economy, public investment and direct involvement in the innovation process will be necessary.

Prospects for Institutionalisation of RRI

Horizon Europe highlight the Sustainable Development Goals and contains instruments that might direct and drive innovation towards these goals, whilst promoting openness and collaboration with stakeholders and citizens. The introduction of ‘mission-oriented ‘research, co-designed and created with stakeholders and citizens, might also open new pathways to collectively direct and mobilise strategic research and innovation towards societal challenges under-pinned by European values .It is worth noting Horizon Europe is possibly the first public research funding programme globally to include open science as part of the excellence evaluation criterion for research proposals: these need to describe how they will implement open science practices, including open access to project outputs, and implementation of so-called FAIR principles aimed at responsible data management. Evaluation of project proposals will include assessment of the quality and appropriateness of open science practices that extends to the engagement of citizens, civil society and end users. This broadening of the excellence criterion in combination with significant funding for calls that explicitly ask for the inclusion of citizens in the development of research agendas and implementation of research and innovation projects is notable. These interventions are the first steps towards an institutionalisation of RRI, by changing the rewards and incentives system for research and innovation. Further steps would require a stepped-up public governance of our economy.

Web of Innovation Value Chain – the IAMRRI conceptual model

Introduction to the conceptual model

Geerten van de Kaa
Delft University of Technology

The conceptual model of the IAMRRI project consists of actors and factors that are related to performance indicators. The model is set up as a (social sciences) conceptual model. This model serves as the scientific foundation upon which the IAMRRI project is build. Economic performance, social performance as well as strategic impact has to be achieved in order to successfully implement additive manufacturing in Europe. Economic performance is measured in terms of profits and social performance is measured in terms of social acceptance and acceptability of innovations. Strategic impact refers to all impacts that the realization of AM in Europe has on society.

These performance indicators are affected by actors and stakeholders that operate in the innovation value chain. Three stages can be distinguished; idea generation, product development and innovation diffusion. Complex webs emerge as actors become interconnected.

One can ask the question how the actors and stakeholders in the networks affect the performance indicators so that selected solutions can be achieved? Factors affect economic performance in terms of for example installed base directly. Also, by for example integrating values such as democracy into a technology user acceptance might increase. Many of these factors affect the actors and their relations directly. Figure 1 provides an overview of the conceptual model of the IAMRRI project.

Lets give an example. A standard development organization is mostly active during innovation development and diffusion. It may encourage a high level of inclusivity during the standardization process which may positively affect social performance in terms of user acceptance. Encouraging inclusivity can then be seen as an opening for RRI that can be affected by that standard development organization.

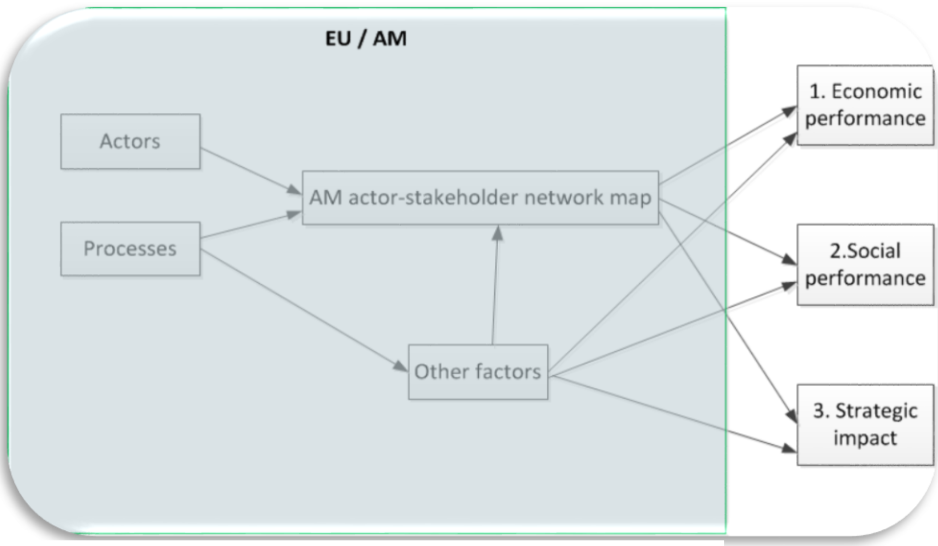


Figure 1: Overview conceptual model IAMRRI

Factors for Additive Manufacturing Innovation Success

Vladimir C. M. Sobota, Geerten van de Kaa
Delft University of Technology

Webs of innovation value chains

In the context of IAMRRI, we conducted several literature studies on factors for (additive manufacturing) innovation success. These fed into two deliverables that were written in the beginning of this project, and one paper that was published in Journal of Manufacturing Technology Management[1].

These literature studies were led by the observation that additive manufacturing (AM) is not a single technology, it is a bundle of new production technologies. These technologies offer innovative functionalities of products and services. Firms may generate ideas, develop these, and then introduce these to the market and promote these. This is what we call innovation value chains. However, innovation and technology development do not happen in isolation. Different technologies interrelate, for example, machine manufacturers may benefit from complementary products such as metal powders or filaments. This means that there are many innovation value chains next to each other.

Figure 1: List of factor from literature and most important, economic and strategic impact, societal performance

It is important to note that these innovation value chains also interrelate. As in the previous example, machine manufacturers may benefit from complementary products such as metal powders or filaments, and vice versa. Innovation value chains of several technologies may interrelate and result in so-called 'webs of innovation value chains'. Actors in webs of innovation value chains may use different alternative technologies. For example, actors may rely on different metal AM machines.

Factors for additive manufacturing success

For webs of innovation value chains, it is highly relevant to understand the diffusion of technologies. This line of reasoning was captured by studying factors that affect AM success. As Geerten van de Kaa has mentioned in the introduction to this session, AM success is measured in terms of the key performance indicators economic performance, social performance, and strategic impact. Adding those introduces three layers of AM success. Based on how these layers are approached in the literature, it makes sense to conduct the study in two lines of research: economic performance and strategic impact form were studied together, while social performance formed the other line of research.

Furthermore, we studied these dependent variables at the (inter)organizational, business model, and project-level. To summarize, this review consists of four studies. Each studies factors for AM success, but with respect to different performance indicators and at a different levels of analysis.

All four studies relied on similar methodology. Potentially relevant literature was identified based on a search with keywords. The relevant papers from this initial search were used to identify further studies based on forward and backward search. The resulting sample of studies was then analysed for relevant factors. Following this methodology across all four studies resulted in a longlist of more than a 100 factors across different levels. After removing duplicates, excessive level of detail, we were left with a more refined list. We organized related factors in categories. After all, we concluded with 52 factors, plus definitions, across 9 categories.

In a next step, AM experts from industry and academia prioritized these factors based on based on the Best-Worst-Methodology, as shown in Figure 2.

In figure 1, factors are ranked by their relative average weight. Prioritizing factors is important as it allows practitioners to concentrate scarce resources on important factors, and it allows scholars to build more parsimonious models. The most important factors are framed in red.

Economic performance	Social performance	Strategic impact
Imitability, scalability, and integrability	Social norms	Science literacy and scientific education categorisations
Customer demand	Public health	Learning orientation
Failure to consider influential factors	Environmental sustainability	Relative technological performance
Failure to consider actors / stakeholders	Science literacy and scientific education categorisations	Customer demand
Open access categorisations	Ethics categorisations	Regulator

Figure 2: Most important factor for WIVC in additive manufacturing

The most important factors

Having a closer look at the five most important factors regarding economic impact, it is evident that business model-factors dominate this list. Regarding social performance, we see that factors relating to values and norms, and RRI indicators are most-important. The most important factors are shown in Figure 2.

One factor, customer demand, turns out to be among the most important factors with respect to two key performance indicators

[1] Sobota, V. C. M., van de Kaa, G., Luomaranta, T., Martinsuo, M., & Ortt, J. R. 2020. Factors for metal additive manufacturing technology selection. Journal of Manufacturing Technology Management, 32(9): 26–47.

Additive manufacturing actor-stakeholder mapping

Toni Luomaranta
Tampere University

Additive manufacturing as an invention is already rather old. However only during the last decade it has started to gain foothold in the industrial manufacturing sector. Additive manufacturing means building objects layer by layer making it different from milling or casting production methods.

Additive manufacturing should be understood as umbrella term, meaning that additive manufacturing is actually a set of many different technologies. These different technologies use different methods for build up the object, for example by melting material with laser or extruding heated material layer by layer. Each of these different technologies may use different raw materials and can be applied to even growing numbers of application areas.

Additive manufacturing industry is not, at least not yet, a mature technology to be used in linear supply chain of goods but consisting of many different levels at the level of operations as well as with innovations. To develop new innovations both in product and AM technology, there are five levels we identified (not in particular order): AM material research, AM technologies, AM services & business models, software and digitalization for AM, and finally the new product innovations for customers manufactured with AM. In each of these levels there are innovations taking place.

In addition, in the additive manufacturing industry there are many kinds of organizations active. Research in universities and other research institution is taking place all of the mentioned five levels. Similarly, research and innovation is taking place in industrial companies who either develop new materials, new kinds of machines, new kinds of software, new kinds of products, or new kinds of business models to make business with additive manufacturing. Both universities and companies are transferring the knowledge of additive manufacturing either through education system or trough industrial cooperation, and little by little the new technology is being adopted widely to the industry.

In project IAMRRI we studied the innovations where our project partners had been active by retrospectively mapping the organizations active in different phases of this innovation. These innovation cases were then divided into three phases of ideation, development, and diffusion. These phases form innovation value chains, as we defined in our project.

The first example is an AM product innovation, which was a surgical gripper that was completely designed to be manufactured with additive manufacturing and the ideation was done together with surgeons from the hospital and with medical device manufacturer, and additive manufacturing service provider and design providers. Product development was done mainly by additive manufacturing service provider and designer, but they collaborated with local research center for material testing and of course also with medical device manufacturer who was the project owner. So,

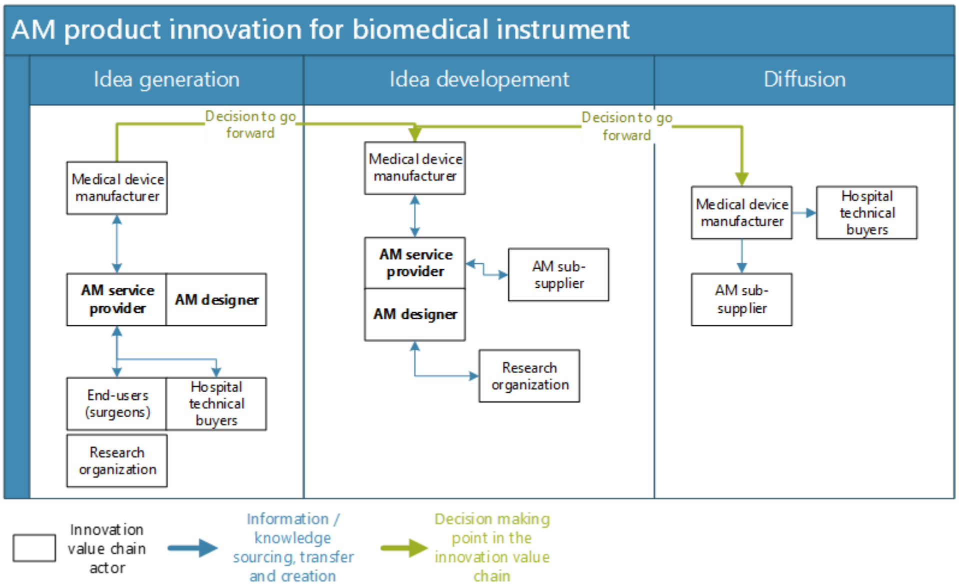


Figure 1: AM innovation phase and actors, which are in the three phases of innovation on a device medical

they had the ultimate decision to go forward when they had satisfied product at their hand. The product, a new instrument, was diffused the market by marketing and selling these instruments into hospitals. New manufacturing supply chain was also established using a sub-contractor. In the below figure you can see this example.

During the early part of the research nine innovation cases was studied and mapped. Later in the project we studied three bigger innovation programs and three on-going cases of innovation. Which resulted similar maps and tables of activities happening during these cases. These cases included basic research on mechanics and material, innovation for new kind of additive manufacturing machine, developing of new software, developing new additive manufacturing materials, and several product innovations.

Please notice, that retrospectively the innovation value chains look rather linear processes, but in reality, there were many feedback loops within each phase and even between the phases. Also notice that different organizations most likely have their possible different powers to influence and drive the innovation system.

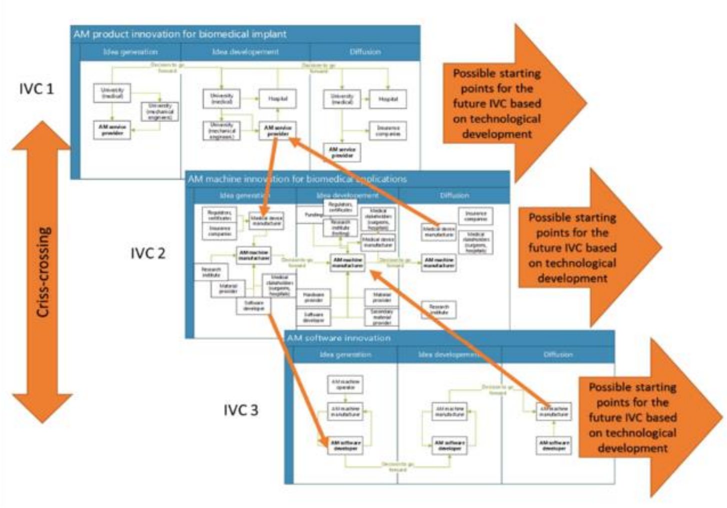


Figure 2: Innovation value chains in WIVC and model for criss crossing mechanism

Furthermore we noticed that these apparently independent innovation cases are not necessarily independent at all but they are interrelated to each other, meaning that for example additive manufacturing machine innovation started a new material development so the idea for new machine actually was a the starting point also for the idea of new material. The figure below is illustrating how this Criss-crossing of these innovation value chains is happening, it illustrates how certain innovation might lead to a starting of another innovation.
Also, after one innovation is diffused to the market, it is providing a possible starting point for future innovations based on the technological development. So, in other words the new AM machine did start new material development and software innovation. And after the AM machine is ready and, in the market, it enables new kinds of additive manufacturing product innovations - those products that can be manufactured with the new AM machine. For example, a new kind of biomedical implant.

Regarding responsible research and innovation (RRI) the learning from these maps of innovations is that there are several possibilities within these webs of innovation value chains to contribute to the responsibility in innovations. Whether it is then timewise, innovation phase-wise or organization-wise.

Future discussion on webs of innovation value chains (WIVC)

Vladimir C. M. Sobota, Geerten van de Kaa
Delft University of Technology

Panellists
Roland Ortt, Delft University of Technology
Miia Martinsuo, Tampere University
Marianne Hörlesberger, Austrian Institute of Technology
Antonia Bierwirth, Tecnalia

Moderation
Geerten van de Kaa, Delft University of Technology

The panel session on Webs of Innovation Value Chains (WIVC), moderated by Geerten van de Kaa, featured four prominent researchers in the area of (project) innovation management, futures research, and RRI; Roland Ortt, Marianne Hörlesberger, Miia Martinsuo and Antonia Bierwirth.

Headline 1

A key feature of IAMRRI is the inclusion of the three key performance indicators economic performance, social performance, and strategic impact. The first question that was posed to the panelists concerned how the performance indicators that were arrived at in the project (strategic impact, economic performance, and social performance) related to each other. Panelists had different views. Economic performance is all about markets, whereas social performance includes actors beyond those directly involved, including the safeguarding of values and norms. Strategic impact refers to the long-term consequences for the EU at the whole, or at lower levels of analysis. The three performance indicators are complementary – sometimes they reinforce each other, sometimes they conflict. The complementarity sometimes also depends on the level of analysis. The complementarity of the performance indicators also comes from the fact that they are affected by the same factors. Some important factors are similar across the performance indicators, and they might be influencing the performance indicators at the same time, but not necessarily in the same direction. Different value chains are linked to each other and actions in one chain may impact the other, having versatile effects on the performance indicators. Having so many organizations involved in this project begs the question on who's performance indicators we are looking at. The factors may also differ in their temporality, some playing out earlier, some later. The panelists emphasized that on the one hand a balance should be sought whereas on the other hand social performance can be seen as a precursor to economic performance.

The second question concerned who are the actors that have the power and possibilities to drive the AM innovation system. While the conclusion regarding the most important actor depends on one's position in the network. Most panelists agreed that standardization organizations can be important and key players, as there are currently no dominant designs that rule and lots of power rests in the collaboration between firms. Standardization organizations and regulators are very important for social responsibility, environmental responsibility, and for setting the boundaries of the system. At the same time, it was stressed that no single actor has *the* power. There is a role division, meaning that coalitions can have power, and even the EU can only stimulate and steer, but not enforce AM adoption. With standards, timing is really important, as wrong timing has been shown to be detrimental for progress.

Finally, the panelists shared what they saw as being the most interesting areas for future research. On the level of factors and performance indicators, it would be interesting to formulate the indicators as disjoint indicators. The model could be developed into a fuzzy model for the assessment and evaluation of the indicators. The performance indicators could be formulated such that they are always socially grounded, meaning that there are always social dimensions underlying them. Given the current state of AM, the panelists plead for research on how to scale up AM. How can AM move from its current niches towards scaling up while safeguarding social performance? Scaling up is required to achieve social implications. To answer this question, one could learn form applications that grew fast. At the same time, panelists suggested to scale down – for example, what are the factors for a certain detail and with respect to a certain outcome? Further, environmental sustainability, the interplay of actors in AM, AM as a service, its business logics, or customer service experience of those who use AM were brought forward as promising research directions.

Additive manufacturing in automotive and medical application: trends, challenges, opportunities and the role of RRI

Introduction to the use cases of IAMRRI

Danny Soetanto
Lancaster University

Within IAMRRI project, the use cases were intended to provide a strong empirical investigation on the roles of RRI and to assess the reliability and the applicability of the simulation tool developed by other work package. For that reason, we will examine cases that enable us to study the process of innovation value chain. By performing 'real-time' and experiential experiment, the cases were expected to capture the details of the specificity and context of innovation process as well as to observe how innovation in AM and RRI are interconnected.

AM covers a wide variety of manufacturing technologies involving various business models, market characteristics and different level of adoption. Our approach, then, is to focus on the use cases that create more significant changes in the product's capabilities than the product that is currently available in the market.

After several consideration, two use cases in automotive and medical application were selected. The use cases started in summer 2019 and were carried out until March 2021. Both use cases represent contrasting concerns in relation to some of the thematic RRI keys. For instance, ethics is supposed to be more prevalent in the context of medical application while other RRI keys such as public engagement related to safety is a necessary condition for automotive application.

In addition, it is necessary to include examples of innovation that are able to represent the phenomenon of 'criss-crossing' innovation. Here, collaboration from several different public organizations and companies are expected to bring a new idea into a commercialised product. By examining the use cases, this project was able to identify the process of innovation value chain including feedback loops and interaction that may not have been visible on the basis of simpler innovation models or literature review. In order to capture the process of innovation and its intricacy, we employed several different research methods including interviews, workshops and participant observation. The methods allowed us to explore both a wide contextual understanding of the innovation value chain and its interaction of various technological development as well as a more specific understanding of the collaboration process and the interaction among agents during the process of innovation value chain.

Automotiv use case

Two companies, voestalpine AM and Centro Ricerche Fiat S.C.p.A (CRF), were involved in developing this use case for automotive application. To demonstrate how the process of innovation value chain works, the observation focused on the development of a single demonstrator, a front suspension arm. Compared to traditional manufacturing technology, additive manufacturing technology will bring several new advantages for the product such as lightweight, reduction of the equipment and better management of the assembly phase. The first step was choosing the material that accommodate the context where the part operates. The selected material should pass several structural component and complex geometry tests such as material properties, fatigue resistance, thermal stresses and warping. The next step is the selection of printer technology. Again, several criteria were imposed including the dimension, quality, printing time, the orientation of the part in the print volume, and the availability of a laser powder bed fusion machine. In the design phases, several activities were performed such experimenting with different loading and directionality, conducting post processing optimization, and made sure that structural performance was satisfied. The outcome of this step was the production of CAD. After all conditions were met, the prototype was built.

Medical use case

In the medical use case, several partners were cooperating, so a chain from research to SME partners were built. Lithoz, Orthobaldic, Montanuniversität, Deskartes and Interessansa. Contribute to the medical use case.

In the medical use case 2 different application were investigated, the skull and spine implant. Common topic in both cases was the application of ceramic material.

In the following section, we will outline our reflection on each element of the use cases. Following the structure of the session 2 - Future talks conference, we start the chapter with the process and the outcomes from employing participant observation as a tool to observe the use cases. The next section discusses the process, reflection, and outcomes of the use cases in automotive and medical application. The next section presents the analysis of the innovation cooperation during the use cases, followed with the summary from round table discussion.

Participant observations of the use cases

Elena Sischarenco
Lancaster University

To observe the use cases, participation observation was employed. Participation observation is a methodology used in social science in particular in social anthropology. Such methodology includes long periods of time observing and active participating in the activities of a specific group, community, society, which is the focus of the study. Participant observation enables both a wide contextual understanding of the specific field of their innovation process and their contexts. A researcher from Lancaster University was assigned to the project. The study involved traveling to the company's partners, conducting workshop, and visits to the users of the technology. The study was conducted in real time by participating in meetings and performing real experience at the locations. Together with Voestalpine and Centro Ricerche Fiat (CRF), the researcher involved in the development of front suspension arm for automotive application. In medical application, the observation was conducted to study the interaction between Lithoz and Orthobaltic in developing a spine implant and Lithoz and Interesansa for a skull implant.

There are several important findings and insights that are generated from employing participant observation to study the use cases. First, participant observation has proven to be effective as an analysis tool especially for studying the process of innovation value chain. Extracting valuable information for the use cases can only be gained through immersing into the process of innovation. By acting as an active agent during the meetings and discussion, the researcher was able to get insight into viewpoints, meanings, values, consideration which later gives authentic data.

Moreover, as we found during the use cases, the innovation process is not linear but full of uncertainty. Consequently, a flexible approach needs to be employed to allow researcher to follow up different direction or ideas if something interesting emerges. This led us to the second important point which is about the active role of researchers. In our context, the researcher acted as a catalyst of idea generation and facilitator for networking activities. By bringing industrial partners together, the process of innovation can be started and observed. By actively involved in the process, the researcher was able to capture the different mechanism of collaboration from serendipitous interactions in the office corridor to planned networking activities.

Thirdly, in performing collaboration, each industrial partner needs to appoint a reliable person-in-charge who always available to interact, communicate and make a crucial decision. Having a stable person-in-charge helps the researcher to access more detail information regarding the use cases and to clarify some confusion during the data collection process.

With regard to RRI, we found that most of the industrial partners had a little understanding about the subject. However, after several iteration of observations, we found that some RRI keys had already became an integral part of mindset and routines which involve company strategy, regulation, policy and working procedure.

Automotive use case – industrial report

Giulia Servoli, Centro Ricerche Fiat (CRF)
Christopher Wiednig, voest Additive Manufacturing Center Düsseldorf (voest AM)

In the IAMRRI project, Centro Ricerche Fiat S.C.p. is responsible for the automotive use case by involving the additive manufacturing technology.

The activity undergoing in the automotive use case is the process of redesign of a component previously produced with traditional well-assessed technologies exploiting advantages and addressing possible limitation of the AM technology. The core partner for the automotive use case is Voest Additive Manufacturing but CRF share all the information also with the University of Lancaster.

The component chosen as demonstrator is a part from limited series sport car model. In particular, it is a front suspension arm. The choice of proposing a component used in small series is consistent with the current use of additive manufacturing in the automotive sector.

Figure 1: Demonstrator of the suspension arm showing the potential of AM production for automotive application

The benefits in designing this demonstrator in additive manufacturing are light weighting, which is always important in terms of reducing CO_2 emissions for the automotive sector and reduction in equipment that is tied to reduce costs and management of the assembly phase.
To make a good design, the mission of the component must be taken into consideration.
Since the chosen demonstrator is an object with structural task, its design must start from the choice of material, considering the mechanical properties needed in the final part. The complex geometry leads typically to high thermal stresses during printing and warping after removing the printing-support structure. This is an important factor to consider for the success of the object. The design of the front suspension component needs a material, which is easy to print, and does not necessarily need a post heat treatment. The properties of the material "as built" already meet the structural requirements. Finally it is very important the cost of the

powder. Since the material is brand new, the process parameters has to be developed and the process quality and stability evaluated.

The choice of a printer must take into account the dimensions of the part, the quality that is desired in the final component, the printing times and a whole series of fundamental parameters for the design. This phase is done together with the choice of the material. Achieving optimum material performance in relation to production times can require customization of process parameters for each printer.

From the point of view of mass production, we are interested in the possibility of producing several parts together to reduce production times. To do this, you can print more parts in the same machine (with a larger dimension) or equip yourself with more machines. This approach needs an experienced programmer to careful set up the additive manufacturing process.

The orientation of the part in the machine influences several factors, like the surface quality, the support situation and the possible geometry.

The redesign the part follows a workflow. The first step is the definition of the design space. Next, assign different loads and boundary conditions to the design space perform topology optimization. Providing an orientation of the part under construction allows taking into account the directionality. This allows optimizing the demonstrator by reducing the supporting elements that have to be removed in the post-processing.

Then FE analysis is used to evaluate the structural performances of the obtained lightweight design after a loop with CAD modelling.

We focus on reaching mechanical requirements in order to obtain a design that satisfies the structural performances with a reduction in weight.

Based on the material data received from VAMC partner, we run a first optimization: a topology optimization considering both fatigue and misuse loading. Topology optimization takes a 3D design space and literally remove material within it to achieve the most efficient design. After we carry out an additional loop of topology optimizations by introducing, new load cases to take into account the stiffness of the component, minimizing the mass of the demonstrator.

To understand the limits of AM technology, we test structures that challenge the limit of achievable thicknesses. We further optimize the solution obtained by introducing tubular structures where it is appropriate and we run a size optimization that merely changes the structural-element parameters (e.g. element thickness, cross-sectional area) to satisfy the design requirements.

After the first FE analysis, we prepare a first CAD model of the demonstrator and send it to the partner to evaluate its feasibility. The requirements regarding tolerances and additional material for machining are shared. The additional material is important in the area that a precise dimension or a machined surface is required, especially for the bearings and screw holes.

VAMC explain the importance of the holes so that the powder trapped inside the hollow structures could be removed.

We carry out the FE structural analyses on the final CAD model, using internal standards to check the performance of the designed component.

The CAD file is transferred into machine data and VAMC manufactures the first part. Manufacturing is carried out without any issues. A first investigation of the part does not show any distortions. When separating the part from the platform and removing the supports inner stresses are transform to distortions.

The measurement shows that stress relief heat treatment after AM and before removing the support is needed. A heat treatment procedure for this material is designed for the following demonstrators. We check that the measurements are consistent with the tolerances of the component. We ask to reduce as much as possible the extra material in the areas where further processing is not required for this demonstrator. The reason is to push technology to the limit and to reduce post-processing where possible.

It can be seen that designing a part with AM technology is a compromise between performance optimization and printability in terms of technical and economic feasibility. Therefore, the collaboration of several technicians is required for the final success of the part.

Medical application use case – industrial report

Martin Schwentenwein, Lithoz
Ignas Gudas, Orthobaldic
Igor Drstvensek, Interessansa
Tanja Lube, Montanuniversitaet

In developing use cases for medical application, several companies were involved including Orthobaltic (ORT), Interesansa (INT), Lithoz (LIT), and Montanuniversitaet Leoben (MUL). Dekartes gave input on software. Two demonstrators for use cases were selected, skull and spine implant. Orthobaltic and Interesansa played the role of the end users and decided the selection and criteria of the demonstrator while Lithoz acted as a technology provider. Together with Montanuniversitaet, Lithoz were active in the realisation and characterization of the materials and the demonstrator. For the materials for this use case, aluminum oxide and zirconium dioxide ceramics were selected due to several advantages such as high modulus, high wear resistance, chemical durability, low thermal conductivity, biocompatibility, aesthetics/color. While the process looked linear and straightforward, the reality is, however, there were a constant interaction among industrial partners.

For the first medical use case, a solid skull implant was selected by Interessansa. The chosen technology for this use case was the lithography-based ceramic manufacturing process (LCM) that was developed and commercialised by Lithoz.

The LCM process enables the direct production of 3D ceramic components starting directly from CAD files via a shaping-, debinding-, and sintering-workflow. This allows direct fabrication of an implant with some additional features such as an integrated hole for liquor drainage, which are practically impossible to fabricate with other conventional fabrication technologies or other materials such as silicon rubber. Overall, the case study produced a positive result with no defects and good precision of the final ceramic implant, which is depicted below.

Figure 1: Sintered 3D printed skull implant

The second use case in medical application was initiated by ORT. Three project partners LIithoz, Orthobaldic and Montanuniversitaet, were collaborating to develop a spinal implant. The design was developed by Orthobaldic after collecting data and consulting with surgeons. In this use case, ceramics have been considered in particular because of their biocompatibility and the high strength and stiffness with good fracture toughness.

In developing spinal implants, the challenge was to find materials where bone tissue can grow and which can be structured in very high resolution to provide an advantageous micro-environment. In other words, the implant should be built with material that allows a production of a defined macro-porous cellular network of interconnected channels with a desired outer geometry. In addition, the selected material should meet other mechanical properties such as fracture toughness because of the fine geometrical features present. In this use case,

Lithoz decided to try different types of ceramics, namely silicon nitride, zirconium dioxide and aluminium dioxide. The outcomes were positive no defects, high precision. Further testing concerning the strength data is still pending. The sintered spinal implants are depicted below.

Based on the above observation and analyses, several findings and outcomes can be generated.

Figure 2: Spine implant with cellular structure

RRI Outcomes related to the two use cases

Danny Soetanto
Lancaster University

Following the success of use case in automotive and medical application, several points can be made. First, collaboration is critical for the development of a new product or technology. As the use cases have shown, the development of each demonstrators needs a constant iterative process among the companies to provide data, knowledge, skills and technology. As the process is always about balancing performance of optimization and technical economic feasibility, more collaboration will increase the speed of the process and quality of the product. Second, further steps can be exploited in the direction to diffuse the product into the market. This include pursuing standardization, performing more mechanical and chemical testing (strength, modulus, fracture toughness, hardness, leachability, phase purity, microstructure), and applying for ISO 13356 and ISO 6872 certification.

Reflection on the role of RRI and possible RRI opening

Overall, the use cases allow the project teams including the industrial partners to reflect on the roles of RRI during the process of innovation. Prior to performing use cases, most of the industrial partners had a minimum understanding about RRI. After several workshops, discussions and reflection process during the use cases, industrial partners started to see RRI as an integral part of innovation process. Rather than using RRI as a checklist material, they started to appreciate the roles of RRI in the innovation process. This new mindset allows them to use RRI as a guidance and direction in decision-making process. The following table show the reflection result for project partners.

The following table depicts the summary of perception for each RRI keys during the use cases.

RRI key	Automotive application	Medical application
Open access	It is common that companies need to protect their knowledge which makes them reluctant to share their data or knowledge. However, they consider open access useful when they need to access others' information and knowledge. Balancing those needs seems to be a good	For companies, this key is mainly serving as promotion and advertisement for expanding market. However, the direct contribution is not easily measured. Companies that are closely linked to public organizations will be participated in open access activities but they

	strategy for companies.	won't intentionally focus on building their portfolio in this RRI key.
Gender Equality	Due to the characteristics of the industry, gender balance is difficult to achieve.	Companies do not have a specific policy to address the lack of gender balance.
Ethics	This RRI key has been present in many aspects and stages during the innovation process. It helps companies to accommodate the emerging issues such as sustainability, security, health, and energy.	Ethics has been an integrated part of the process especially for developing a product using additive manufacturing in medical application. Moreover, many of the development and research were conducted by scientific organization or university which have already developed ethics committee to assess new research.
Public engagement	In many cases, companies were struggling to engage with public. However, they do see as bridge to communicate their technology and product to a wider audience.	Companies were keen to collaborate with public organizations such as university or clusters. Cooperation with those organizations will allow a new development of technology.
Science education	Companies saw this activity as a way to reach a wider audience. They also consider science education as a tool to harvest future employees and customers.	Companies used this activity to enhance their contribution to society. Through conference seminars, private companies were willing to participate.

Analysis of innovation cooperation in the IAMRRI use cases

Toni Luomaranta (Tampere University) and Elena Sischarenco (Lancaster University)

Cooperation in innovation projects

The use cases of IAMRRI were conducted in two different industrial contexts, namely automotive and medical fields. In the automotive context the product innovation under development was a car front suspension arm made from metal alloy. This use case consisted of two industrial project partners (other quite directly from automotive industry and the other more from AM industry) as well as research partner following the use case. In medical context there was two different product implants under development, namely spine implant and skull implant made from technical ceramic material. These two medical use cases included two medical device research and manufacturer partners, one AM industry partner, one material research university partner as well as research partner following the use case.

The industrial context as well as the desired material choice influenced the use case cooperation formation. Each partner had already some pre-existing knowledge of the potential of the other partners and this was the starting point of cooperation formation. After the cooperating partners had started to exchange knowledge the initial idea for product innovation came from the partner who were the closest to the 'customer'.

In each use cases pre-competitive phase of additive manufacturing industry allowed companies to exchange knowledge quite freely. This however had also a downside as this situation created no 'urgency' of use cases execution. The researcher following up use cases had to 'push' the use case partners to begin the actual development work. So, on the other hand this early phase of AM development companies might be quite open in terms of knowledge exchange, but they will need either time or motivator to carry out. This might be because of the exploratory nature of the AM innovations at this point.

During the uses case we noticed that cooperation requires a common trust between the partners, and gaining this trust was important in the use-cases. We noticed that each partner participating to the use cases had their specific competences and cooperation allowed them to support other partners with their competences. This kind of cooperation enabled the comprehensive development of the product innovation: from usability or functionality in end use location, from material suitability, from AM manufacturability, AM design feasibility, and cost structure. Partners concluded that cooperation was one of the key points for successful use cases.

Identified possibilities for RRI

Perhaps the easiest concept from use case industrial partners to visualize RRI was to consider it as impact thinking. Impact thinking meaning that during the innovation work there are many potential development directions to choose, and to foresee the possible danger of certain solutions of future paths of certain decisions was considered to be important. This highlights the aim to prevent negative outcomes. There could be also a possibility to include the social desirability within impact thinking in the future, by educating engineers more about the socially desired directions of innovations.

The use case industrial partners also revealed that they already have some routines or protocols, which they considered as close relatives of RRI, such as internal codes of conduct or ethical guidelines of companies. These kinds of routines or protocols could be infused with RRI and it would require the commitment of high-level management and the whole company as well to establish them. This kind of infusion of RRI could serve as internal opportunity for RRI openings.

As an inter-organizational level one possible self-regulating (bottom-up) mechanism could be standardization where companies can themselves influence how RRI could be implemented. This requires the exist of standardization organization to coordinate this work and requires also active participant of companies and most likely also some guidance about RRI from outside of the companies.

Another inter-organizational level could be cooperation with universities and other organizations that are RRI governed already. During the use cases industrial partners explained that publicly funded research projects give them possibilities to cooperate with universities. During the cooperation the knowledge and infrastructure of universities can be utilized in the innovation work. Universities already have RRI governance in place and it was said to have some degree of influence to the innovation work.

Industrial partners expressed that there might be a need to create certain regulations to guide the innovations (and perhaps level the industrial field). However, if there is a change to exploit existing routines or protocols or other inter-organizational mechanism as much as possible, it would prevent straining companies with additional external rules and regulations.

Future discussion on innovation networks in additive manufacturing considering RRI

Panellistes
Johannes Homa, Lithoz
Armin Wiedenegger, voestalpine
Igor Drstvensek, Interessansa
Panu Rekola, Deskartestes
Ignas Gudas, Orthobaltic

Moderation and Summary
Danny Soetanto, Lancaster University

Additive manufacturing has already started to show a profound impact across many industries, from frontend product development and prototyping to enabling whole new products with established business models and supply chains. From making a skull implant to automotive components, the possibilities are endless. But with endless possibilities comes challenges. Will additive manufacturing be ready to reshape our industry in a more responsible way? What will it mean for the current development of technology? Is there a happy middle ground where a Responsible Research Innovation framework can be implemented by the Additive manufacturing industry?

In the spirit of Responsible Research and Innovation, IAMRRI project brought together practitioners from across industries for a future discussion. The round table considered the lessons learnt from performing live innovation experiments and discuss how RRI is affecting and helping AM both now and, in the future, and how organizations can develop strategies to ensure the continuation of technology and market adoption.

Lessons from the use cases and the implementation of RRI

An opportunity to reflect upon the innovation process from the inception of a new idea to the development of the prototype. In the context of additive manufacturing, all relevant players should be more open and willing to share their knowledge. Working in silos, the old paradigm of innovation does not work anymore. RRI element such as open science and public engagement is critical for the success of bringing AM into wider societal use. Having someone asking the reasons for every step and decision during the innovation process helps AM industries to better understand their own innovation, strength, and path of progression.
Collaboration is challenging but critical. Collaboration may spark innovation because each partner offers a unique set of knowledge, skills, and expertise to the project. Combining heterogeneous skills and knowledge gives birth to new ideas. The reality is, however, any successful collaboration needs a well-developed trust. The challenge is to build trust through commitment and good intention among AM industries. While the process may take time, the result is rewarding.
AM industries need to deal with uncertainty during product development. There are no companies that claim to know the disruption playbook caused by AM. However, failing to recognize the commercial value of a new idea will result in a losing opportunity.

The future of AM and the roles of RRI

AM is still at the beginning of a steep curve of technological and market development. Looking at AM market share, there is still a huge opportunity for developing bespoke AM products. Small firms may benefit from this gap in the market as long as the big players in the industries are still not paying attention to it.

From a technological view, AM will be developed in parallel with other technologies such as software, artificial technology, etc. The development of other technology may influence the development path of AM technology. In this critical stage, openness and collaboration at all levels from regional to national level are critical for a successful innovation process.

Overall, the panel has agreed on many aspects such as the importance of collaboration, the need for science education, and open science. It is widely acknowledged by the panel that making AM research more accessible contributes to the better and more efficient development of AM industry and to quickly diffuse AM technology and product in the public and private sectors. The panel also stated that RRI is not a barrier to innovation. By contrast, implementing RRI as a new paradigm of innovation will increase the speed of innovation diffusion and reduce uncertainty.

The discussion with the expert panel has taught us, amongst other things, the following lessons which in our point of view can inform the implementation of RRI in the context of additive manufacturing.

First of all, the total market of additive manufacturing is still growing with plenty of opportunities.

However, there is huge uncertainty regarding the selection of technology or material. Thus, we deem it appropriate and prudent that players in AM to take a modest approach concerning its future. As we witnessed from the use case, collaboration is critical for the development of new technology or product, but it comes with challenges and prices. One of the obstacles to collaboration is because individuals or companies are reluctant to share their competitive knowledge. In the context of AM, we learnt that competition is irrelevant. one of the intriguing ideas that came out from the round table is the relevancy of employing coopetition strategy which is defined as a collaboration between business competitors with an objective to receive mutual benefits. Here, RRI keys such as open access may help to facilitate the collaboration. Companies that are keen to share their knowledge openly will attract more collaboration, faster in developing trust with partners and potential opportunities in other applications. At the same time, potential failure in the future can be mitigated.

Secondly, RRI should not be seen as a barrier to innovation. In contrast, RRI offers a new paradigm in innovation. Firms need to be aware that they are a part of society. Consequently, they have to contribute to the development and well-being of society through performing innovation in a responsible way. In doing so, RRI should become a new way of thinking as it will help companies to anticipate the future as well as understand the dynamic between innovation and the impact of their innovation. It requires the involvement of stakeholders in every step of innovation process. For many small firms, this demand requires a lot of resources and commitment. However, there is one solution which is through collaboration with publicly funded organization such as universities or research institutes. Their formal procedures in conducting research have already incorporated RRI keys such as ethics and open access. Additionally, such collaboration will help small companies to implement not only RRI keys account, but also the social and environmental implication of the innovation.

References

Soetanto, D; Sischarenco, E; Nguyen, N; Jensen, A; Cozzoni, E; Horlesberger, M; Kriszt, B; Schwentenwein, M; Menegazzi, S; Martinsuo, M; Luomaranta, T; Widnig, C; Gudas, I; Tercek, T. (2021) D4.1 Report on the framework for use-case exploration. Deliverable for project IAMRRI (Webs of Innovation and value chains of additive manufacturing under consideration of responsible research and innovation).

Sischarenco, E; Luomaranta, T; Izaskun, JI; Giulia, S; Wiednig, C. (2021) D4.2 Report on use case automotive application. Deliverable for project IAMRRI (Webs of Innovation and value chains of additive manufacturing under consideration of responsible research and innovation).

Sischarenco, E; Luomaranta, T; Izaskun, JI; Schwentenwein, M; Gudas, I; Drstvensek, I; Lube, T. (2021) D4.3 Report on use case medical application. Deliverable for project IAMRRI (Webs of Innovation and value chains of additive manufacturing under consideration of responsible research and innovation).

From model to simulation: transforming theory and data into the IAMRRI agent-based model (ABM)

Introduction to agent--based modelling (ABM) in IAMRRI

Nhien Nguyen
Nordland Research Institute

The IAMRRI SKIN agent-based model

The key idea of the IAMRRI project is to *build a model that can describe the dynamic interactions in the webs of IVCs for additive manufacturing, including the interaction related to RRI*, using agent-based modelling (ABM) simulation. ABM are computer models that attempt to capture the behaviour of actors in their environment. In our project, we aim to develop a model of webs of innovation value chains in Additive Manufacturing using ABM, in specific, SKIN model.

SKIN is an agent-based model built on a conceptual framework as well as on empirical studies and policy research. It can help improve our understanding of collaboration networks, spin-offs, and other kinds of networking actions, as well as market interactions. SKIN was developed in a European context. Previous studies using SKIN have successfully used European data to make their models more accurate and realistic. This makes SKIN particularly useful for us. Models such as SKIN enable policymakers to test innovation polices in advance so that they can better understand the effects of the policies. Sometimes these effects are counter-intuitive and surprising. This is due to the complexities of policymaking—a change in policy can have ripple effects beyond the intended area. SKIN allows policymakers to deal with such complexity.

In the IAMRRI project, we extend the SKIN model—making it the IAMRRI SKIN model—so that we can include features for studying webs of Innovation Value Chains and Responsible Research and Innovation (RRI) with a special focus on the Additive Manufacturing sector. The extensions have been designed based on thorough literature reviews, consultation with industry partners, and data collection. Once the model is up and running, it will allow us to study, for example, the effects of implementing responsible research and innovation, or how responsible thinking can spread through innovation networks, what the outcomes will look like, etc. This will help European policymakers, the additive manufacturing industry, and the public to understand the consequences of responsible innovation and translate it into successful practice.

Summary of the session

During the IAMRRI project, we have been feeding with valuable knowledge and data from other partners. In this session, we present how these knowledge, information and data are turned into an IAMRRI agent-based model, and what we can do with it.

First of all, Professor Nigel Gilbert from Centre for Research in Social Simulation, University of Surrey, who has kindly accepted to be our guest speaker, talks about the history of SKIN model and its application. In his presentation, professor Gilbert reviews the origins and history of the Simulating Knowledge Dynamics in Innovation networks (SKIN) model and describes some of the ways that it has been applied, both to conceptualise theories of innovation and to simulate specific innovation domains and sectors. He also gives a brief high level overview of the model and consider how it may be verified and validated. His presentation ends by considering future directions for the model including the challenge of using conclusions drawn from the model to make an impact on policy makers.

After that, Dr. Are Jensen from Nordland Research Institute talks about the design process of the IAMRRI model, explains the research and empirical data underlying the model, as well as potential areas of application beyond the IAMRRI project. He also illustrates and talks about why the SKIN model was chosen as a foundation for the IAMRRI model, and how the SKIN model was adapted and extended with features for supporting Webs of Innovation Value Chains, RRI, and AM industry characteristics.

Next Professor Cristina Ponsiglione from University of Naples Federico Secondo presents how the IAMRRI SKIN model has been implemented using the NetLogo modeling tool, including the fundamental modeling choices, the characterization of the agents, and so on. She also shows how it is possible to observe, through the NetLogo interface, how the complex networks of innovation agents dynamically evolve.

Then Dr Enrico Cozzoni from Grado Zero Espace presents two simulation experiments which have been used to verify and validate the IAMRRI SKIN model. The first experiment tests the impact of regulation on spreading ethical values. The second experiment investigates the impact of increasing the weight given to RRI values during selection of partners.

Finally, four of them joined the future discussion moderated by Nhien Nguyen from Nordland Research Institute to discuss the IAMRRI SKIN model and its future. The panellist provides insight on how RRI could be incorporated into ABM, and how IAMRRI project results can be leveraged further in the future.

History of SKIN model and its application

Nigel Gilbert (Centre for Research in Social Simulation, University of Surrey)

History of SKIN model

In 1996, I was playing around with simulating the growth of science and needed to model the knowledge content of scientific papers in a way that could show how one paper relied on knowledge emanating from previous papers. To do this, I treated each paper as a different random bit string and called this a ‘knowledge gene’ or ‘kene’. The kene idea was then re-used in the SKIN model.

At that time, Petra Ahrweiler (now at Johannes Gutenberg University, Mainz) and Andreas Pyka (now at the University of Hohenheim) and I were colleagues working in a project funded by the European Union called *Simulating Self-Organising Innovation Networks*. Despite the title of the project, we had very little idea then how to simulate innovation networks, and the project funding was coming to an end. In several intense work sessions just six months before the end of the project, we conceived the first version of what became the SKIN model.
Over the course of several further European Union funded projects, the model was extended and refined. I

Initially, the success of innovations was judged by a wise but unrealistic ‘Oracle’, but we eventually found ways of modelling innovation endogenously, without having to simulate a supernatural being. The model was also adapted to suit a range of applications: it was initially developed to model innovation in mobile phone technology and biotechnology, but later we applied it to the Framework Programme’s proposal bidding process and to university – business links. Meanwhile, we used the model to investigate more theoretical topics such as organisational learning and the relationships between agency and social structure.

Our publications on SKIN began to attract attention and we found that other researchers were interested in adapting SKIN to their own research problems. Somehow, without any forethought or planning, SKIN had achieved a fan base of people who liked and were using the model or the concepts that lay behind it.

What is SKIN model?

It is firstly a theory that innovation depends on networks, where innovation is defined as 'a new idea that has been transformed into practical reality'. Secondly, it is a simulation model that implements that theory. And thirdly, it is a piece of computer code. When people talk about SKIN, they often don't make much distinction between these three, which can be a little confusing.

The theory is along the lines that innovation networks consist of agents (firms, research groups, or other organisational units) that operate on two interacting levels: knowledge and market. New knowledge is derived from people having bright ideas or doing research, but also, importantly, from the cross-fertilisation of different kinds of knowledge coming from different sources. These knowledge creation processes generate variation in the agents' knowledge. However, innovation only occurs when this new knowledge is put into practice, for example, to make a new product or process. Such new products and processes may be taken up by users, or may be ignored because they are unsuitable, too expensive, not effective and so on. Successful agents, those that manage to distribute a lot of their product in the market, grow and attract others to copy them. One way of thinking about this is to consider the knowledge held by an agent is the agent's genotype. The agent produces a product, analogous to a phenotype. Together, the knowledge and market levels act as an evolutionary engine, with variation being created at the knowledge level by mutation and recombination, selection at the market level, and reproduction when new agents enter the system and death when agents continue to be unsuccessful with their innovations.

This theory is the basis of the SKIN model. The model includes much more detail about, for example, how an agent's knowledge is represented – with the kene that I mentioned, but just what the kene consists of will vary between applications of SKIN. In some applications, agents will be endowed with capital and their activities will cost money, and they die or exit when their capital is exhausted. In others, agents don't have a budget at all. The canonical SKIN model is described in many publications, including a very clear description in this project's Deliverable D3.1.

Turning to the program code, the SKIN simulation was originally written in NetLogo, a programming language and simulation environment that is excellent for prototyping agent-based models. A generic version of this code is freely available and makes a good starting point for those who would like to use SKIN. As such it is rather well tested. There are also implementations in other languages, notably one in Java. Such re-implementations in other languages are very helpful. If they give the same results as the original version, this helps to show that both that the code is correct, and that the documentation is adequate to allow replication.

The challenges of SKIN and what we can use it for

Replication of program code provides evidence that the program does what the modeller intended – which ABM people call verification – but what about validation, that is, does the model correctly represent the real world? This is a much trickier matter. To start with, we need to ask ourselves whether we do in fact expect a SKIN simulation to match anything in the real world. Every model is a simplification of reality – we cannot even in principle include everything that could possibly have an influence. Moreover, the SKIN model includes a lot of randomness – it is a stochastic model – so that each time it is run, even with the same parameters, it gives a slightly different result.

These are issues that affect all agent-based models, but SKIN has some additional challenges. Because it is a closed evolutionary system, multiple runs can give dramatically different results; sometimes the population of agents dies away completely and other times the population increases almost exponentially. Simply averaging over many runs conceals this variation and will not give meaningful results.

One might ask what the use of a SKIN model is then, if it is so difficult to validate. My answer is that we should not try to make SKIN an exact representation of the world, what I have called a 'facsimile' model. Rather, we should consider a SKIN model as a plaything, with which one can try out different scenarios to see what happens. Then it is open to the modeller to see whether what they see when running the model suggests any hypotheses about what might happen in the real world. This is a much less ambitious, but in my opinion, more useful way of thinking about the value of SKIN. And the implication is that a straightforward notion of validity, where validity is measured by comparing model outputs with observations of the real world, is not appropriate. Instead, we should be assessing SKIN on whether it suggests interesting and actionable insights into how innovation works and how innovation policies can be improved.

How might SKIN be further developed? The first is about agent decision-making. Recall that the agents in SKIN typically represent organisations: for example, hi-tech SMEs. These agents need to be programmed to decide, for example, when to invest in research and how to price their products. But social scientists don't know much about how organisations actually make these kinds of decisions. Could SKIN be used to study firm decision-making and firm learning? Second, we need to be better at transforming SKIN into practical reality – how can we present SKIN to policy makers in a way that they will value it? As I have already hinted, I see SKIN as a tool for thinking, not for prediction. This means that we as modellers need to be prepared to have a continuing dialogue with policymakers in which both they and we think through what the model is telling us and what the implications are for policy.

Designing the IAMRRI-SKIN model

Are Jensen
Nordland Research Institute

Establishing a foundation for the design

Given the objective of the IAMRRI project focusing on innovation value chains (IVCs), webs of IVCs and openings for responsible research and innovation (RRI), reviewed existing models of innovation processes. The review resulted in choosing the agent-based model SKIN as a foundation for further work. SKIN is a recognized model, well documented and tested in various contexts, and has been actively used in policy-oriented research (e.g., Ahrweiler, 2017; Ahrweiler et al., 2015; Gilbert et al., 2018). The basic elements of SKIN such as "kenes" (the set of competences and knowledge an organization possesses), market mechanisms and innovation processes were assessed to be suitable and useful for modelling the additive manufacturing (AM) industry.

Design overview

First, the proposed IAMRRI model incorporates more complexity than SKIN by the way the innovation process is modelled. It covers the stages of idea generation, development, and implementation, corresponding to the concepts established in the IAMRRI project and our simulation review. The extended model permits generating ideas where not all the capabilities and abilities are readily defined, allowing agents to develop innovation hypotheses over

extended periods of time and in cooperation with other agents, not all of whom necessarily profit directly from the sale of the innovation. These idea generation/development and diffusion processes constitute the separate Innovation Value Chains. The model allows for criss-crossings between different IVCs resulting in the development of webs of IVCs.

Second, additional attention is paid to timing in the IAMRRI SKIN model. Unlike in the original SKIN model, innovation and market-related processes may unfold over several time units (ticks, or iterations, in modelling and software development terms). This makes it possible to simulate processes of various durations and use time-related variables in addition to price-related and other mechanisms regulating agents' decision making.
Third, in line with the empirical observations in the AM industry, learning mechanisms are extended so that the agents can learn from each other in more ways (compared to the original model) in the processes of idea generation, development, and diffusion.

Fourth, the RRI policy agendas, also called policy keys (open access, public engagement, ethics, and science education) are introduced, mainly through parameters influencing decision-making processes. These RRI policy keys play an important role in allowing the model to address the research objectives of the IAMRRI project.

Finally, some extensions are introduced to adapt the model to the automotive and medical cases. New classes of agents are added, model initialization parameters are adjusted, probabilistic functions are altered, and additional performance indicators are added.

It is important to keep in mind that the model is designed in such a way that it can be adapted to examine other phenomena in the future. For example, we can look at the dynamics of how solutions to novel manufacturing problems are developed. We can also examine how change in regulations or sanction might impact industry structure. And we can re-adapt the model for studying Key Enabling Technologies and how they address societal challenges which can help create advanced and sustainable economies.

Implementation of the IAMRRI SKIN model

Cristina Ponsiglione, Carmine Passavanti
University of Naples Federico II

In the following sections, we will present the main building blocks, characteristics, and mechanisms of the IAMRRI SKIN model as it has been implemented in an agent-based environment. The chosen software platform is NetLogo in version 6.1.1.

From SKIN to IAMRRI SKIN model: The Kene

The development of an agent-based model is at the core of the IAMRRI project. This was done by extending and adapting an existing reliable model to reach efficiency, reliability, and a greater diffusion in the scientific community. The choice was the SKIN model (Ahrweiler et al., 2017): a multi-agent model simulating innovation networks in knowledge-intensive industries in which knowledge spreads among agents. The fundamental component taken from SKIN is the modeling of the agents' knowledge base, also called Kene. It is formed by several triples, consisting of a Capability (a broad scientific or technological domain), an Ability (a more specific skill within the knowledge domain), and an Expertise, a level of experience associated with the Capability-Ability pair. Thus, knowledge is modeled as a set of triples. Each agent, starting from his knowledge, elaborates then an idea of innovation, called Innovation Hypothesis.

The IAMRRI SKIN model

In the IAMRRI SKIN, the first building block is several types of agents populating the innovation system in the context of Additive Manufacturing (AM). The model is a double industry model, two industrial sectors are considered in the project: automotive and biomedical. Agents are grouped in different classes, named breeds. Each type of agents (AM-technology companies, OEM, Supplier, Customer, Research-institution) has a specific type of knowledge, and they cooperate in a network to define and develop an innovative idea. Other agents that intervene in the process of innovation (funding and regulatory bodies and organization) are modelled as external bodies establishing requirements that successful networks and innovations have to cope with (from the computational point of view, requirements are settled as global variables in the model).

Agents may be from the Automotive or Biomedical industry or both. Each agent is characterized by three variables that represent the inclination to Responsible Research and Innovation (RRI) practices. Not all the internal dialogue within the GZE-UNINA Research Group.

In the setup phase, agents are initialized with the same financial resources and given a Kene, create an Innovation Idea, and an advertisement to advertise the knowledge used in the Innovation Idea. Only a subgroup, called focal agents, can refine their idea through cooperation with other agents. If an agent is not involved in any network, it engages in incremental internal research to increase its knowledge. The focal agents at this point begin

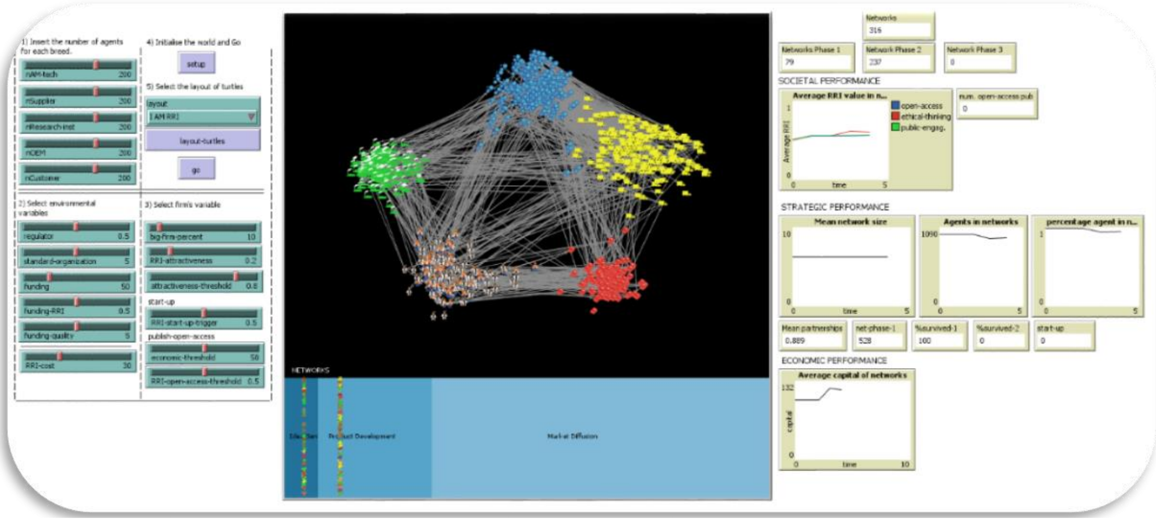


Figure 1: Screen shot of the IAMRRI software interface

dimensions developed by the European Commission (EC, 2012) have been implemented, but Public Engagement Open Access and Ethical Thinking are considered priorities. In the project's last steps, "gender equality" has been introduced and connected to Ethical Thinking.

Phases in the IAMRRI SKIN model

The model follows a stage-gate approach in which the process of assessment becomes predictive and not only reflective. The phases are Idea Generation (of 3-tick duration - the temporal unit of the simulation cycle) and Product Development (of 12-tick duration). Innovations are assessed by the regulators, funding, and standard organizations. The typology of agents and the related knowledge, mechanisms, and duration of the phases descend from the analysis of use-cases provided by the IAMRRI Project partners and from the the Idea Generation phase looking for the best partners to define and realize the idea of innovation, preferring agents of other types, but with skills in the same domain of knowledge and with adequate RRI values. The focal continues the search until the minimum number of partners is reached, considering the available financial resources. Once the minimum number of partners is reached, the network is established.

Once the network is established, participants pay contributions. Once the RRI values of the network have been defined (the result of the average of the participants' RRI values), the agents adjust their own RRI values to those of the network through a step function that takes into account the inertia to change and learn new skills from the partners, clearly with a lower level of Expertise. At the first gate, the idea of innovation is evaluated by regulators (based on the ethical thinking of the network) and funding bodies (based on technical quality and RRI values). European Union mechanisms of grant assistance inspire the behaviour of the latter. In the first phase of Product Development, some partners might leave the innovative project due to economic default, while experiential learning is realized with an increase in the expertise levels of the knowledge used. The last gate still has as protagonists the regulatory bodies and the Standard Organization that evaluate the technical quality, so the network can materialize in a start-up or be dissolved.

The IAMRRI SKIN model interface

The model interface is shown in the figure below. On the left, there are various sliders to set input variables, such as the number of agents, environmental variables, and those internal to the company, e.g. the threshold of attractiveness, the weight to be given to the RRI values in the selection of partners or the economic threshold to be exceeded to publish in open access. It is possible to choose the layout of the visualization. At the bottom the networks proceed along the innovation process and the agents that approach their focal. The Market Diffusion phase at this stage has not yet been implemented. On the right side, some various monitors and plots indicate the social performance (such as the average RRI values in the networks), the strategic performance (e.g., the number of agents involved in the innovation process), and the economic performance (such as the average capital of the networks). The model is available on GitHub at the link: https://github.com/GradoZeroTeam/IAMRRI

References

Ahrweiler P. Agent-based simulation for science, technology, and innovation policy. Scientometrics. 2017;110: 391-415. doi:10.1007/s11192-016-2105-0

European Commission. Responsible Research and Innovation. Europe's Ability to Respond to Societal Challenges. 2012.

Ahrweiler, P., Schilperoord, M., Pyka, A., & Gilbert, N. (2015). Modelling research policy: Ex-ante evaluation of complex policy instruments. Journal of Artificial Societies and Social Simulation, 18(4), 5.

Gilbert, N., Ahrweiler, P., Barbrook-Johnson, P., Narasimhan, K. P., & Wilkinson, H. (2018). Computational modelling of public policy: Reflections on practice. Journal of Artificial Societies and Social Simulation, 21(1).

Simulation results on webs of innovation value chains in AM

Enrico Cozzoni
Grado Zero Espace

Simulation experiments presented represent an excerpt of the campaign carried out to verify and validate the IAMRRI AB model. The first simulation presented, tested the role of regulatory bodies in spreading ethical values, forcing more stringent regulations on the RRI ethical thinking variable, and observing the diffusion of the remaining RRI keys and the impact on the number of agents participating into the networks. In the second experiment was investigated if a greater weight given to the RRI values during the selection of partners, mainly forcing RRI-attractiveness as the input variable, corresponds to an increase in the heterogeneity of the actors involved in the networks.

In the first experiment we "neutralized" the input variables, but not of interest, transforming them in control variables, and therefore with assigned values. Then, 300 simulation runs of 30 steps each were performed in which the Regulator factor was set at three levels: [0.3 0.5 0.8].
The variables of interest of this experiment were the three RRI keys (open access, ethical thinking, and public engagement), and the number of agents involved in the innovation networks. Steps 4, 6 and 30 of the simulations, were selected to be further analyzed, because linked to knowledge spreading mechanisms and simulations history. Descriptive statistics were performed on the outputs, specifically Analysis of Variance (or ANOVA), followed by post-hoc

tests, specifically the Honestly Significant Difference (HSD) test of Tukey.
From a first superficial analysis, results have shown that was enough to regulate or focus more on the ethical thinking of companies, to encourage the use of RRI practices. A more depth investigation, on the other hand, refuted this inference too loosely treats, showing a secondary effect, that to a too stringent legislation corresponds a dramatic drop in the number of networks. Meaning that in fact, we need to leave some room for the innovators, without rushing to regulate, clearly understanding when and how to regulate.
The literature presents a reality in which to an increase in the use of RRI practices corresponds a greater heterogeneity within innovation projects. In the second experiment proposed, we so investigated if to a greater weight given to the RRI values during the selection of partners corresponds an increase in the heterogeneity of the actors involved in the network, where this variable (the Average Heterogeneity of Networks), was expressed as the number of different types of agents, out of the total number of network participants. 300 simulation runs of 30 steps were performed for 3 different weights of the RRI values in the selection of partners, while the output variable was set exactly as the heterogeneity previously defined.

The results of the simulations showed that to an increase in the weight of the RRI values in the selection of partners corresponds an increase in the heterogeneity of the networks, in line with the literature search results, that to an increase in the diffusion and importance given to RRI practices showed an increase in heterogeneity within innovation systems.

This similar tendency was one of the verification points that have been used to show how IAMRRI AB model behaves in a conceptually correct way, mainly in line with what expected in the reality of the innovation value chains.

Future discussion on the IAMRRI agent based model and future research

Panellists
Cristina Ponsiglione, University of Naples Federico II
Are Jensen, Nordland Research Institute
Enrico Cozzoni, Grado Zero Espace
Nigel Gilbert, University of Surrey

Moderation and Summary
Nhien Nguyen, Nordland Research Institute

The future discussion, moderated by Nhien Nguyen, with four panellists Nigel Gilbert, Are Jensen, Cristina Ponsiglione, Enrico Cozzoni provides insight on how RRI could be incorporated into ABM, and how IAMRRI project results can be leveraged further in the future.

Working with ABM and IAMRRI SKIN model: Challenging and Rewarding

Due to the complexity nature of the reality, it is challenging to get the model right. It is also difficult to get enough information into the model but not too much. Developing the model requires multidisciplinary and multi-actor approach. Different researchers and practitioners, with diverse backgrounds, interests, perspectives, and languages, have to work together, discussing most of the time in defining a conceptual model that has to be coherent with theory on the topic and with reality. After a conceptual model is ready, it has to be implemented and subject to experimentation. In all stages, the contribution of all the team's members is fundamental.
Once we manage to solve these challenges, it is a very rewarding feeling for the modelers. The process is time-consuming and complex but the end product which is a software code which represents the collaboration effort will bring many benefits. It can be replicated, can be easily shared in an open science perspective, and can be extended. In the case of IAMRRI SKIN model this process happened. The development of IAMRRI was a learning process for all partners involved, from researchers to business

companies. The results of co-creation bring rewarding feelings to all of us.

Innovation is a complex and non-linear process which success depends on the collaboration of varieties of actors. For this reason, ABM was chosen as the methodological approach in the IAMRRI project because ABM can model a heterogeneous population of actors who interact with each other and with the environment in a complex system with unpredictable results. Additive manufacturing is an emerging technology used in a fast-changing environment involving complex interactions among a multitude of actors. Thus the advantages offered by ABM make this method well suited to modelling the additive manufacturing ecosystem. The result of the simulation experiments carried out using IAMRRI SKIN was a confirmation of what is also suggested by literature: Diversity, one of the main characteristics of innovation systems, is the main driver of innovation process. In the model, diversity among agents regarding knowledge bases and RRI inclination was introduced from the beginning. During the simulation process, the learning occurring when agents meet each other to develop ideas and the diffusion of RRI practices contribute to preserving this diversity over time in a dynamic way.

Translating the "responsibility" dimension into ABM in general and the IAMRRI SKIN in particular

The theme of responsibility has been considered in modelling IAMRRI SKIN in different ways: First, agents in the model (big and small firms at different stages of the value chain, suppliers, designers, universities and research centers, customers) are endowed with Responsible Research and Innovation (RRI) inclinations, particularly with respect to open access publication, ethical thinking, public engagement, and gender equality. These inclinations change over time according to their relationships, their interactions, the nature of learning process they are involved in. Second, collaborative networks and innovation value chains must cope with RRI requirements asked by some central organizations, such as Standard Organizations, Regulatory bodies, and Funding Organizations. These requirements act as incentives for agents to invest in RRI practices and in interacting with other agents that show higher levels of RRI inclinations. Third, in the last developments of the model, NGOs, representing the Civil Society, have been included in the modelling of the innovation systems. They cooperate with other agents in developing the innovation ideas and innovation products, guaranteeing the public engagement of webs of innovation value chains.

However, the conceptualization of responsibility should not be limited by incorporating RRI keys into the model but should be reflected in the way of co-designing and co-developing the model. Furthermore, during the process of modelling, we have the opportunity to improve the concepts much clearer, make the theory stronger. That is an important way to bring the "responsibility" dimension into modelling.

How to leverage the impact of IAMRRI SKIN model in the future

To maximize the impact of IAMRRI SKIN model, it is important that the model will be used, experimented and extended in the scientific community and policy makers. It is important to let other researchers to replicate the model, to extend it, to discover other behaviours, or observing new properties emerging from bottom up. At the moment, the model is referred to two industries: Automotive and Biomedical. It could be very interesting to apply the model to different industrial sectors or other technologies over the Additive Manufacturing.

The most important thing is to involve the users from the beginning of the process. To avoid the model's catch-22, which refers to the issue that the model results come from what the modellers think it should be, it is important to bring in the users of your model right at the beginning to co-design, co-produce and own the results at the end. They should be convinced that their time is worth it. It is a matter of trust. We should do it in the way that they can understand but not becoming the programmers or statistics. One way to do so is gamification where the users can steer the game controller and see what would happen. IAMRRI has included the users from the beginning, we need to continue encourage them to play with the model and provide more data for improving the model.

It is also important to keep in mind that ABM is a tool for thinking, not for prediction. We observe the results from simulation and reflect on the implication behind it. We also need to keep a continuing dialogue with the users to gain an in-depth understanding about the model results and what the implications are for policy.

Responsible research and innovation (RRI) in the innovation system of AM

Introduction to RRI understanding in IAMRRI

Izaskun Jimenez Iturriza,
Ana Arroyo
Tecnalia

This Future Talk session was devoted to providing an overview of the characteristics and specificities of Responsible Research and Innovation (RRI) in the additive manufacturing (AM) sector.

First, some insights were presented on the interrelationships among RRI keys and on how they influence both the different stages of the innovation value chain and the different AM actors.

Second, we glimpsed the relevance of RRI in the development of key enabling technologies and on how standardisation could support the uptake of RRI by industry. Focusing on the views of different AM actors on RRI, we analysed the perspective of a cluster which gathers different actors within the AM value chain, namely, industrial companies, research organisations and local and regional authorities.

Thinking on RRI in your innovation value chain? This is what we learnt

Ana Arroyo, from TECNALIA R&I, presented the results of the IAMRRI project in relation to the behaviour of RRI within AM webs of innovation value chains. It covered two aspects; on the one hand, we learnt about the interrelation among the different RRI with the AM WIVC and, on the other hand, she presented some learnings derived from the observation conducted in the IAMRRI use cases.

One of the conclusions of the research carried out is that all the RRI keys are highly interrelated and that any strategic action to strengthen one key in the AM WIVC have an impact on the others as well. In addition, not all the keys have the same effect on the AM innovation value chain, open access being the strongest key and guiding the AM innovations towards RRI concept's objectives.

We also see that RRI's effect on the innovation value chain is higher at early stages of the innovation process, that is, at the research and idea generation phase where there is more freedom in decision making and the risk for integrating RRI considerations is rather low. At the idea development phase, the possibilities for introducing RRI decreases although some keys such as gender equality and science education still have strong influence at this phase.

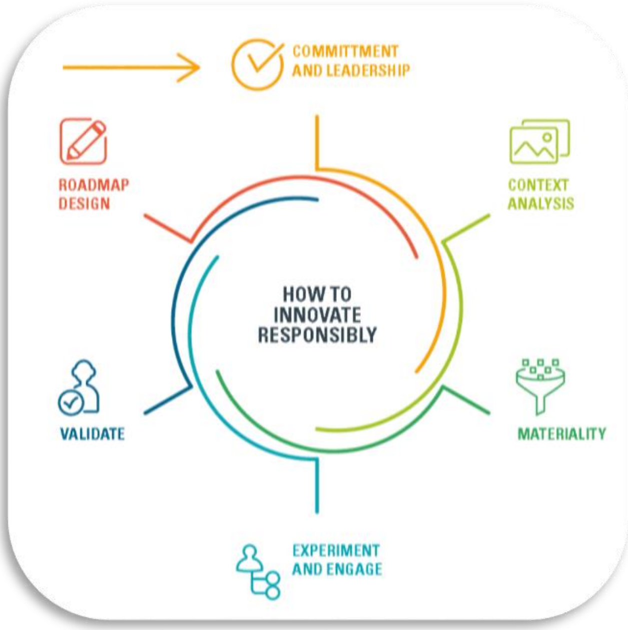
Finally, the observation of the IAMRRI use cases gave some insights on how the AM actors behave in relation to RRI keys. One of the conclusions was that on business-to-business relationships RRI inclinations do not play a big role and few of the RRI aspects are transferred among companies. However, ethical inclinations related to sustainability, security and health and security of workers are transferred between partners and could increase the RRI inclinations of the agents.

RRI beyond additive manufacturing to other KET sectors

Andrea Porcari, from the Italian Association for Industrial Research – guest speaker, introduced us in the perspective of RRI beyond additive manufacturing, focusing on the work that has been done to build a pre-standard to build RRI roadmaps for industry.

He first mentioned the need to to include RRI in the innovation processes of companies, especially when working with enabling and key technologies. Integrating RRI is a manner to address the increasing complexity of the innovation ecosystem and of societal demand, a way to anticipate uncertainties and to respond to actual and unexpected impacts of innovation. Comparing RRI in a business context with existing management practices, it is observed that RRI is aligned with business practices in social responsibility, risk, environment, innovation management and others and that RRI complements these practices.

In this context a new CEN pre-standard has been developed, focusing on responsibility-by-design.



The pre-standard provides guidelines to develop long-term strategies for innovating responsibly so that organisations can achieve socially desirable outcomes from their innovation processes.

Finally, Mr. Porcari mentioned some key aspect to bear in mind to ease RRI uptake in industry:

(1) the need to have a company-tailored approach to deal with differences accross sectors, companies and technologies;

(2) the relevance of influencing the culture and management of the organisation, including its vision;

(3) the importance of looking for a return of investment for both companies and stakeholders, considering that impacts of RRI uptake could be tangible or intangible, short or long-term.

Views of different actors of additive manufacturing innovation system on RRI

Alexi Perrino, from Materalia cluster, has offered the vision of a cluster, being one of the stakeholders in the AM IVC and emphasising the role of such organisations as promoters or facilitators for companies to adopt RRI approaches in their R&I activities. Mr. Perrino started stated that current revolutions are redefining the socio-economic balance with its reflection in the way of doing and assessing businesses, transitioning from economic performance indicators to socio-economic performance indicators. In this context, he considered that RRI is a tool for socio-economic performance.

From Materalia Cluster's perspective, RRI influence the activities of the cluster in the sense that the cluster is evolving towards being a stakeholder aggregator, especially regarding civil society, and it is acting as a RRI ambassador in their territory. In his opinion, integrating RRI concept and approach in the activities of the cluster, it allows bringing the main socio-economic challenges to the knowledge of clusters' stakeholder; it provides the territory with the necessary tool to transform major transitions in to levers of economic and social growth; it enables actors already engage in responsible dynamics to identify themselves and join in the RRI approach, and, finally, make the RRI community grow with new players, fostering its visibility in our network .

RRI in web of innovation value chain: The case in IAMRRI

Ana Arroyo, Izaskun Jimenez
Tecnalia Research and Innovation

Considering RRI in Additive Manufacturing Innovation system.

Responsible Research and Innovation – an EC approach- intents that societal actors work together during the whole research and innovation process to **better align both the process and its outcomes, with the values, needs and expectations of European society**. Within the IAMRRI project, RRI is considered as the implementation of the defined political agendas in RRI. These are often called RRI keys too; they are gender equality, public engagement, open access, science education, ethics, and governance.
 Our research is focused on the webs of innovation value chains (IVC) in additive manufacturing (AM), on how these chains intersect and interact, and, especially, on the impact of RRI keys within the webs of innovation value chains (WIVC) and the optional openings of these webs for RRI.

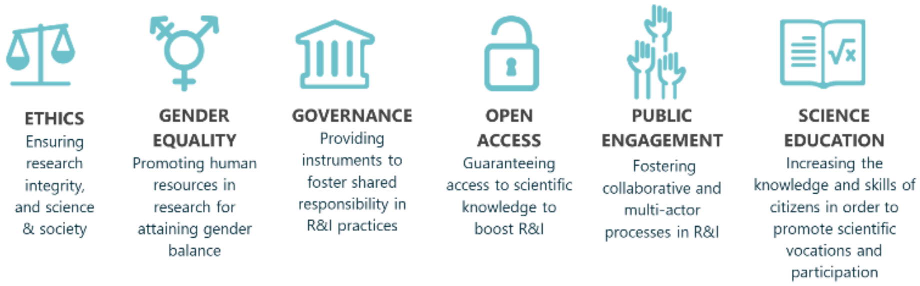


Figure 1: RRI keys according to RRI tools https://rri-tools.eu/

In our research we assumed that the innovation process consists of three process phases, namely, idea generation, idea development and idea diffusion (market dissemination), as defined by Hansen and Birkinshaw[1]. We analysed the AM innovation value chains from the perspective of RRI to provide answers to the following questions:
“Where does RRI keys have a role?”
 “Where can RRI be implemented within the system in the innovation process or the network the itself”or
“In which stage/phase of the innovation process does RRI have greater more impact?” and
“ What is the influence of RRI on the different actors of the IVC?”

To answer those questions, we analysed how RRI behaves withing AM WIVC. This comprised three aspects: a) a cross-impact assessment of RRI keys, showing the interrelation among the different RRI keys; b) analysis of the impact of the RRI keys on the different phases of the innovation process and where openings arise in the different innovation phases; c) understanding how RRI keys influence the different actors of the AM WIVC.

Our research focuses on finding the best option to implement RRI to the system during the innovation process or the network, and we called these options “openings for RRI”. Therefore, openings are places within the WIVC where RRI can be implemented. These places can be in each innovation process step or gate, defined as a criterion for fulfilling measures or any organization in the WIVC as well which implements RRI measures in their organizational structure
According to the research results, openings for RRI will more effective in the research and idea generation phase, more precisely in the transition from idea generation to idea development phase.

Phase 1 (idea generation) is seen as the design/research phase and offers more freedom in decision-making. This helps to define criteria following RRI keys, for example, focusing on societal values, needs in science and education, or aim to offer gender related products. Funding organizations can support

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

the RRI orientation by asking for open access, gender equality, including education or assessments on societal impact.
When the innovation enters Phase 2 (idea development), the option for introducing RRI becomes remarkably lower, even though some keys, such as science education, have a direct impact.

RRI Key	idea generation	idea development	diffusion
gender equality	direct	direct	direct
ethics	direct	indirect	direct
open access	direct	indirect	hardly any
public engagement	direct	indirect	hardly any
science education	direct	direct	indirect
governance	indirect	indirect	direct

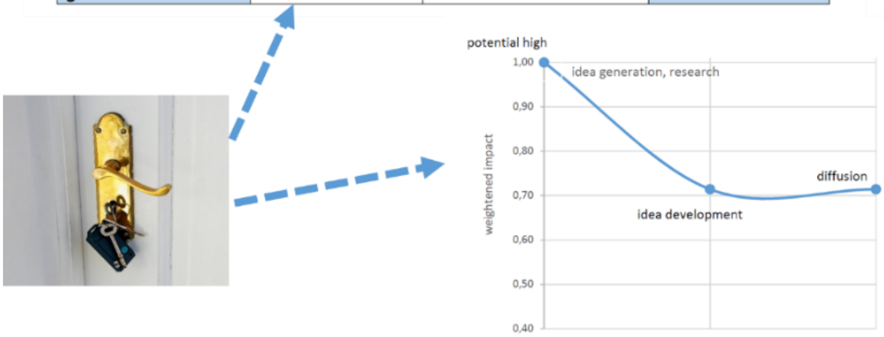


Figure 2: RRI keys in innovation process according to IAMRRI D2.4

In each phase openings for RRI-interventions can be found either bottom-up, adopted by organizations within the WIVC, or top-down, promoted by the EU and other policymakers. These RRI-interventions have a double effect: they influence the behaviour of actors in each phase and they influence the performance of the entire IVC.

Not all keys have the same effect on the AM innovation system. The RRI key ethics has the bigger effect on the AM innovation system. Ethical considerations are very important when developing new technologies at an early stage of development in order to reach what it is societally needed. Similarly, when expanded, science education can bring about tremendous benefits for the development of the innovation, because it enables having a highly qualified workforce.

Organisations take different roles in the AM innovation network and this entails that the different actors have different potentials with respect to pushing towards RRI and a social oriented innovation. From that analysis, it can be interpreted that universities and research organisations are most affected by RRI keys and can trigger the introduction of measure for implementing RRI keys, thus influencing the whole WIVC. In the case of firms, the keys gender equality and public engagement are the ones having the strongest effect on them. Additionally, policy makers have the most intensive relation to all the RRI keys and can promote RRI and influence others by their actions.

Finally, our research shows that RRI keys are not independent they interrelate in different grades. RRI have not a symmetric relationship which means that some keys have more effect on others. Thus, any strategic actions to strengthen one key in the WIVC have an impact on the others as well.

Reference

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

IAMRRI D2.4 Final Conceptual model on webs of innovation value chains, 2020, be published on webpage of www.IAMRRI.eu after approval by the EC

Views of different actors of additive manufacturing innovation system on RRI

Alexi Perrino
Materalia

Current revolutions are redefining the socio-economic balance with its reflection in the way of doing and assessing businesses. This can be derived from the speeches of different business leaders, journalists, and policy makers whose speeches are increasingly oriented toward socio and environmental themes. This is also confirmed at other levels such as new business assessment methods, where, for instance, new criteria to evaluate business leaders are being set, including amongst them ecological footprint and gender equality. This entails a shift form an economic business world to a socio-economic business world.

The consequence is that there is a transition from economic performance indicators to socio-economic performance indicators and that businesses will need to add responsible research and innovation (RRI) principles such as equality, ethics, open data, etc. to their way of doing business. This means that for the very first time, an industrial revolution does not occur at the expense of social consideration, but thanks to it. In this context, RRI is a tool for socio-economic performance.
If clusters are at the forefront of the promotion of business innovation, they must take into account the mentioned paradigm shift. In this regard, Materalia has already started working with RRI, especially within the IAMRRI project. Its consequences can be divided in two scales. On the one hand, it has had a direct influence on our daily activity, with a growing interest in projects with strong RRR or social focus, an increased awareness and willingness of applying RRI principles in Materalia's services and increasing our capacity to disseminate RRI in our territory, acting as "RRI ambassadors". The cluster is also evolving towards being a stakeholder aggregator, especially regarding civil society.

On the other hand, it has had a cascade-influence and benefit for the members of the cluster. Materalia has integrated the RRI concepts in the university lectures it provides. The cluster has also trained its members on the principles of RRI and has strongly reinforced the societal and responsibility aspects in the projects carried out by its members and supported by the cluster.

Integrating RRI concept and approach in the activities of the cluster, it allows bringing the main socio-economic challenges to the knowledge of clusters' stakeholder.

It provides the territory with the necessary tool to transform major transitions in to levers of economic and social growth; it enables actors already engage in responsible dynamics to identify themselves and join in the RRI approach, and, finally, make the RRI community grow with new players, fostering its visibility in our network.

To conclude, RRI approach is a way to align the activities of the cluster with the needs of our members and the societal challenges that we must face.

Summary on future discussion on RRI in the AM Innovation System

Panellists:
Andrea Porcari, Italian Association for Industrial Research
Andrea Kaszler. Austrian Institute of Technology
Brigitte Kriszt, Montanuniversitaet
Alexi Perrino, Materalia

Moderator and Summary
Izaskun Jiménez, Technalia

The discussion started with trying to identify the main challenges for implementing RRI in the additive manufacturing sector. From the perspective of the IAMRRI project, one of the most important challenges faced was the different understanding on the concept by different actor and the different level of familiarity and understanding regarding the different RRI keys.

The panellist agreed upon the need to combine bottom up and top down approaches to foster the implementation of RRI, emphasising on the need of liaising with the strategy of the organisations, of providing the necessary resources and having RRI-related capacities. In this sense, it was stresses that the role of clusters, associations, and networks to promote and facilitate the implementation of RRI in companies is essential.

It was stressed that the challenges of the AM sector might not be significantly different from other sectors' as the complete industrial environment is evolving and will change, and companies will have to deal with new concerns and constraints. However, the AM sector might be more ductile or flexible and be more prepared to adapt to these changes. In this sense, in addition to the bottom up approach mentioned before it was emphasised that regulation can be a key factor for the future of the AM sector.

The relevance of education was also emphasised, in the sense of providing high education to enable people having the capacity to integrate diverse thinking and take decisions in a critical and reflective way, which is the heart of the RRI concept.

The need of collaboration and stakeholder engagement was also considered of paramount importance to trigger the implementation of RRI and of building common understanding, creating shared values and providing common processes to behave responsively, (the pre-standardisation process was put as an example for this stakeholder collaboration and creation of common understanding). Also, including stakeholders at early stages of the innovation process raises creativity and, ultimately, the innovation outcome.

The question of which aspects need to be considered to trigger the implementation of RRI in the AM also offered interesting viewpoints. It was stated that there are different ways for companies to shift towards responsible innovation, from stimulating and incentivising (with funding, tax reductions, etc), to forcing them to move to the new model (through regulation, taxes, etc). However, the most interesting way for this shift to happen was considered the companies' internal transition and motivation. In this sense, it was stated that RRI should be presented to companies as a solution for the new challenges they need to face.

It was emphasised the need of mainstreaming in companies a critical thinking so that they systematically reflect on the reasons of doing business, acknowledging that companies cannot survive without being profitable but that being profitable is not their only reason to exist.

This was linked to a point mentioned before, that is, the need of educating people so that they can have a critical and reflective thinking, educating them to be reflective, anticipative, and inclusive. This new mindset would decrease the risks associated to all rapidly growing technologies.

Focusing on triggering the implementation of RRI in companies, it was stated that SMEs seem to be more easily adaptable and pervasive to the concept of RRI, mainly because their decision-making structures are more agile. These companies, however, need resources and expertise to put RRI in practice. To solve this challenge two ideas were proposed: first, to make the most of companies' *de facto* experiences with RRI and already existing processes related to RRI, such as risk management, health and safety management, environmental management, etc. Second, to reinforce the role of clusters, industrial associations, and networks to promote and facilitate the implementation of RRI in companies.

In the last statements of the panellists, the following messages were emphasised:
The need to educate people not only on the concept of RRI but foremost providing them high education to create a critical and reflexive society, where responsible thinking is integrated in people's mindset.

The importance of collaboration between different and diverse stakeholders at early stages of the innovation process. University campuses are perfect places for the collaboration among companies, research organisations and civil society to happen, fostering the uptake of the RRI concept.

The relevance of finding RRI ambassadors to promote and facilitate the implementation of RRI in organisations. These ambassadors could be clusters, industrial associations and other networks as mentioned before but it is equally important to find persons that are at ease with the concept of RRI and that are able to drive its integration in organisations.

IAMRRI Foresight

Foresight in IAMRRI

Marianne Hörlesberger
AIT Austrian Institute of Technology

The foresight work in IAMRRI project puts the AM webs of innovation value chain in a broader context and develops future scenarios with specific emphasis on the innovation value chain and RRI aspects there. The IAMRRI project applied a classical scenario technique starting with a context analysis of the thematic focus, which results in key factors, anticipating futures based on these key factors, identifying consistent scenarios, and understanding the consequences. The step from the context analysis done via influencing factors (seventy in the case of IAMRRI) in the STEPP structure to thirteen key factors was performed by applying an uncertainty / impact analysis, a social network analysis (where each factor is a node), and a cross-impact analysis.

Figure 1 shows the foresight process from a system analysis to future scenarios.

Out of 70 influencing factors describing the context of the AM innovation value chains thirteen key factors were detecting. These key factors were analysed regarding RRI aspects. For each key factor various disjoint futures ware developed. This approach would like to outline any future. It does not only elaborate the most desirable future or the scenario with the highest likelihood to occur. Considering any possible future gives a foundation for deriving consequences and action for reacting already today of challenges coming from these futures.

In this IAMRRI case the scenario development is one of the foresight methods which are linked to stakeholder involvement. This combination is already addressing the RRI process dimension. The involvement of "relevant" stakeholders is crucial in such studies. The best results and the best impact are achieved if the affected stakeholders also have the power, the urgency, and the legitimacy for the transfer of the results into strategies.

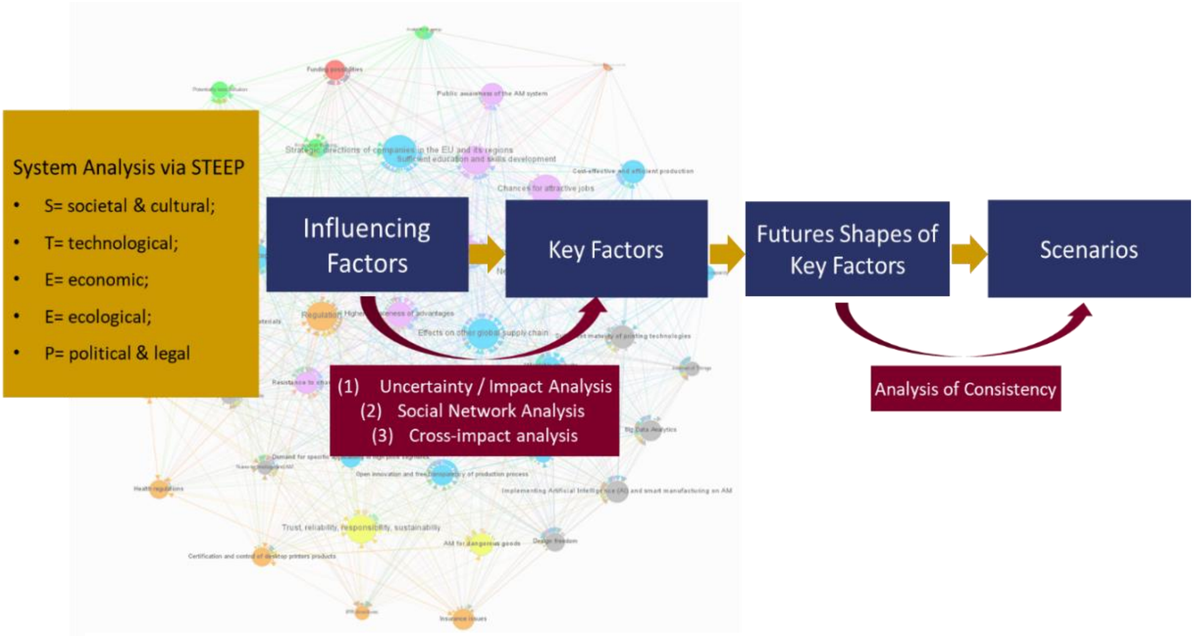


Figure 1: From a system analysis to future scenarios

This is the limit of this study. The IAMRRI foresight was organized in three workshops, however with different stakeholders in each workshop mostly. Only the core team participated in each of the workshops.

This is because of the limits of resources of IAMRRI. Unless this fact, foresight process co-created a common communicable and well-structured picture and awareness within stakeholder groups about future shapes and strategies for AM and for webs of innovation value chains in AM with openings for RRI through a diverse & inclusive, anticipative & reflective, open & transparent, and responsive & adaptive to change process.

2040 – Four future scenarios

Andrea Kasztler
AIT Austrian Institute of Technology

The developed four scenarios are about “responsible Europe”, “self-organizing society”, “elites of money and knowledge”, and about “robots world”, each in the field of AM and with RRI aspects.

Figure 1. The four IAMRRI future scenarios with their core messages.

The scenario “responsible Europe” can be summarized in the following. European way will be continued. In a well-structured world of openness and regulation ethical values, democracy, sustainability, and education are high values within policy and society. Society is built by democratic open societal makers. There are many options to choose for the individuals. Science education becomes more important. Also, public engagement and ethics become more important to individuals.

In the scenario “self-organizing society” differentiation, democracy, individual solutions, and knowledge society are the keywords. In this colourful and diverse world individuality is the highest value. Individuals share a common understanding of high ethical values. Everybody is responsible for him/herself, for education, and job. People have so many possibilities that it is hard to find a “red line”. Regulation varies and is not well established everywhere. The innovation and education systems are open and transparent but not harmonized. Education is a good for everybody and a very high value.

The scenario “elites of money and knowledge” presents a geographical and societal imbalance in society. It is dominated by elites who own money and knowledge. Economy is dominated by only a few powerful enterprises. AM is a mature, highly automated, reliable, and

Figure 1: For developed IAMRRI future scenarios

efficient technology. RRI principles are tried to be implemented top-down, but they are not of societal interest. There is no gender equality. Only concerning resources, efficiency is a high value due to resource scarcity.

The scenario "robots world" consists of smart systems everywhere. Artificial intelligence (AI) and robots replace human beings in the production process. The machines serve all humans for wealth and prosperity. Humans have more spare time as the machines do all the hard work. Data on humans is collected and used by AI, and consumption is steered. Our houses are smart homes (e.g. the refrigerator is able to refill itself) and a lot of daily life products are identified as being able to be delivered by AM technology immediately and regionally either in our own houses or at AM manufacturing sites ordered and produced on demand. RRI is part of the algorithm. Which RRI aspects are programmed into the AI and robots is defined by the people with force. However, the general education level is high. The machines and robots work for the human's wealth and prosperity.

Innovation phases of the scenarios and modelling

Enrico Cozzoni, Grado Zero Espace,
Andrea Kasztler, Marianne Hörlesberger
AIT Austrian Institute of Technology

The AM innovation phases in each scenario were analysed regarding Collaboration in the value chain, Actors, Network structure and economic opportunities Innovation ideas generation, and finally regarding RRI in the innovation process in each scenario. The different dynamics can be tested with the IAMRRI Agent Based Model for simulating the effects of these different dynamics.

The innovation phase in scenario "responsible Europe" is characterised by stable conditions for collaboration. The supply chains are balanced, partly dominated by big players, but also small players innovate well. Big companies need small companies and research organisations for being innovative. Smaller companies collaborate among each other. The actors are universities, research organisations, and big companies and specific smaller companies for the idea generation. For the innovation development also, small companies are involved. The public is engaged in specific cases where a bigger society is affected. There are fab labs. Regarding RRI there are strict regulations for open access, gender and ethics. Regulations protect the costumer. Public engagement takes place by involving smaller groups that develop ideas. Good education is the basis. The governance perspectives in this scenario give more opportunity to learn from each other, the market opens, the innovation rises. Science education is inclusive.

The innovation phase in scenario “self-organizing society” is characterised by high dynamics, increased bottom-up initiatives such as individuals active in cooperatives, maker spaces, fab labs. There is linked facilities for complex solutions, more informal collaboration without contracts (maker spaces). The actors share knowledge. Companies still important to provide machine and material innovations in collaboration with research organizations. Machines for communities will be co-funded. RRI aspect are as follows. The society is highly inclusive and diverse. Gender equality is a matter of fact. Ethical principles diffuse bottom-up within society and among innovators. High level of transparency and open access are implemented e.g., as online platforms and marketplaces. High education is the basis for high ethical values of society.

The innovation phase in the scenario “elites of money and knowledge” is stable with few strong collaborations. There is a top-down control of collaboration and knowledge by the elites. Knowledge carriers installed by the elites control knowledge flows. Only big companies and elite research institutions collaborate. Networks exist in the non-elites (semi-official). These are very important to develop low-tech innovations. The elites define ethical principles. The elites protect the of own class. The poor are exploited by the rich. There is no public engagement because of the danger of upheaval. Poor and uneducated people try to rise through innovation, but also a danger of being exploited. There is no open access and transparency.

The innovation phase in the scenario “robots world” is characterised by a highly adaptive structure and dynamics. Collaboration and networking are supported and controlled by both technologies, AM and AI. The collaboration structures are modelled and adapted quickly when needed. AI and robots are important partners within the collaborations. Networking takes place through data management, rather than as the competence of people. Ethics is important in each stage of the innovation process. AI must include an understanding of ethics. AI is programmed in a way it supports gender equality. However, there is no public engagement. There is easy access to knowledge because of the data platforms. Higher specialisation in AI and AM is provided in higher education.

Future discussion about foresight

Panellist

Karl-Heinz Leitner, Austrian Institute of Technology
Stefano Menegazzi, Hub Innovazione Trentino
Izaskun Jimenez Iturriza, Tecnalia
Eric Klemp, 4D Concepts

Moderation and Summary

Marianne Hörlesberger, Austrian Institute of Technology

The Foresight future discussion reflected the developed IAMRRI future scenarios and the innovation phases in these scenarios from an innovation management point of view, by and RRI expert, from a technology and networking aspect, and from an SME perspective. Karl-Heinz Leitner is professor for Entrepreneurship and Applied Business Studies at University Graz in Austria and leads the Research Field “Innovation Systems & Digitalisation” at AIT Austrian Institute of Technology. Izaskun Jimenez Iturriza works as a senior researcher at the Policies for Innovation and Technology area in TECNALIA in Spain. In the last years she has been involved in projects related to Responsible Research and Innovation, particularly dealing with the engagement of society in research and innovation processes. She is graduated in Law from Basque Country University in Spain. Stefano Menegazzi is an innovation manager at Fondazione HIT – Hub Innovazione Trentino, Italy. He graduated in Mechatronic Engineering at Trento University and has ten years experiences in research for the automotive industry. Eric Klemp is CEO of 4D Concepts, an SME in Groß-Gerau, next to Frankfurt in Germany. 4D Concepts provides prototype and model making services and innovative 3D printer systems in the 4th dimension – time. He has worked for additive manufacturing also in big companies. He lectured at university Paderborn. He holds a PhD in machine engineering.

Foresight methodologies supports innovations processes and innovation management so Karl-Heinz Leitner. Foresight methodologies are not new and are already used for approximately sixty years. Foresight and especially scenario technique were developed in the defense sector. These methodologies were adapted by large companies and later in the 1990ies for smaller firms.

Nowadays foresight methodologies are important for policy making on the national and European level. Foresight is used in relation to the development of new technologies.

Technology development relates to high risks and uncertainty. Investments in R&D should pay off on the long term, and this is also given for additive manufacturing. There is a very fast development, which is not only triggered by scientific breakthrough or technological readiness, but also by economic factors, societal impacts, regulation, and environmental drivers.

All these factors work together and frame the future of a specific technology, in the case of IAMRRI, the range of the various technologies for additive manufacturing[2].

One of the foresight methodologies is scenario technique, which was applied in the IAMRRI project. One step in scenario technique is the analysis of the driving forces for the considered technology. The goal for applying foresight is not to predict the future, but to shape the future in the specific thematic focus, in the IAMRRI case "additive manufacturing". There are high expectations in the whole AM sector and on policy side. Considering the entire value chain, regulative factors, sharing data, and the impact on the society can be addressed appropriately by a foresight with participatory process. Actors from the different organizations in the innovation system work together and create a better understanding.

During workshop with the actors from the different actor types such as science & research, education, industry & business, public authorities, and civil society a common language, a common understanding, new ideas and strategies are co-created. Not only the outcome of the workshops is important, but also the discussion during the group work generates new understanding and new ideas. And so, this can foster innovation process and innovation management. Participatory process can reduce uncertainty, create gives orientation, and build up a joint learning process, can challenge and provoke stakeholders and transfer strategies.

For managing the market push and technology pull, the interlinkage of research and industry foresight can create a better understanding. Getting insight about developments of technologies of the futures together with experts from different disciplines and organization types helps to for creating awareness and most important, communication.

The communication between the involved stakeholders coming from different disciplines and organization types is very import. The foresight process in IAMRRI managed to develop a common understanding of the drivers, factors, and requirements of the involved stakeholders. In this way it builds a basis for implementing the technology and assess the possible impact on the society. The four developed IAMRRI scenarios are very interesting regarding their range. In particular, the scenario "Responsible Europe" should be

[2] Additive manufacturing is not only one technology. There are various technologies for producing the powders, different concepts of printing machines, various software tools for designing the products and processes, and for data transfer to the machines. Toni Luomaranta, Tampere University, explained this in the session "use cases" during the IAMRRI Future Talk, 8th September 2021.

considered as realistic and can inspire policy makers on the EU level. Engaging civil society into the innovation process will be more and more useful for companies. The car industry has already started to involve users into the development of specific functionality in cars.
The AM machine market is the whole world and so it faces competition and cost aspects from all over the world. Considering responsibility and RRI provides a big challenge and needs new ideas for developing RRI in this context.

The scenario about Artificial Intelligence (AI) and AM can inspire the innovation ecosystem so that it is better prepared for challenges coming from AI and its link to RRI.

Standardization of data and providing access to this for other companies will be an important step also for SMEs. Certification and norms in AM open new pathways for repeatability. RRI keys were discussed and addressed in the whole foresight process. Each of the four developed IAMRRI scenarios reflect the RRI aspects. However, merging RRI with additive manufacturing is a challenge, because when considering business on the globe, where competition and costs are the main drivers, implementing RRI needs further new approaches and ideas.

Universities and research organizations are driving the ideas. SMEs have to earn money. Only when the innovation is ready for the market and can be sold, an SME is able to step in. SMEs do not have the capacity for co-creating the future. SMEs are driven by the everyday business. It is important to include the actors at the end of the innovation phases, especially SMEs.

Future discussion on “How could RRI gain a competitive advantage in AM for Europe?”

Panellist
Johannes Henrich Schleifenbaum, RWTH Aachen
René von Schomberg, European Commission
Roland Ortt, Delft University of Technology
Marianne Hörlesberger, Austrian Institute of Technology

Moderation and Summary
Brigitte Kriszt, Montanuniversitaet

The final panel discussion in the IAMRRI future talk brought together all topics of the IAMRRI Future talk and developed future perspectives on the European competitiveness under the umbrella of RRI. In the panel, European experts on RRI, innovation research and management and additive manufacturing shared their knowledge and concerns about the future of European society and governance policy.

The panel discussion ranged from changing the innovation paradigm against the backdrop of a vastly changed market to the call for a strong openness to interdisciplinary collaboration and exchange with stakeholders and society.

Openness, Innovation and European Competitiveness:

Today, the World Wide Web has enabled us to easily move from user to entrepreneur. However, for society, the boundaries between public domain and private global enterprises are increasingly blurred. Lost in the enthusiasm for the supposed freedom of private use and creation is the realisation that the “added value” is created by a few powerful globally acting companies. Today some of these global acting companies are even economically stronger than European states. Their strong role in the field of data very often leads to a globally controlled homogenisation and to a reduction

of the positive effects of innovations for Europe. The potential of new technological innovations cannot unfold in terms of European value creation because the interests of the European society might be different to those of the strategy of global business. This is one aspect which gave raise to RRI approach in relation to European competitiveness and growth. The Europeans must not leave the shaping of our future to international mega groups; new approaches will be needed for future and new ways will have to be gone.
RRI in its original understanding will be a normative response to the insufficient innovation paradigm with all its problems.

Additive manufacturing is a good example of this; the value-creating process is idea generation and design, not in first order the production, but unfortunately the ability to turn our ideas into real products was lost by the most people. International, global platforms offer help to turn new ideas into designs. Once the ideas had been shared with big non-European platforms, the design is provided, and new innovative product can be produced. 3D printing (in industrial context called additive manufacturing) appeals to creative people. The invest in home use printers is affordable. A creative and active maker community is built. The knowledge transfer goes from the private domain to industry and to innovation in additive manufacturing. However, what happens to the created ideas? Europe has a long, distinguished tradition of idea creation, being very open and sharing knowledge with the global communities (early-stage innovation).

However, the European weakness is seen in the exploitation ability of novel ideas. Other global economies are more successful in transferring research results in successful innovative solution. Europe has to change the innovation strategy in future, when it will become more successful in innovation; Europe cannot risk lose the control over the application of ideas in future as it was done in the past. Sometime European idea can turn to innovations which bring negative impact to the European society. This future scenario will give raises to the political but also societal discussions what will be the right level of openness for keeping and increase competitiveness again.
From deriving a picture of the European future situation in innovation, the discussion panel formulated requests to the different stakeholders, such as European policy, science community and society in general for our future.

Request to the future European policies

The dilemma of society to become innovative entrepreneurs and the increasing dependence on international, global private companies leads to some requests to the European policies Europe policies should get stronger in strategic global market decision making.

Plea:

- A clear innovation governance policy should be established that would direct innovation toward socially desirable outcomes (RRI).
- Take position on new technologies based on experience of the future impact of technology, and on expertise, foresights, future scenarios, the technology assessment are the openings
- Make the European societal norms and values clear and transparent; build the principles of action on them, but do not overburden with regulation and rules
- Develop future visions, derive the programs, perspectives and implement the actions like funding programs and other activities to *develop and implement technologies, but do not stop before the vision come reality – transform to a facilitator for future innovation development*

Request to the European scientific and innovation community

- Think in advance about the consequences of the novel ideas, anticipate the future developments; take and share the responsibility with society and stakeholders should become good scientific practise.
- Get out of the "scientific bubble", engage with other disciplines, learn to develop scenarios, and broaden the scientific perspective should be the principle of excellence science.

- Engagement of stakeholders and the start a societal dialogue with society will become important element in shaping Europe's future instead of pushing your ideas to market.
- Turn stronger to cooperation and collaboration instead of being the owner of ivory towers; explore new benchmarks (metrix) for scientific success

Request to the European society

Plea:

- Start being engaged in dialogue about our future and future technologies;
- Take the opportunity to expand your knowledge through learning,
- Be open for finding solutions in complex systems but avoid linear thinking.
- Dare to cross boundaries, take the advantage from learning form mistakes, and use them as source of knowledge,
- Do not allow that the European society´s future dependent on the global market and powerful global companies.

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

www.IAMRRI.eu

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under grant agreement No. 788361.