I AM RRI

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

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D6.4 SUMMARY OF THE FUTURE CONFERENCE

D6.4 The future conference (named IAMRRI Future Talk) reflects the entire work undertaken throughout the project including the foresight process. The reflexion of foresight and discussion points are given, this open-up the developed scenarios and the RRI understanding of the future.

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Author(s) and company:	Marianne Hörlesberger, Beatrix Wepner, AIT Austrian Institute of Technology Brigitte Kriszt, Montanuniversitaet Leoben
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Abstract:	The report reflects mainly the recommendations derived from the panel discussion during the IAMRRI Future Talk. It underlines that innovation can be more successful if RRI is applied properly. Foresight processes combined with stakeholder involvement reflect a main part of the RRI approach. The IAMRRI SKIN Model and the followed simulation supports decision makers.
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Contents

1. Summary

Additive manufacturing (AM) refers to a whole bundle of technologies. Software technologies, design technologies such as CAD[1], material and machine technologies combine to form a high-tech system. This system has the potential to undergo very dynamic changes and is an interesting object of investigation for the approach of Responsible Research and Innovation (RRI). The IAMRRI project has studied the webs of innovation value chains (WIVC) in AM and created a model for the innovation phases and that type of innovation system. The Agent Based Model (ABM) serves as a basis for simulations of AM innovation phases, identifying RRI openings and analysing the implication of RRI implementation. This theoretical research was tested on use cases, once in the automotive sector and once for medical applications. All these topics were addressed in the IAMRRI Future Conference –named "IAMRRI Future Talk"[2], which took place in September 2021.

Applying Responsible Research and Innovation (RRI) works very well with a foresight process combined with stakeholder involvement. In the foresight process, future scenarios for AM were developed, and the innovation phases in these scenarios were examined in more detail. In addition, the possibilities for RRI implementation were analysed. RRI, appropriate implemented, supports the innovation process. Innovation can be more successful if RRI is applied properly.

The results were presented in an IAMRRI Future Talk[3] and discussed with external experts and specialists. This report focuses on the recommendations for action to be derived from these discussions. For example, cooperation is indispensable in the innovation phase if knowledge is to be built up and if rapid innovations are to occur. For this, the information must also be publicly accessible. Scientific education is one of the most important foundations, especially in AM, where expertise in various scientific disciplines is necessary to achieve success. However, in order to arrive at an RRI application that also has a noticeable impact on society and the environment, it also needs openness for engineers to learn to talk to social scientists and vice versa. However, this culture must first be well developed. The IAMRRI SKIN Model developed can support decision makers in simulating the effects of measures and framework conditions and deriving action measures on this basis.

This report emphasis on the recommendations derived from the panel discussion during the IAMRRI Future Talk. The presentations and panel discussion can be found in the IAMRRI Booklet.

[1] Computer-Aided Design

[2] www.IAMRRI.eu /events/iamrri-future-talk

[3] https://www.iamrri.eu/iamrri/events/iamrri-future-talk (doi.org/10.34901/mul.pub.2021.4)

2. Introduction

2.1 Future Conference

The final event of the IAMRRI project was a future conference, called an IAMRRI Future Talk. A future talk is a dialogue among different stakeholders who bring in different experiences and expertise. In this way, the topic to be discussed is placed in a broader context, or in an innovation system as in our case, and viewed from different points of view. In this way, future measures that are necessary for all stakeholders can be better outlined. Based on the scenarios developed in the project, the future talk firstly considers the status quo and assesses the current state of knowledge. Next, identified upcoming trends are discussed and future developments are highlighted. Based on this, recommendations can follow. This report derives recommendations based on the discussions with the panellists.

The IAMRRI project (i) investigated innovation webs of innovation value chains in additive manufacturing (AM), (ii) developed an agent-based model (ABM) for this purpose, (iii) simulated the dynamics in these innovation value chains, (iv) verified the experiences on two use cases, (v) applied a foresight process involving external stakeholders to develop futures. All of this was elaborated to identify the openings in the AM sector for RRI (responsible research and innovation).
The future conference gave an overview to these steps in the project. These IAMRRI concepts and methodologies are also briefly outlined in Chapter 3.

2.2 Positioning of Additive Manufacturing and Innovation Systems

Additive manufacturing (AM) is currently experiencing a very dynamic development. AM is not a novel technology, but a bundle of different methods, processes and techniques to manufacture a product not subtractively, but additively. For this, the product must already be designed accordingly, which requires special software tools. The design data must be correctly worked out. This data must be transferred to the 3D print in the best possible way. The materials, the powders, wires or resins must meet the requirements of the product and the machine processes. The product must also comply with standards and norms and be useful for customers and consumers. Furthermore, these different processes in the AM are subject to a development dynamic in the area of printing machines, design and software tools, in the further development of materials, up to novel processes e.g. for metal alloy generation during the printing process. This high number of parameters in the network of innovation value chains (technologies, materials, products, software) create a complex system and an incredibly dynamic development in AM. This trend is already well observed. The IAMRRI project seeks to contribute to further development. Furthermore, IAMRRI tries to introduce the approach of Responsible Research and Innovation (RRI) into AM technology development and AM product development.

2.3 Goal of IAMRRI Future Talk – Elements of a Foresight

The IAMRRI Future Talk presents the core results of the project work (see IAMRR booklet). The focus is on investigating the networks of innovation value chains in AM and the theoretical background of innovation phases, the empirical investigation of the IAMRRI use cases, namely AM applications in automotive and medicine. The RRI keys (policy agendas) such as ethics, gender equality, science literacy, open access and public engagement are considered in every innovation step in IAMRRI, starting with the initial innovation ideas, across the value chain and in different applications of AM. In addition, the foresight work in the IAMRRI project applied methods such as stakeholder engagement and RRI integration. Stakeholders came from science and research, education, AM industry and companies, public administration and civil society. These stakeholders developed future scenarios together based on context analysis and a shared understanding of the starting point. This process is responsive and

anticipative, diverse and transparent, and thus perfectly aligns with the RRI process dimensions. The future scenarios developed provide a basis for the discussion of the respective innovation phases. The analysis of actors, networks, idea generation in each scenario also serves as input for the IAMRRI ABM.

2.4 Future Talk Panel Discussion with Experts

The IAMRRI Future Talk was divided into a part for the presentation of the project results and a part in which each sub-theme of the IAMRRI project was discussed with invited experts. The panel discussions opened perspectives on future trends and developments in the focus topics of the IAMRRI project. The panellists are members of the project team and European experts in RRI, experts in additive manufacturing, specialists in ABM and innovation science. Participants of the IAMRRI Future Talks were invited to contribute their thoughts to the panel discussions. Keynote speakers gave a scientific perspective on the different topics of the IAMRRI project. René von Schomberg (European Commission, Visiting Professor, Technical University of Darmstadt, Germany) gave a keynote on the RRI approach. Johannes Henrich Schleifenbaum is Professor for Digital Additive Production at RWTH Aachen University. He talked about the future of the manufacturing industry requiring advanced and sustainable solutions for the economy, the environment and the climate. Digitalisation as well as additive manufacturing offer exceptionally profitable answers to these challenges.

3. The used Concepts and Methodologies in IAMRRI

The applied framework, concepts and methodology of IAMRRI projects are diverse. IAMRRI works with a bundle of technologies and processes of additive manufacturing. It explores in detail the innovation phases in these networks and webs. It is elaborating Agent-Based Modelling for AM and its application for simulation. IAMRRI has empirically investigated the applications in the automotive industry and medicine and worked out some demonstrators. At the innovation system level, the technologies and processes in AM were analysed, their influencing factors at this system level were identified and evaluated, and four future scenarios were developed based on this. Finally, the innovation phases in each of the four developed scenarios were specifically analysed. The entire work of IAMRRI focuses on Responsible Research and Innovation (RRI) in the whole AM sector. RRI played a central role in the overall project. In the following chapter, the most important results of the IAMRRI project are summarised in order to bring together the experts' statements in the discussion about the future and to derive recommendations.

3.1 Responsible Research and Innovation (RRI) Approach

Science and innovation are, after all, for society. Responsible Research and Innovation (RRI) has begun to gain momentum across the research community under European Horizon 2020, and there in particular in the Science with and for Society (SwafS) programme. RRI policy is based on the premise that society has lost control over science and innovation, despite increased direct and indirect public funding to stimulate and facilitate research and innovation. Research policy is increasingly focused on scientific excellence. Innovation policy is increasingly focused on competitiveness. In the process, there is a risk that the societal values of research and innovation will be lost, or at least increasingly have to be maintained by the researchers and innovators themselves.

RRI seeks to raise issues related to research and innovation in order to anticipate and incorporate the consequences of technological innovations and products for society. The RRI approach discusses how

science and technology can contribute to creating a society we want for future generations. It emphasises that research and innovation must be aligned with the values and needs of the society. The policy agenda for RRI therefore focuses both on mitigating the negative impacts of research and innovation in areas with potentially negative societal impacts and on actively supporting research in areas with high societal benefits, for example in addressing major societal challenges. RRI envisions responsible researchers and innovators actively shaping their 'stewardship' to reflect the needs of researchers and to communicate and discuss their findings in order to build social support and provide social leadership for their research efforts (Owen et al. 2012).

The IAMRRI project therefore considers RRI on the one side with the involvement of stakeholders from science and research, education, industry and business, government and civil society, on the other side with the use of foresight methods to develop future scenarios with these stakeholders, and furthermore, with addressing RRI policy agendas such as gender equality, science education, open access, public engagement and ethics in these future scenario developments. The IAMRRI project emphasises the consideration of these RRI policy agendas in the IAMRRI Agent Based Model and the IAMRRI Use Cases.

3.2 Webs of Innovation Value Chains

The innovation network value chains are described in the report D2.4 "Final Conceptual Model on Web of Innovation Value Chains in Additive Manufacturing" (Martinsuo et al., 2020), where an overview of the relevant literature is also provided. It is generally agreed that an innovation system consists of a number of actors or entities such as companies and other organisations. These actors interact in the creation, development and diffusion of new knowledge, product ideas and commercially viable products. The innovation systems approach provides a useful framework for understanding why some firms, sectors or regions are more economically successful than others.

Companies have different motives to participate in innovation networks. One aspect is that cooperation can spread risks and increase individual uncertainty. Another important aspect is that knowledge and innovation are increasingly created in collaboration with different actors.

In IAMRRI, actors and processes have been linked and analysed regarding their economic performance, social performance and strategic impact for the AM stakeholder network.

In the IAMRRI project, the innovation value chain is described as a three-stage sequential process. It includes idea generation, idea development and dissemination of the developed concepts. Different actors from AM research and business are active in each stage. At all stages and in the transition from one stage to the next. At each stage, it is important for the organisations involved to overcome the critical stages in order to reach the next stage of the innovation value chain. The activities in these steps and transitions (gates) can be influenced by stakeholders such as regulatory, standardisation or funding agencies. Stakeholder engagement is considered as environmental influence.

3.2.1 Types of Innovation in AM

In AM five types of innovation are characterised. The comprehensive treatment of this topic can be found in Deliverable D2.4.

a. The production of AM products is mainly driven by **the demand and use of the AM products**.
b. **AM and digitalisation are closely intertwined and software** for AM processes are important foundations for innovation.

c. **AM services** covers the AM production, beginning from the AM feedstock manufacturing to the finished AM product and its distribution.
d. **AM machines** and technologies are a critical resource for AM production,
e. **AM materials** are also a critical resource for AM production.

3.3 IAMRRI Modelling

The IAMRRI project worked out a conceptual and agent base model that can describe the dynamics and interactions in the networks of innovation value chains in the additive manufacturing sector. This includes the interaction related to RRI. The conceptual model based on the mapping of processes and actors in WIVC and a set of indicators which describe innovation behaviour. The observations of the WIVC were transferred in an agent-based model (ABM) and the simulation methodology was applied. ABM is a computer model that attempt to capture the behaviour of agents in their environment. In the IAMRRI project a model for the dynamics of the innovation value chain networks in additive manufacturing was developed, specifically the SKIN (Simulating Knowledge Dynamics in Innovation Networks) model was adapted to the IAMRRI SKIN model. The simulation using the IAMRRI SKIN model helps to see trends in the network development and the openings for RRI. (see especially, D 5.1. "Report on the IAMRR AM Model" and further preparative deliverable form IAMRRI.).

3.4 Use Case Automotive Application and Use Case Medical Application

In the IAMRRI project, the use cases were selected to represent significant changes in terms of value creation and capabilities in the industry as a result of incorporating additive manufacturing technology. The use cases were intended to capture the complexity of a particular innovation process as well as observe the role of RRI. In order to achieve the object, an anthropological research approach was employed which involve several data collection methods such as observation, panel discussion, interviews, and action-based research.
Two use cases in automotive and medical applications were selected. In the automotive application, the use case was dealing with the development of a front suspension arm for limited series of sport car model. Two industrial project partners (large companies) were involved in the development of the use case, one is an automotive manufacturer, and one partner is an AM expert.

In the medical application, the use case exploited the development of a skull and spinal implant using ceramics as AM materials. The use cases were developed by several project partners involving two medical devices research and manufacturer, an AM industrial partner, and a university. Overall, the use cases produced positive results. In addition, the experiential experiment with the use cases allows the project teams and the industrial partners to observe the roles of RRI during the innovation process. Within the use case, collaboration is critical for the development of a new product or technology. In this case, building trust and providing complementary expertise for cooperation are the key points for successful use cases.

In the automotive context, the product innovation was front suspension arm of a car front end. Two industrial project partners elaborated this use case, one is an automotive manufacturer, and one partner is an AM expert. The use case work was influenced strongly by automotive industry internal best practices, internal regulation and requirements and standardisation procedures to get passenger safety and environmental sound solution by light weight design. Having two companies belonging to large global companies in the use case, the access to global AM production plants and more resources of pre-knowledge was realized.

In addition to the concrete developments of the use cases, these developments were also anthropologically observed with regard to RRI, and the innovation cooperation was analysed. Building trust and providing the complementary expertise for the cooperation are the key points for successful use cases.

3.5 Foresight and Stakeholder Involvement

The work regarding foresight is embedded in the whole project and deals with stakeholder involvement and a scenario development process for these "webs of innovation value chains in AM with openings for RRI". The more general objective of this task was to generate a common communicable and well-structured picture within the stakeholder groups about future shapes and strategies for AM and for webs of innovation value chains in AM with openings for RRI.

Four future scenarios were developed. The names of these scenarios already contain the core idea of the scenario. They are "Responsible Europe", "Self-organising Society", "Elites of Money and Knowledge" and "Robot World". These scenarios span the range of possible courses of action for the AM industry and beyond for the innovation economy. The risks and challenges in each of these scenarios entail concrete measures to ensure that the innovation and economic system is prepared for them.

3.6 Panel Discussions

The future talk panel discussion brought clear statements based on all the results from chapters 3.1 to 3.5. It was talked about which actions and considerations will be relevant for the near future. Bringing together all outcome of the project, the statements of the future talk led to the recommendation from the perspective of the foresight and the future on innovation research on IWVC. In addition, the developments in AM and AM products are underlined. A central role was played by the consideration of RRI and how to get access to this specific innovation system of AM.

4. Recommendations

The recommendations are derived from the output of the project and the statements of the experts during the future talk.

4.1 RRI in General

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

> "*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)*"

Conventional innovation and technology management processes in companies and at the political level do not sufficiently consider the impacts on society and the environment. **Stakeholder and citizen participation will bear more responsibility for the impacts of the technologies developed.** The EU Green Deal approach is now a good approach to achieve accountability in the innovation system as it involves stakeholder engagement and anticipation.

Anticipatory governance is strongly recommended: Public authorities need to apply extended forms of technology assessment (TA) and scientific and technological forecasts or scenarios. Foresight is based on excellent methods that support the consideration of innovation in a broader context at the level of innovative economic systems and long-term developments and impacts on society. In particular, **the combination of foresight and strong stakeholder engagement** (a) creates awareness of the technology and its impact, (b) supports holistic thinking in the stakeholder group, (c) reflects new ideas and points to new directions for the future, (d) brings up open questions and scenarios of possible risks and unresolved challenges.

To ensure access to knowledge and data, the first step for researchers and scientists is to share data and information (knowledge) as early as possible when working on publicly funded projects. Very important is the development of a culture of cooperation in science, research and innovation. A change in the metrics and indicators for excellence science should open up a stronger orientation towards cooperation with other science communities, but also with society. This new approach should also be an integral part of **science education**.

In order to make the development of technologies and innovations more acceptable and environmentally compatible, it is necessary for **research and innovation to be societally value-oriented and economically aligned**. This requires **new concepts for innovation and technology promotion**, but also a new culture in companies and technical universities. Therefore, prioritisation of research and innovation and the design of research policy agendas must be more open and shared with stakeholders. The IAMRRI Future Talk clearly brought out the contradiction between maximising economic business success (money) and maximising value, which is particularly virulent in new technological developments or early innovations such as AM.

Current developments are redefining the socio-economic balance and are reflected in the way companies operate. This is also evident from the EC GREEN Deal Strategy. Politicians, scientists, opinion and business leaders, journalists, young people and society as a whole are increasingly oriented towards climate and environmental issues because of the impact on future society. This is also confirmed at other levels, such as new methods of assessing corporate values, where, for example, new criteria are being established to evaluate corporate executives, including the ecological footprint and gender equality. This represents a shift from a purely business-oriented field to a socio-economic European corporate world.

The consequence is that **a transition from economic performance indicators to strategic- societal-economic performance indicators** is taking place and companies need to expand their business operations to include principles of responsible research and innovation (RRI) such as gender equality, ethics, open data, etc. Thus, for the first time, industrial change is taking place not at the expense of but thanks to social consideration. In this context, RRI is a tool for socio-economic performance. It is recommended to **make this transition transparent by using socio-economic value indicators** instead of purely economic indicators. In terms of the RRI approach, business indicators should be complemented by indicators for gender equality, ethics, open access or data. Make this new trend transparent as a desired goal in the EC's policy considerations for the future. Research and innovation funding can be an incentive to promote this approach in research and innovation actions (projects), but is limited in its impact to research actions only. The shift to a **socio-economic view can be underpinned by standards or even more by regulation**. Standardisation, a powerful bottom-up community mechanism, could also support this transition process.

An important outcome of the RRI reflection is that the RRI approach is seen as an absolutely necessary development in European research and innovation policy. The multitude of major challenges for European society requires RRI-oriented solutions and approaches. It was seen as a disadvantage that the current construct of RRI is often difficult to understand for practitioners in companies. The RRI concept is better implemented in civil society and business if the principles and goals are clearly formulated

and easily accessible. Business and society are less reluctant to adopt this approach if the understanding is developed that the RRI principles represent sustainable action for the future of the European Union.

4.2 Additive Manufacturing Applications

AM technology is still in the early stages of development, but by building knowledge we are moving faster into application. Market forecasts for AM, as in the annual Wohler Report[4], show a steep upwards trend. However, there is no doubt that AM has developed enormously in recent years. Nevertheless, AM is still scratching the surface of the full application potential. AM and virtual design benefit greatly from the parallel advancement of digital technologies. Creating a 3D model of a new product with a computer was a major challenge years ago. Today, the digital solution is a success factor for the implementation of AM technologies.

4.2.1 Collaboration and Convergence of New Technologies

Based on the trend of convergence of new technologies, it is assumed that AM will strengthen its potential in the production of new products in the future. AM experts have made things work without knowing all the details of the ongoing innovation system. In the future, society will see more new AM solutions and products.

Because of this strong intertwining of new technology development with other parallel developments, strengthening AM across the market requires strong networks and partnerships, AM internally and also with other growing technology domains. Instruments such as patent or other IP protection procedures are time-consuming, the convergence of many new technological solutions today very often leads to the development of marketable products in a very short time. SMEs are important players in the increasingly fast-paced innovation processes. Networking is an important instrument for gaining access to new knowledge and new technological approaches. In order for AM application to succeed, AM oriented design and technologies need to be adopted. **A paradigm shift is taking place in these phases of AM innovation collaboration**. **This can be supported through awareness raising, publications, network exchanges, new project collaboration, and education and training. Access to knowledge is a very strong driver of innovation.**

New business models need to be developed for AM application. Knowledge, creativity and understanding of the customers' needs are the essential ingredients for success. Since the automotive industry naturally has a different innovation structure than medical technology, knowledge about the segment in which one operates is also a success factor that can be built up through networking and cooperation.

Recommendations for funding organisations or innovation partners derived from these statements are:

- Do not consider one technology, try to tilt other new developments to arrive at the best innovative solution
- Be open to supporting cooperation and promote the building of networks to carry out innovation projects, but be objective and solution-oriented in the context of RRI.

[4] Wohlers Report on Additive Manufacturing – Wohlers Report, https://wohlersassociates.com/

4.2.2 Cross-Disciplinary Thinking and Collaboration

The RRI approach helps to open up our thinking. **Cross-disciplinary thinking and collaboration need to be established in order to get better and more responsible idea options and thus results. New collaboration designs are necessary for this.** The RRI concept supports solution finding through openness and transparency. Lithoz has thought a lot about partnership from the beginning. This way of building partnerships and involving outside stakeholders helps you bring the product to market much faster.

Most engineers are only trained to solve technological problems. Therefore, it is a challenge for them to discuss the entire innovation ecosystem or AM networks of the innovation value chain with its interconnectedness. Social scientists have a completely different focus in their scientific work. Moreover, engineers and social scientists speak a "different language". Therefore, they have to learn to understand the other scientific disciplines in order to find a fruitful collaboration. Training or seminars during education on how to collaborate with completely different disciplines can help, openness and willingness to cooperate is a strong driver to overcome this problem. In addition, product developers need to build knowledge along the entire process or network of the innovation value chain.

4.2.3 Trust and Collaboration

Building trust is crucial both within the project partners and for the overall cooperation. However, building trust takes time. This is a fact that needs to be taken into account in the innovation phase of idea generation.

New ideas and concepts are needed. In order to build trust, many exchanges are needed before a joint idea generation process can begin. This barrier can be broken down by facilitators from technology transfer units or clusters. Building partner relationships in consortia should take this role into account. This partner should also have the knowledge to bring together partners from different types or organisations and sectors to achieve a diverse network constellation and competences. The IAMRRI use case showed that the only concentration of company partners in the project team had potential for improvement later in the innovation project phase.

Networking and cooperation create partnerships and ideas. Networking, collaboration and bundling of competences drive not only RRI, but also AM. Therefore, **appropriate cooperation structures must be created.**

4.2.4 Contradiction in Getting and Giving open Access

Access to knowledge is very important for AM. Open access and transparency make the discussion within competitors more relaxed. Open innovation and access to knowledge are important for SMEs. If AM the rapidly knowledge build up will be protected and proprietary, it will be not diffuse broadly and openly. But on the other hand the owners of the AM technology knowledge will have their market competition advantage. This build a critical contradiction in getting and giving access. **The development of appropriate concepts for access to knowledge for SMEs is necessary. On the other hand, the knowledge advantage is the success factor for innovation.**

A way which moght handle that contradiction can be standardisation, which shares parts of technologies/ knowledge, so that openness is created and diffusion of technology can go on faster, and enables faster growth in the industry. But standardisation as community bottom-up process will also need strong engagement of the AM player.

AM is open to the idea itself. **RRI aspects are very important drivers, like openness and ethics. The more we open up, the more feedback we can get. By considering RRI, AM innovation will benefit and bring innovations to market faster.**

What is different in the two IAMRRI use cases is provided on the one hand by the economically strong and consolidated automotive industry and on the other hand in the developing market of single implants. In medical applications, players from different countries, e.g. Orthobaltic in Lithuania and Interesansa in Slovenia, can easily innovate together without being competitors, or more precisely, without losing a market. They can easily innovate together without being direct competitors in their domestic market, or more precisely, without losing market share in a still developing market. Opening up knowledge to a wider community in the industry could be an important aspect of RRI implementation. The automotive industry faces a very different situation. This industry operates in a consolidated and investment-intensive market with strong global competition. Here, innovation seems to be always related to high risk. The opening up of knowledge must be approached more cautiously here. **However, opening up knowledge requires awareness, rethinking, confidence building, holistic and comprehensive thinking of the whole value chain and the whole AM sector.**

4.3 From Model to Simulation – the IAMRRI Agent Based Model

Innovation is a complex and non-linear process whose success depends on the cooperation of different actors. Because of this complexity of reality, it is difficult to build the model in detail. Various assumptions have to be made for this purpose. Agents in the model are large and small companies at different stages of the value chain. These are suppliers, designers, universities and research centres, or customers. In the IAMRRI Model, they are companies, either automotive or medical application oriented, some of them brokers operating in both segments. They are characterised by the level of knowledge in their field and the technologies used.

These agents are endowed with inclinations towards responsible research and innovation (RRI), especially in terms of open access publications, ethical thinking, public engagement and gender equality. These inclinations change over time depending on their relationships, their interactions and the type of learning process they are involved in. Collaborative networks and innovation value chains must meet the RRI requirements of some key organisations such as standardisation organisations, regulators and funding agencies. These requirements serve as an incentive for agents to invest in RRI practices and interact with other agents who have a higher level of RRI inclination.

4.3.1 Agent Base Modelling and Simulations

To maximise the impact of the complex IAMRRI SKIN model, **it is important that the model is used, tested and extended in the scientific community and among policy makers. It is important that other researchers can replicate the model, extend it, discover other behaviours or observe new traits from scratch.** Currently, the model is being applied to two different industries: the automotive industry and for medical devices. Future options are to apply the model and simulation to different industry sectors or other technological developments.

The model needs a community of users to run simulations, give input for improvements and build up resources to further develop and improve the model. Gamification would be a wonderful approach where users can control the game controller.

It is also important to remember that **ABM is a tool to gain an understanding of complex systems**. Simulation results are observed to reflect the implications behind them. **A continuous dialogue with users is needed to gain a deep understanding of the model results and their implications for policy**. The findings are that mathematical modelling such as the agent base model will be a tool to better understand the complex systems such as a WIVC and derive measures to improve the system. But it is also clear that the effort to develop such a model will require more resources beyond the IAMRRI project. It also needs a stronger scientific community to champion its development. The insights from

mathematical simulation will be very valuable for innovation research. Mechanisms and decision-making pathways can be tracked through models. Effects of interventions and decision-making can be analysed in a mature state of agent-based modelling.

4.4 Foresight Combined with Stakeholder Involvement

Foresight combined with stakeholder engagement are core methodologies for implementing responsible research and innovation. In the IAMRRI project the scenario technique opened the mind set for different futures so that the affected stakeholders and policy makers can respond to the challenges in the possible scenarios. Therefore, foresight combined with stakeholder involvement is crucial for all technology development which affects the society and the environment, or nature. As mentioned already, such forward looking methodologies create awareness inside the stakeholder group, generate a new mid-set regarding the specific topic, build new knowledge because of the interlinkage with other disciplines and different logics. Furthermore, foresight methodologies create a commitment for common action.

5. Final Remarks from the Future Talk

AM is strongly embedded in a globally operating innovation ecosystem. Therefore, looking at it on this meta-level is necessary. The World Wide Web has enabled us to easily move from user to entrepreneur. However, for society, the boundaries between the public domain and private global enterprises are becoming increasingly blurred. Lost in the enthusiasm for the supposed private freedom of use and creation is the realisation that the "added value" is created by a few powerful global corporations. Some of these global corporations are economically stronger than European states. Their strong role in data very often leads to globally driven homogenisation and a reduction of the positive impact of innovation for Europe. The potential of new technological innovations cannot unfold in terms of European value creation because the interests of European society may diverge from the strategy of the global economy. This is one aspect that has led to the RRI approach to European competitiveness and growth. Europe must not leave the shaping of our future to international mega-corporations. New paths are needed and will be taken for the future. RRI in its original understanding will be a normative answer to the insufficient innovation paradigm with all its problems. Additive manufacturing is a good example of this. The value-creating process is ideas generation and design, not production, but unfortunately the ability to turn our ideas into real products has been lost on most people. International, global platforms help turn new ideas into designs. After exchanging ideas with large non-European platforms, the design is made available, and a new innovative product can be produced. Europe has a long, significant tradition of idea generation, is very open and shares knowledge with global communities.

It is already stated in the IAMRRI Booklet. Since it is very important and was discussed by the plenary panel during the IAMRRI Future talk, it has to be repeated here as well.

5.1.1 Request to the Future European Policies

The dilemma of society to becoming innovative entrepreneurs and the increasing dependence on international, global private companies leads to some demands on European politics. European politics should become stronger in strategic decision-making in the global market.

Appeals

- A clear innovation governance policy should be established that **directs innovation towards socially desirable outcomes (RRI).**
- Take a position on new technologies based on **experience of the future impact of the technology, and on foresight, future scenarios, technology assessment** are the openings.
- Make European **social norms and values clear and transparent.** Based on this, the principles for action are established, but do not overload them with regulations and rules.
- **Develop future visions, derive programmes and perspectives and implement measures such as funding programmes and other activities to develop and implement technologies**, but do not stop before the vision become reality and transform into a facilitator for future innovation development.
- **Develop clear strategic funding program** that the development of AM technologies and AM produced product with novel functionality support the strategic European objectives.
- **Take the AM system as a brilliant example for a European technology and study the innovation system** to transfer that knowledge to other upcoming technologies. Strengthen new approaches like system modelling by agent base modelling, for supporting the learning of behaviour of complex system by "gaming" methodologies.

5.1.2 Request to the European Science and Innovation Community

Appeals

- **Thinking in advance about the consequences of the new ideas, anticipating future developments,** taking responsibility and sharing with society and stakeholders should become good scientific practice.
- Get out of the "scientific bubble", **engaging with other disciplines, learning to develop scenarios and broadening the scientific perspective** should be the principle of excellence science.
- **Engaging stakeholders and starting a dialogue with society** will become an important new element in shaping Europe's future, rather than only putting products on the market.
- **Turn more towards collaboration and cooperation** instead of being owners of ivory towers; explore new benchmarks (metrix) for scientific success.

5.1.3 Request to the European Society

Appeals

- **Start a dialogue about our future and future technologies**.
- Take the opportunity to **expand your knowledge through learning**.
- Be open to solutions in complex systems, but **avoid linear thinking**.
- **Cross borders and learn from mistakes**. Use the learning as a source of knowledge.
- Do not allow the future of European society to depend on the world market and powerful global corporations.

6. References and Additional Readings

Cozzoni, E.; Ponsiglione, C.; (2021). D 5.1. “Report on the IAMRR AM Model”. IN IAMRRI project GA 788361. Public after approval

Kriszt, B., (ed.) (2021). D7.4 The IAMRRI Booklet. IN IAMRRI project GA 788361. Public, DOI doi.org/10.34901/mul.pub.2021.4.

Martinsuo, M.; Toni Luomaranta T.; Sobota, V. C. M.; Van de Kaa, G.; Ortt, R.; Soetanto, D.; Spring, M.; Sischarenco, E.; Kriszt, B.; Jimenez Iturriza, I.; Bierwirth, B.; Hörlesberger, M.; Wepner, B.; Kasztler, A. (2020). D2.4 “Final Conceptual Model on Web of Innovation Value Chains in Additive Manufacturing.” IN IAMRRI project GA 788361. Public after approval.

Nguyen, N.; Vinogradov, E.; Jensen, A.; Ørding Hansen, J.; Cozzoni, E.; (2019). D3.1-V1“Report on Research Target and Model Design Specification”. IN IAMRRI project GA 788361. Confidential.

Wilkinson, M. D.; Dumontier, M.; Aalbersberg, I. J.; Appleton, G.; et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. IN: Scientific Data. 3: 160018. doi:10.1038/sdata.2016.18. OCLC 961158301. PMC 4792175. PMID 26978244.