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

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D5.1 Report on the I AM RRI AB model

ABSTRACT (3 LINES): DOCUMENTATION ON THE DEMONSTRATOR FOR THE AVAILABLE I AM RRI AB MODEL, PRESENTATION OF THE MODEL VERIFICATION CAMPAIGN AND OF ITS REFINEMENTS IMPLEMENTED BETWEEN THE VERSIONS V0.1 AND V0.2

I AM RRI Identifier:	IAMRRI_D5.1_final_v1_28092021
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Work package:	5
Document status:	Final
Dissemination Level:	PUBLIC
Keywords:	Agent-Based modelling, simulation, additive manufacturing, innovation value chains, responsible research and innovation
Abstract:	The deliverable contains the description of the final I AM RRI AB model (v0.2), including its first verification and the description of refinements implemented between the versions v0.1 and v0.2
Version & date:	V1, 28/09/2021

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

I AM RRI

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List of Abbreviations

ABM&S	Agent-Based Modelling & Simulation
AM	Additive Manufacturing
HW	Hardware
ID	Identification Number
IH	Innovation Hypothesis
IVC	Innovation Value Chain
NGO	Non-Governmental Organisation
OEM	Original Equipment Manufacturer
RRI	Responsible Research and Innovation
SKIN	Simulating Knowledge Dynamics in Innovation Networks
SME	Small-Medium Enterprise
SW	Software
WP	Work Package

1. Deliverable summary

The deliverable contains the final description of the I AM RRI AB model also known as I AM RRI SKIN model, in its version v0.2[1], including the description of verification steps and the refinements implemented with respect to the version of the model presented in the deliverable 3.3, the version v0.1[2].

The deliverable it is divided into the following main parts.

- Demonstrator's brief presentation, in which the model it is briefly presented, and are reported the links to some videos that describe the more significant parts of the I AM RRI SKIN model as demonstrator: interface (introduction), model set-up, model run, outputs, and outputs download.
- The verification of the I AM RRI SKIN model, where the "Verification" process is presented, for the version of the model as proposed in the deliverable D3.3. The verification it is also accompanied by the presentation of the preliminary simulation experiments (a more detailed discussion about the simulations outputs will be provided in the deliverable D5.2).
- The model refinements introduced in the I AM RRI SKIN model between v0.1 and v0.2, with the presentation of the related simulation experiments (a more detailed description will be provided in the deliverable D5.2).
- The "Verification" process of the refined version of the model, the version v0.2.

An appendix, including the tables of the last "Verification" carried out on the final version of the I AM RRI SKIN model (v0.2), and the bibliographic references, conclude the deliverable.

[1] https://github.com/GradoZeroTeam/IAMRRI/blob/master/IAMRRI-ver0.2.nlogo

[2] https://github.com/GradoZeroTeam/IAMRRI/blob/master/IAMRRI-ver0.1.nlogo

2. Demonstrator presentation/tutorial (videos realised on version v0.1)

2.1 Introduction

One of the main challenges of the SwafS program is to model complex networks of Innovation Value Chains and study the opportunities offered by RRI practices. The I AM RRI project responds to this challenge. Here, through an Agent-Based Model, we try to simulate the behaviour of complex networks, enhance the knowledge base on research and innovation and create a tool to support policymakers in the formulation of strategic guidelines.

From the first steps, the I AM RRI project was oriented to reuse a model that could be adapted to the project's objectives to have a decrease in development time and a greater possibility of disseminating the model. The choice fell on the SKIN[3] model: a multi-agent network model in knowledge-intensive industries in which knowledge spreads among agents. The fundamental component taken from SKIN is that of modelling the agents' knowledge base, also called *kene*. It is formed by several triples, each of which consists 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.

Each agent, starting from its knowledge, elaborates then an idea of innovation, an (IH) Innovation Hypothesis. The agents can belong to the Automotive or Biomedical industry or both. Each agent is characterized by variables representing the inclination to RRI practices: *Public Engagement, Open Access,* and *Ethical Thinking* were implemented in the version v0.1 of the model. Each type of agent (*AM-tech, OEM, Supplier, Customer, Research-inst, …*) has a specific type of knowledge and cooperates in a network to define and develop an innovative idea. Other agents that intervene in the process of innovation (*funding* and *regulatory bodies* and *std organization*) are modelled as endogenous variables to the network. The model follows a stage-gate approach in which the assessment process becomes predictive and not only reflective. The phases are two: idea generation (of duration 3 tick - the temporal unit of the simulation cycle) and product development (duration 12 tick). In gates, innovations are evaluated by regulatory, funding, and standard organization. The model is implemented in the programming language NetLogo[4] (v.6.1.1.), a multi-agent programmable modelling environment, where, one the model it is loaded, we can see three main tabs: the **interface** (which we will explain shortly), the **info tab** (which contains instructions about the model such as: what is the focus of the model, how it works, and how to use it), finally the **code** (which contains useful comments to variables and procedures to facilitate the understanding).

See video: https://www.dropbox.com/s/5bf1sep1i4plf5p/1_Introduction_and_Interface.mp4?dl=0

2.2 Model set-up

The interface of I AM RRI SKIN allows an easy use and an easy understanding of the mechanisms and results of the simulations.

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[3] Gilbert, Nigel, Ahrweiler, Petra and Pyka, Andreas (2010) The SKIN (Simulating Knowledge Dynamics in Innovation Networks) model. University of Surrey, Johannes Gutenberg University Mainz and University of Hohenheim - https://github.com/InnovationNetworks/skin

[4] https://ccl.northwestern.edu/netlogo/

The sliders, on the left side of the interface, have been divided in a modular and sequential way to guide the user.

In the first block the user can choose the number of actors involved for each breed.

In the second block, the user must set the values of some exogenous and environmental variables, including those related to funding bodies and standard organizations.

In the third one, the experimenter can choose some endogenous characteristics of the agent, especially related to the aspects connected to the RRI values that influence the interaction mechanisms.

Finally, before starting the simulation, one can decide to adopt a particular layout to visualize the collective behaviour of the agents. For example, the “UNINA” layout allows to visualize the links between the focal agent and its partners, while the created networks/IVCs occupy the lower part of the environment in which the agents move. It can be seen how the networks traverse the various stages of different lengths and which networks have a time advantage over the others.

Clicking on the “SETUP” button creates the agents. The agents are initialized with the same financial resources and given a kene, they 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.

See video: https://www.dropbox.com/s/q63o338gu7dx0s3/2_Interface_and_Model_Setup.mp4?dl=0

2.3 Model run

Clicking on the “GO” button, we see below the networks proceeding along the innovation process and the agents moving towards their focal. Once at the first gate, the innovation idea is evaluated by the regulatory bodies (based on the ethical thinking of the network) and by the funding bodies (based on technical quality and RRI values).

In the first phase of product development, some partners might leave the innovation project due to economic default, while experiential learning is realized with an increase in the expertise levels of the knowledge used. The last gate has as protagonists again the regulatory bodies and standard organizations that assess the technical quality, and finally the network may concretize in a start-up or be dissolved. In the upper bar it is possible to view how many months are passed in the artificial world and it is possible to increase the speed of the simulation.

See video: https://www.dropbox.com/s/9kemmapy2isw1a8/3_Model_run.mp4?dl=0

2.4 Outputs

The outputs are divided into three macro-areas of impact: social, economic, and strategic.

The economic performance of the system is analysed through the continuous evaluation of the average capital of the networks that make up the system.

The strategic performance is evaluated through several indices:

- the number of start-ups created;
- the average size of the networks;
- the number of agents involved in the networks;
- the percentage of agents involved;
- the percentage of surviving agents for each phase.

The result in social terms is estimated through a graph that expresses the time trend of the average value of RRI values, for each RRI variable identified. Thus, the increase, decrease, and periods of greatest spread of RRI values are observed.

Another proxy used is the number of open access publications that were made during the simulation.

Obviously, at each time point in the simulation, the number of networks/IVCs relative to each phase and the total number of networks is provided.

See video: https://www.dropbox.com/s/3zsk80mlxoycmig/4_Outputs.mp4?dl=0

2.5 BehaviorSpace (ouputs download)

NetLogo offers various tools, including the **BehaviorSpace**, with which we can set various experiments by assigning, at once, various levels of input variables, the number of simulations, and the desired output.

By clicking "OK" and then "RUN", it is possible to choose the format of the results (e.g., .csv) and then analyse the data through various statistical analysis software such as Excel, R studio, or SPSS.

See video: https://www.dropbox.com/s/40rqj5tq1oms25k/5_Outputs_Download.mp4?dl=0

3. "Verification" of the I AM RRI SKIN model and presentation of the preliminary simulation experiments

Verification and Validation are two processes used to ascertain the rigor and the valence of Agent-Based Models (ABM). According to North & Macal (2007), before being subjected to these two processes a model is a toy; successfully passed these two processes, it becomes a tool.

Verification and Validation are often used both in natural and social sciences, taking different meanings depending on the field of study and its methodologies. The literature abounds with similar definitions, leading to confusion and conflict, attempting to cover wide areas of application (David, 2009). In order to overcome this problem, here we focus on narrow definitions used in the literature relative to ABMs, where:

- *Verification* is the process of "checking that a program does what it was planned to do"(Gilbert & Troitzsch, 2005, p. 22) or "is the process by which the implemented model is shown to correspond to the conceptual model, and it is carried out during the design and construction steps of the model development" (Rand & Rust, 2011).
- *Validation* is "the process by which the implemented model is shown to correspond to the real world, and it usually occurs during the model analysis" (Rand & Rust, 2011), or "while Verification concerns whether the program is working as the researcher expects it to, Validation concerns whether the simulation is a good model of the target"(Gilbert & Troitzsch, 2005, p. 23).

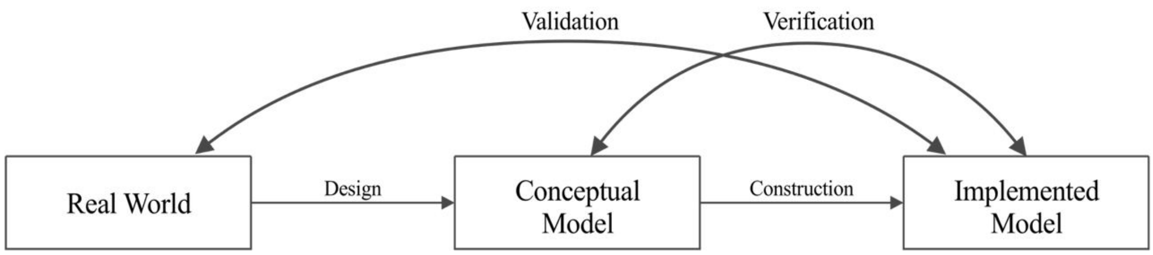

Figure 1: ***Verification and Validation***
(Rand, Introduction to Agent-Based Modelling, 2020).

We can say that a model is a possible explanation of how the real-world works, a synthetic representation. This explanation must be tested. However, it is important to note that no model can be totally validated or verified (Grimm & Railsback, 2005), and this is true for all the models and not only for ABMs. Even a topographic map is a model, one of the oldest and most used in the world. But is it reasonable to totally validate a topographic map? Of course not. According to Schlesinger (1979), Validation is a "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model." Thus, the extent to validate a model depends on its purpose and the typology of systems under investigation.

The Verification is closely related to the model's results analysis, especially when we have to analyse complex results, as is the case with ABMs. When we observe unexpected and interesting emerging results, we wonder if they result from particular modelling decisions or a simple error in the code. To answer this question, we need to investigate this issue from the early writing stages, following methodologies similar to *software verification* used in computer science. In the next Section, we will illustrate some Verification experiments that have been conducted, while the Validation experiments, with their methodologies, results, and discussions, will be the subject of the deliverable D5.2.

3.1 Verification

Unfortunately, NetLogo does not have a dedicated debugging tool (to figure out and fix mistakes).

Moreover, a curious aspect of NetLogo that one learns by experiencing it, is that NetLogo has such a *high-level language* (very similar to spoken language and translated into machine language by a dedicated program called "compiler") that it convinces the developers of the absence of errors, just because they have not been notified. For these reasons and to guarantee rigor and efficiency to the model, it is necessary to look for such *bugs* with methodologies from the first phases of the code's writing, increasing the possibilities to identify and isolate them. At this point, it should be clear that Verification determines how well the implemented model corresponds to the conceptual one.

The work of Verification does not have to be published. However, for greater transparency, we have thought to preserve a record of the efforts and to make available the source code in a dedicated repository on GitHub[5]: in this way, other researchers can verify the model and perhaps, offer new ideas for the modification of the conceptual model at the base.

The Verification process has been conducted following three fundamental steps, described by Rand (2011),one of the most authoritative creators of ABM and co-developer, together with Uri Wilensky, of NetLogo software. These three steps, synthetized in the

Table 1, are named *Documentation*, *Programmatic testing*, and *Test cases*.

Documentation is the process of creating documents that describe both the conceptual model and the implemented model, with a level of detail sufficient to compare the two models (North & Macal, 2007). Thus, it is necessary to carefully document all modelling choices from both a conceptual and purely coding perspective. The conceptual model was described in the various documents produced by the partners, while the description of the implemented model was the focus of the deliverables D3.2[6] and D3.3[7].

Moreover, following Gilbert's indications (2008), inside the code, we inserted some comments to help less expert programmers to understand the correspondence between parts of the code and the relative block of the conceptual model. Therefore, we can affirm that good documentation must facilitate comparing the conceptual model and the implemented model.

Programmatic testing is to make sure that the model does what the programmer expects. This step can be approached in four different ways: *unit testing, code walkthroughs, debugging walkthroughs,* and *formal testing.*

- *Unit testing* consists of writing for each piece of code, or each procedure, a test that verifies its consistency (Beck, 2002). For example, the reporter *compatible?* (with which agents score potential partners) was tested in a new simulation environment to verify the accuracy of the numerical

[5]GitHub, Inc. is a provider of Internet hosting for software development and version control using Git. It offers the distributed version control and source code management functionality of Git, plus its own features - https://github.com

[6]Report on the modelling framework.

[7]Demonstrator on computational representations of the model.

output under specific inputs. Alternatively, the equation defining the quality of the innovation idea was tested in MATLAB[8], demonstrating its correctness.

- *Code walkthroughs* represent the moment when a group of researchers is guided by the programmer through each procedure in the code, explaining what the examined procedure should do (North & Macal, 2007). Activity carefully executed by the entire research team during the development of the deliverable D3.3.
- *Debugging walkthroughs* represents the process through which the programmer executes various runs of the simulation and controls that the simulation's results are similar to the expected results.
- *Formal testing* uses logical constructs to prove that the code works correctly (North & Macal, 2007). However the agent based models are too much complex in order to be able to use such methodology (Rand & Rust, 2011).

Test Cases verify that the model works according to the expectations. There are four kinds of test cases: *corner cases, sampled cases, specific scenarios, and relative value testing.*

Test cases are borderline between Verification and Validation. This because the Verification tries to establish a correspondence between the conceptual model and that one implemented, but the conceptual model is based on the real world. Therefore, we could say that in some way, we are already testing the correspondence between the real world and the implemented model, but at a less "stringent" level of rigor. In the next, we report a brief description of four types of Test cases described by Rand (2011):

- *Corner cases* are extreme values of the inputs (Gilbert, 2008). With the corner cases, we made sure that the model did not have absurd and impossible outputs. For example, when testing a model that simulates networks or IVCs' behaviour, it is expected that no networks or IVCs are formed without agents. If not, there would be an error. This type of Verification does not need to use empirical data, since the results are extremely simple to predict. This process was run throughout the code's development, on each procedure - somehow intertwined with the *unit testing* - and finally was run on the complete code.
- *Sampled cases* consist in identifying a subset of input values, which can be sliders or global variables declared in the code, chosen in various ways: randomly, with the design of experiments methods or other methods using exploration software (Miller, 1998). In this case, there are not wished output that are known a priori. However, it is logical to expect the ranges of the outputs. Therefore, if the simulation results do not fall in such ranges, it is probable that there is an error.
- *Specific scenarios* are used when exact outputs are known for particular input values (Gilbert, 2008). This specific methodology will be better utilized and analysed in the next steps of the project I AM RRI.
- *Relative value testing* is applied when we know the relationship between an input and an output. We do not know exactly the type of link between input and output (e.g., linear or nonlinear), but we can easily guess the behaviour of the output: increasing the parameter x, we will have a decrease of the output y (Rand & Rust, 2011).

Test cases, Verification Step 3 (see

[8]MATLAB combines a desktop environment optimized for iterative analysis and design processes with a programming language that expresses mathematical operations with matrices and arrays in a straightforward manner.

Table 1), will be extensively discussed in the next paragraph since it is closely related to *Sensitivity Analysis*: we will try to explain how much sensible a result is to changes in a model parameter.

The steps to follow to assure rigor to a model are synthetized in **Errore. L'origine riferimento non è stata trovata.**.

Table 1: Steps to ensure rigor in the Verification process.

1	**Documentation**	Conceptual design and the implemented model should be documented.		
2	**Programmatic Testing**	Testing of the code of the model.	*Unit Testing*	Each unit of functional code is separately tested.
			Code Walkthroughs	The code is examined in a group setting.
			Debugging Walkthroughs	Execution of the code is stepped through.
			Formal Testing	Proof of Verification using formal logic.
3	**Test Cases and Scenarios**	Without using data, model functions are examined to see if they operate according to the conceptual model.	*Corner Cases*	Extreme values are examined to make sure the model operates as expected.
			Sampled Cases	A subset of parameter inputs is examined to discover any aberrant behaviour.
			Specific Scenarios	Specific inputs for which the outputs are already known.
			Relative Value Testing	Examining the relationship between inputs and outputs.

3.1.1 Test cases and scenarios

This paragraph will discuss the experiments that have been carried out to demonstrate the requirements demanded from the third step of the Verification, *Test cases and Scenarios*. We will mainly discuss *Relative Value Testing* since it demands a deeper analysis and requires the use of various statistical tools like SPSS (Statistical Package for the Social Sciences, software for statistical analysis of data) or Excel (spreadsheet for data visualization and analysis).

As suggested by Hintze (2015), to start the simulations for the model's Verification, it is necessary to identify the:

- independent variables;
- dependent variables;
- control variables.

Based on an endogenous or exogenous character concerning the individual agent, the independent variables (or inputs) in the I AM RRI SKIN model were divided into: Numbers of agents, Environmental variables, and Firm's variables (see Table 2). A brief description of the variables is given in Table 4 of the deliverable D3.3 (Section 4).

Numbers of agents would be an environmental variable; however, we preferred to treat it separately since I AM RRI SKIN works with five types of agents.

These variables do not depend on the value assumed from another variable and remain unchanged during the simulation. In truth, beyond the variable brought back in the Table below, we would have to mention other independent variables, but they are not settable easy from the user at the beginning of the simulation, since they are declared only inside of the code and not in the interface. This choice is justified since the AB model I AM RRI SKIN aims to be a tool usable easily from diverse figures of researchers, scientists, and policy makers with no coding competencies. Therefore, the experiments that we will examine concern the effects of visible and settable inputs in the interface, on which the less experienced user can easily "play around."

Table 2: Independent variables.

Numbers of Agents [range]		Environmental Variables [range]		Firm's Variables [range]	
AM-tech	[0 300]	Regulator	[0 1]	RRI-attractiveness	[0 1]
nSupplier	[0 300]	Standard Org.	[0 10]	attractiveness-threshold	[0 1]
nResearch-inst.	[0 300]	Funding	[0 200]	RRI-start-up-trigger	[0 1]
nCustomer nOEM	[0 300]	Funding-RRI	[0 1]	*Publish-open-access*	
		Funding-quality	[0 10]	economic-threshold	[0 100]
		RRI-cost	[0 100]	RRI-open-access-thres	[0 1]
		big-firms-percent	[0 100]		

The dependent variables have been divided to evaluate the agents' performance in three different impact areas: Societal, Economic, and Strategic.

Table 3: Dependent variables, outputs.

Societal	Strategic	Economic
Average RRI value of Networks	Mean Network size	Average capital of Networks
Num. open-access publications	Agents in Networks	
	% Agent in Networks	
	Mean Partnership	
	Net-phase-1	
	% Net. Survived-1	
	% Net. Survived-2	
	Number of Start-ups	

Finally, the control variables are independent variables not settable in the interface by the user or that remain fixed because their variation is not of interest in the context of the formulated research questions; thus, they will change according to the experiment taken into consideration.

Corner Cases

Corner Cases, as mentioned before, are experiments in which the independent variables (or inputs) are set to their extreme values. In this way the output of the simulation is easy predictable, and it is possible to ascertain that the model behaves in the wished way.

This method allows checking the presence or absence of bags once the code is assembled; however, it is not always easy to find the error's location. In fact, NetLogo allows the code to be written in a modular fashion, adding one procedure at a time, but once the interconnections between blocks are established, it becomes complicated to explain the causes of aberrant outputs.

Several Corner Cases experiments have been conducted; however, only a few that have shown bugs will be described. Given the structure of the model, one of the first things that come to mind is to check the `GATE-NEXT-PHASE-1` e `GATE-NEXT-PHASE-2` procedures' efficiency. As reported in the deliverable D3.3, these procedures act as a filter between one phase and another, allowing the passage to the next phase only to networks with specific requirements of RRI values and quality of innovation. What happens if the selection constraints are made more stringent?

To answer this question, the Numbers of Agents and Firm' s variables were set as control variables as shown in the Table 4, and the selected outputs were:

- `%survived-1`
- `%survived-2`

The selected outputs, all related to the strategic performance, express respectively: the networks that have faced the Idea Generation phase, the networks that successfully pass the first phase, reach the Product Development phase, and finally, the networks that successfully pass the second phase.

Table 4: Control variables.

Numbers of Agents [value]		Firm's Variable [value]	
nAM-tech	[200]	RRI-attractiveness	[0.5]
nCustomer	[200]	attractiveness-threshold[9]	[1]
		RRI-start-up-trigger	[0.5]
nSupplier	[200]	*Publish-open-access*	
nResearch-inst.	[200]	economic-threshold	[50]
nOEM	[200]	RRI-open-access-thres.	[0.5]

Obviously, the independent variables concern the agents that intervene in `GATE-NEXT-PHASE-1` and `GATE-NEXT-PHASE-2` and act as regulatory bodies, that are the Regulators and the Standard Organisations respectively evaluating the RRI values of the Networks and the quality of the idea of innovation carried out. In the `GATE-NEXT-PHASE-1`, there are also Funding Organisations, but their selective character is expressed in a rewarding way and not stopping the path of the Networks. From the result's predictive point of view and the point of view of the results' analysis, the Corner Cases are relatively simple; therefore, each combination was performed for a relatively low number of simulation's runs.

Table 5 shows the combination of extreme values used for the Regulator and Standard Organization and their output values.

[9] The attractiveness threshold has been set with the value 1 in such a way to create less network and to increase the speed of the simulations, while the others have been set to their average value.

Table 5: Cross cases.

As shown in Table 5, in configuration A, by not requiring any type of ethical or qualitative requirements, 100% of the networks succeed in passing the first and second phases, while for configuration B no network is admitted to the second phase if the RRI ethical values required by the Regulator are maximum. Moreover, we can infer that by initializing the agents' RRI values with random floating-point number between 0 and 1 (using the NetLogo primitive random-float 1) and using the step function described in the deliverable D3.3 (Section 4.2.1) to simulate the adaptation to the common ethical values, no network is characterized by maximum ethical values in the first phase of the innovation process. Obviously, if no network is admitted to the second phase, there can be no network that passes the Product Development phase.

Instead, the configuration C offers us an alternative verification to the unit case for the correctness of the equation that defines the quality of the idea of innovation.

		Standard Organization (ISO)	
		0	10
Regulator	0	%survived-1 [100] %survived-2 [100] **A**	%survived-1 [100] %survived-2 [0] **C**
	1	%survived-1 [0] %survived-2 [0] **B**	%survived-1 [0] %survived-2 [0] **D**

$$Quality = \left(\sum_{i \in IH} A_i \left(1 - e^{E_i}\right) \right) mod\ 10$$

According to this equation, no network can develop a quality value of 10 but a maximum value of 9.99, thus no network successfully completes the Product Development phase.

It should be noted that this type of analysis allows to observe Boolean results (100% of Networks or 0% of Networks) being conceived only as a *debugging* methodology, so it is totally useless any type of multivariate analysis.

Relative Value Testing

Relative value testing represents a method of testing the relationship between an independent variable (input) and a dependent variable (output). Therefore, Relative Value Testing could help to observe the model's behaviour as a whole following the change in the direction of an input (Rand & Rust, 2011). It allows to answer questions such as "Does output X increase if the value of input Y increases?"

Applying this methodology has three orders of consequences:

- Effective debugging.
- Possibility to observe emergent behaviours.
- Avoid misunderstandings.

Given its characteristics, *Relative Value Testing* is positioned on the borderline between Verification and Validation. In general, the Verification aims to verify the correspondence between the conceptual and implemented models, but the conceptual model is a description of the real world.

We report three experiments that were conducted to complete the third and final step of Verification.

EXPERIMENT 1

The first experiment aims, in addition to the debugging activity, to understand how much the attractiveness-threshold influences the choice of partners and, therefore, the construction of networks. Moreover, this experiment helps us to precisely identify the intervals of the attractiveness threshold's (how attractive a firm must be before it becomes a partner; the mechanism of partners' selection and related variables are explained in the deliverable D3.3, Section 4.2.1) value that facilitate or hinder the formation of networks. This information will allow us to choose, with good approximation, the number of networks that we want inside the simulation and, therefore, "to create" more or fewer networks according to our needs of analysis. Therefore, we ask, "by increasing the requirements to be chosen as partner, how much does the number of Networks created decrease?"

Obviously, the threshold of attractiveness in the choice of partners has been selected as an independent variable. At the same time, the behaviour of the model will be analysed by observing the number of Networks created, while all other independent variables are to be considered control and set as reported in the

Table 6.

Table 6: Control variables Experiment 1.

Numbers of Agents [value]		Firm's Variable [value]		Environmental Variable [value]	
nAM-tech	[200]	RRI-attractiveness[10]	[0.5]	Regulator	[0.5]
nCustomer	[200]	RRI-start-up-trigger	[0.5]	Funding	[50]
nSupplier	[200]			Funding-RRI	[0.5]
nResearch-inst.	[200]	*Publish-open-access*		Funding-quality	[5]
nOEM	[200]	economic-threshold	[50]	RRI-cost	[30]
		RRI-open-access-thres.	[0.5]	big-firm-percent	[10]
				Standard Organization	[5]

The threshold of the attractiveness of a potential partner varies in the range [0 1], where the value 1 indicates the most stringent requirements to be chosen as a partner (requirements that are based on RRI ethical values and knowledge base of the potential partner). This interval was divided into five sub-intervals: [0 0.2], [0.3 0.4], [0.5 0.6], [0.7 0.8], [0.9 1]. Therefore, we will examine the model's behaviour

[10] By setting the RRI-attractiveness = 0.5, equal importance is placed on the potential partner's RRI ethical values and knowledge.

by setting the independent variable at the upper limit of these ranges and then test for the presence or absence of significant statistical differences in the output values.

The combination for the above experiment is shown in Table 7.

Table 7: Experiment 1.

Control Variables	Run	ticks	input	output
See Table 6	300	30	Attractiveness-threshold [0,2 0,4 0,6 0,8 1]	net-phase-1

The number of ticks (30 ticks) appears to be relatively low, but in I AM RRI SKIN, the most efficient Networks conclude their innovation path in 15 ticks. A duration of the simulation of 30 ticks, the double of the minimal time to conclude the development of the innovation, seems to us to be sufficient so that the various mechanisms of spreading can be realized. Therefore, also the duration of the other simulations will be fixed to 30 ticks.

EXPERIMENT 1 RESULTS

The results of the different runs have been summarised in Table 8. For each attractiveness threshold, descriptive statistics on the number of networks created are given. The values in the Table refer to the outcome of the simulation at the 30-th tick.

Table 8: Descriptive Statistics Experiment 1.

Descriptive Statistics								
RRI-attractive-ness	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0.2	300	106,55	17,440	1,007	104,57	108,53	45	153
0.4	300	105,76	17,554	1,014	103,77	107,75	49	148
0.6	300	99,19	18,486	1,067	97,09	101,29	13	152
0.8	300	86,35	16,820	,971	84,44	88,26	24	127
1.0	300	45,18	15,721	,908	43,39	46,97	10	103
Total	1500	88,61	28,639	,739	87,15	90,06	10	153

Experiment 1 was formulated in such a way as to obtain information on the effects of the attractive-ness threshold on the number of networks created. The variable attractiveness-threshold, considered as a factor of interest, was set at five different levels: 0.2, 0.4, 0.6, 0.8, 1; 300 simulation runs were carried out for each of these levels.

To investigate the significance of the attractiveness factor, various statistical tests were carried out such as ANOVA and Post-hoc tests.

From the table shown (Table 9), it can be seen that statistic F (Fisher) is associated with a level of significance (Sign.) that is clearly lower than the probability $\alpha = 0.05$, which defines the risk of first kind (probability of rejecting the null hypothesis when it is true). Therefore, we can conclude that there is sufficient experimental evidence to consider the attractiveness-threshold factor to be significant for the number of networks created.

Table 9: ANOVA Experiment 1.

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	.192	2	.096	106.027	0.000*
Within Groups	.812	897	.001		
Total	1.004	899			

After the ANOVA test, further Post-hoc tests were carried out, such as Fisher's *Least Significant Difference* (LSD). Also here, for reasons of synthesis, we will not report a theoretical discussion of this methodology.

We note from the following table (Table 10), we cannot consider the difference between the values $\bar{x}_i$ e $\bar{x}_j$ as significant by choosing as a level of significance $1 - \alpha = 0.95$. Therefore, we can conclude that the samples extracted by imposing a factor level equal to 0.2 or 0.4, come, accepting the risk of first kind, from the same distribution. Therefore, we can identify a first range [0.2 - 0.4], which we could define as low, within the interval [0 1].

Table 10: LSD Experiment 1.

	(I) RRI attractiveness	(J) RRI attractiveness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	0.2	,4	,787	1,407	,576	-1,97	3,55
		,6	7,353*	1,407	,000	4,59	10,11
		,8	20,200*	1,407	,000	17,44	22,96
		1,0	61,367*	1,407	,000	58,61	64,13
	,4	,2	-,787	1,407	,576	-3,55	1,97
		,6	6,567*	1,407	,000	3,81	9,33
		,8	19,413*	1,407	,000	16,65	22,17
		1,0	60,580*	1,407	,000	57,82	63,34
	,6	,2	-7,353*	1,407	,000	-10,11	-4,59
		,4	-6,567*	1,407	,000	-9,33	-3,81
		,8	12,847*	1,407	,000	10,09	15,61
		1,0	54,013*	1,407	,000	51,25	56,77
	,8	,2	-20,200*	1,407	,000	-22,96	-17,44
		,4	-19,413*	1,407	,000	-22,17	-16,65
		,6	-12,847*	1,407	,000	-15,61	-10,09
		1,0	41,167*	1,407	,000	38,41	43,93
	1,0	,2	-61,367*	1,407	,000	-64,13	-58,61
		,4	-60,580*	1,407	,000	-63,34	-57,82
		,6	-54,013*	1,407	,000	-56,77	-51,25
		,8	-41,167*	1,407	,000	-43,93	-38,41

By graphically representing the averages reported in the third column of the Table 8, we obtain the diagram in Figure 2. From the diagram, we can see that the threshold of attractiveness that allows creating a minimum number of networks is precisely the value 1 as we expected.

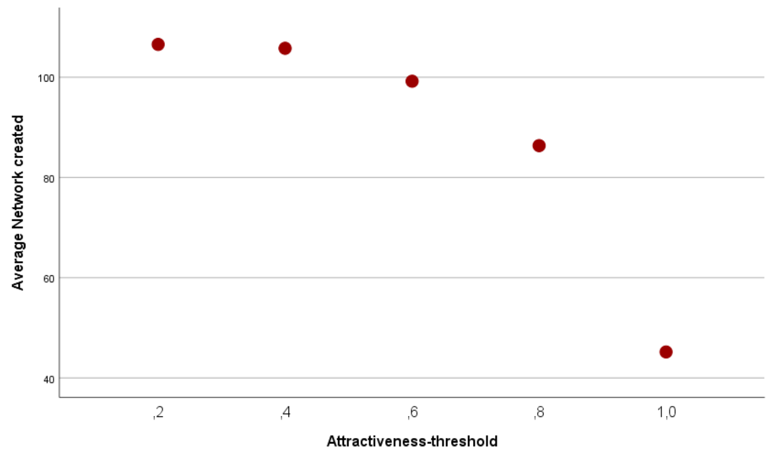

Figure 2: Plot Averages Experiment 1.

EXPERIMENT 2

The second experiment was designed to observe the role of regulatory bodies in spreading RRI ethical values. So, the goal is to assess the societal effect of the Regulators and what might be a better policy to adopt. What happens if the selection of innovation ideas, based on the network's RRI values, becomes more stringent? Will RRI values spread more rapidly? How will this affect agents?

To answer these questions, the threshold of acceptance by regulatory bodies (Regulator) was selected as an input variable. In contrast, the Average RRI value in networks (ethical-thinking, open-access, public-engagement) and the number of agents involved in innovation projects were selected as output variables. All other independent variables are to be considered as controls and are reported in Table 11.

Table 11: Control variables Experiment 2.

Numbers of Agents [value]		Firm's Variable [value]		Environmental Variable [value]	
nAM-tech	[200]	RRI-attractiveness	[0.5]	Standard Organization	[5]
nCustomer	[200]	attractiveness-threshold[11]	[1]	Funding	[50]
nSupplier	[200]	RRI-start-up-trigger	[0.5]	Funding-RRI	[0.5]
nResearch-inst.	[200]			Funding-quality	[5]
nOEM	[200]	*Publish-open-access*		RRI-cost	[30]
		economic-threshold	[50]	big-firm-percent	[10]
		RRI-open-access-thres.	[0.5]		

Finally, the acceptance threshold of the Regulator was set by dividing it into three ranges: *low* [0 0.3], *medium* [0.4 0.7], and *high* [0.8 1]. Therefore, the experiment was performed using three different combinations of variables, one for each Regulator range, as reported in Table 12.

Table 12: Experiment 2.

Control Variables	Run	ticks	input	output

[11] The attractiveness threshold has been set with the value 1 in such a way to create less network and to increase the speed of the simulations, while the others have been set to their average value.

See Table 11	300	30	Regulator [0.3 0.5 0.8]	open-access ethical-thinking public-engagement Agent in Network

EXPERIMENT 2 RESULTS

Unlike the first experiment, to answer the questions raised during the formulation, the output variables were measured for each tick (30 ticks) of the 300 simulation runs. In this way, we wanted to observe the dynamics of the system and analyse a possible mechanism of spreading RRI values due to stricter regulation by the regulators. Given the 300 simulation runs, the graph in Figure 3 shows the average (for each tick, or step) of the networks' average RRI values at the various Regulator levels.

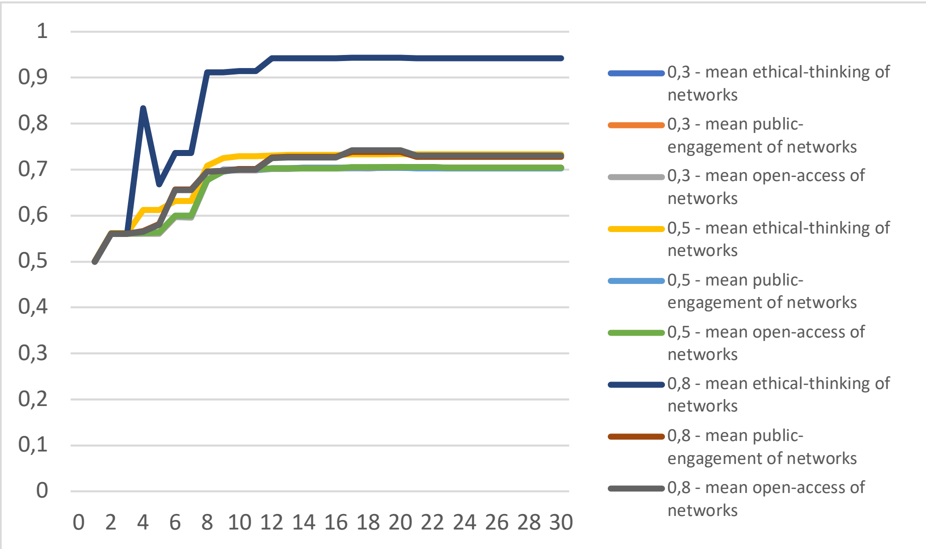

Figure 3: Average RRI-values at each step of the simulation.

The Regulator is a regulatory body that evaluates and stops networks based on their ethical-thinking value. From a visual analysis of Figure 3, in correspondence with the first step (step 4) in which the Regulator's effect manifests itself, we notice an increase in the key RRI ethical-thinking for Regulator values of 0.5 and 0.8 (dark blue and yellow lines). On the other hand, setting the Regulator level to 0.3 did not affect, since the networks already had an average ethical-thinking value between 0.5[12] and 0.6 at the second tick.

First, we need to assess whether the Regulator factor has a significant effect on the networks' ethical thinking at tick 4, as we expect from the conceptual model and the qualitative analysis. For this, we used a *One-way* ANOVA; Table 13 summarises the results.

Table 13: ANOVA Experiment 2.

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	12,374	2	6,187	53102,099	,000
Within Groups	,104	896	,000		

[12] Agents are set with "pseudo-random" RRI values, extracted using a uniform random variable in the range [0 1]. The RRI values of the networks are the average of the RRI values of the members. Values greater than 0.5 are due to the update-RRI procedure.

As we can see, Fisher's F statistic is associated with a *p-value* lower than the risk of first kind $\alpha = 0.05$: we can reject the null hypothesis H_0 of the ineffectiveness of the Regulator factor at tick 4.

As usual, following the significance of the ANOVA, Post-hoc tests were performed. **Errore. L'origine riferimento non è stata trovata.** shows the results of Tukey's HSD *(Honestly Significant Difference*). For each level of the Regulator, the averages of the ethical-thinking values can be considered different by accepting the risk of first kind $\alpha = 0.05$. Thus, at step 4, the Regulator produces significant effects on the networks' average ethical-thinking values.

With satisfaction, we could consider the pure debugging analysis concluded and go a little further, trying to observe the Regulator's consequences on the remaining RRI values.

Table 14: HSD Experiment 2.

	(I) RRI attractive-ness	(J) RRI attractive-ness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,0495417*	,00088131	,000	-,0516107	-,0474727
		,8	-,2700476*	,00088204	,000	-,2721183	-,2679769
	,5	,3	,0495417*	,00088131	,000	,04747278	,05161074
		,8	-,2205058*	,00088204	,000	-,2225765	-,2184351
	,8	,3	,2700476*	,00088207	,000	,26797693	,27211835
		,5	,2205058*	,00088204	,000	,21843517	,22257659

* The mean difference is significant at the 0.05 level.

For this reason, the same type of analysis was conducted for the remaining Key RRIs.

The ANOVA results for step 4 lead us not to reject the null hypothesis of the Regulator factor's ineffectiveness on the remaining RRI keys[13]. There was no procedure that could favour a spreading mechanism of the RRI values (e.g., make-RRI and update-RRI). Therefore, the investigation was also extended to steps 6 and 30.

In step 6, where the effect of the procedures mentioned earlier should be visible, the ANOVA with the dependent variable ethical-thinking leads us to consider the Regulator's effect as significant *(p-value*=0.001); the relevant Post-hoc tests were also successfully. Concerning the open-access and public-engagement keys, the ANOVA was significant, but Tukey's HSD tests lead us to believe that the difference between the mean for Regulator levels of 0.3 and 0.5 was not relevant[14]. However, the two-by-two comparison with a Regulator level of 0.8 (0.3-0.8;0.5-0.8) is significant. Similar conclusions apply for the 30th tick[15].

Ultimately, we could consider Regulator levels 0.3 and 0.5 as belonging to the same range concerning the spreading of RRI open-access and public-engagement values, while they belong to three different ranges concerning the effects on the ethical-thinking of networks.

We note that a Regulator level of 0.8 produces statistically significant effects on the RRI variables open-access and public-engagement, starting from the simulation's sixth step. Thus, stricter regulation on a single Key RRI (ethical-thinking) incentives the increase of the remaining Keys. Would it then be sufficient to increase regulatory bodies' constraints to achieve a spread of RRI practices? Of course not. The Table 15 shows that as regulation increases, the number of innovative networks drops dramatically, reaching values close to zero.

Table 15: Descriptive Statistics related to networks.

Descriptive Statistics

[13] For open-access p-value=0.108. For public-engagement p-value=0.102.

[14] Comparison for Regulator level 0.3-0.5 tick 6: open-access p-value=0.193; public-engagement p-value=0.300.

[15] Comparison for Regulator level 0.3-0.5 tick 30: open-access p-value=0.885; public-engagement p-value=0.974.

RRI-attractive-ness	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	133,07	19,281	1,113	130,88	135,26	67	173
,5	300	106,58	16,220	,936	104,73	108,42	52	154
,8	300	3,14	2,084	,120	2,90	3,38	0	11

This aspect is totally in line with the conceptual model created by the I AM RRI project partners. In fact, in the first workshops with AM industrial partners, the importance of not taking precautions to the detriment of innovations was stressed. As some actors advocate to "give innovators a bit more breathing room" or, "do not rush to regulate", we should keep in mind the possible social cost of under-regulation as well as the possible cost of over-regulation. At this point, the next steps to be taken should concern "*when to regulate"* and *"how to regulate*" (Eggers et al., 2018).

EXPERIMENT 3

The first two experiments allowed us to test agents' performance from a social perspective (average RRI value) and a strategic perspective (number of agents involved in innovation projects and number of networks established). It is necessary to test the model from the point of view of economic performance, so evaluate the networks' average capital, which will be chosen as output. The independent variables, or input, that can influence this output are not few (initial capital of the agents, number of large companies, cost of finding partners, available funding, and others); however, considering the objective of the agent-based I AM RRI SKIN is interesting to study the effect of the cost necessary to support responsible research: RRI-cost.

Efforts to support RRI represent an investment that agents make for the innovative project's benefit, so this investment is tracked in the capital invested in the project. The higher the network's RRI ethical values, the lower the cost to support the RRI, thus simulating a parasitic attitude of the agents. This cost takes over from the less-partner? procedure, by which the network agent may expel members who do not have adequate financial resources to meet the costs of promoting RRI values (explained in the deliverable D3.3, Section 4.2.2). The agents who cannot sustain this cost are expelled from the network, which, in the case of an insufficient number of partners, dissolves.

Increasing the RRI-cost variable should also increase the value of the average capital invested in innovation projects, but what happens to the number of agents participating in such projects? Do they decrease? Should increase investment in RRI be preferred at the expense of increased participation? To answer this question, the control variables were set as shown in the table below.

Table 16: Control variables Experiment 3.

Numbers of Agents [value]		Firm's Variable [value]		Environmental Variable [value]	
nAM-tech	[200]	RRI-attractiveness	[0.5]	Standard Organization	[5]
nCustomer	[200]	attractiveness-threshold	[0.5]	Regulator	[0.5]
nSupplier	[200]	RRI-start-up-trigger[16]	[1]	Funding	[50]
nResearch-inst.	[200]			Funding-RRI	[0.5]
nOEM	[200]	*Publish-open-access*		Funding-quality	[5]
		economic-threshold	[50]	big-firm-percent	[10]
		RRI-open-access-thres.	[0.5]		

[16] RRI-start-up-trigger has been set to the maximum level so that no network can create a start-up and quickly have a complete track of the capital invested in the Networks.

The RRI-cost was divided into three ranges: *low* [0 30], *medium* [40 70], *high* [80 100]. Therefore, the experiment was conducted by setting three different combinations of variables, as shown in the Table below.

Table 17: Experiment 3.

Control Variables	Run	ticks	input	output
See Table 16	300	30	RRI-cost [30 50 80]	Average capital of Network Agents in Networks

EXPERIMENT 3 RESULTS

To answer the questions that emerged during the formulation of the third experiment, as we did for the previous experiments, we made use of some descriptive statistics and *One-way* ANOVA.

The

Table 18 shows some descriptive statistics relative to the Average Capital of Networks for various RRI-cost factors. The values in the table refer to the outcome of the simulation at the 30th tick.

Table 18: Descriptive Statistics Experiment 3.

Descriptive Statistics								
RRI-attractive-ness	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
30	300	195,38	5,861	,338	194,72	196,05	181,90	213,68
50	300	222,14	8,189	,472	221,21	223,07	201,35	247,04
80	300	256,03	13,399	,773	254,51	257,56	216,11	301,58
Total	900	224,52	26,647	,888	222,78	226,26	181,90	301,58

Since the cost of undertaking RRI projects (RRI-cost) is to be considered an investment in the common innovation project, we expect that an increase in the RRI-cost leads to an increase in the average capital invested. The graphs in Figure 4 and Figure 5 confirm our expectations.

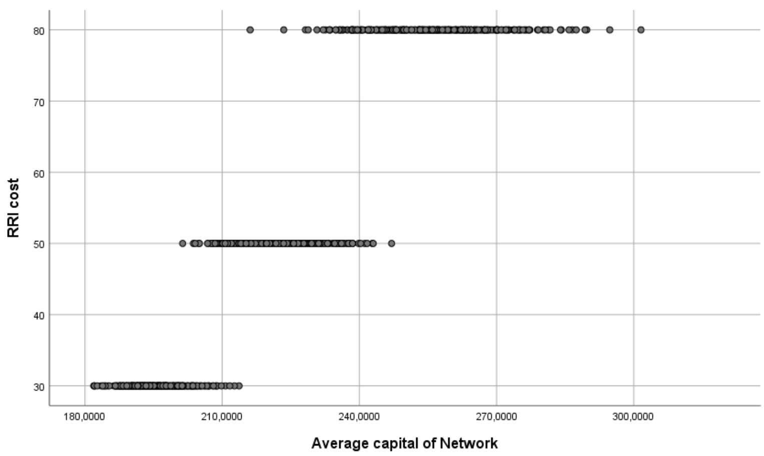

Figure 4: Scatter Plot Experiment 3.

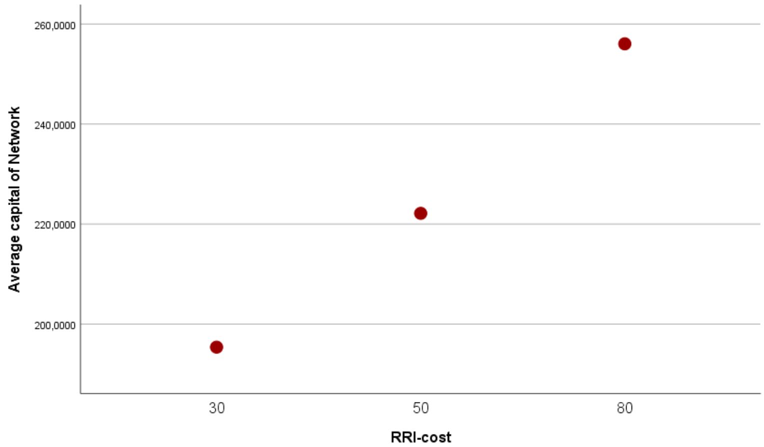

Figure 5: Plot averages Experiment 3.

Furthermore, the effectiveness of the RRI-cost factor on the average capital invested in innovative networks was tested using a *One-way* ANOVA, the results of which are shown in Table 19.

Table 19: ANOVA Experiment 3.

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	554338,243	2	277169,122	2959,325	,000
Within Groups	84012,643	897	93,660		
Total	638350,886	899			

As can be seen from the Table 19, keeping valid the assumptions made for the interpretative model of the data, the null hypothesis H_0 of the RRI-cost factor's ineffectiveness is associated with a lower level of significance of the risk of first kind: we can reject H_0.

As for the previous experiments, after the significance of the factor investigated, Post-hoc tests such as Fisher's *Least Significant Difference* (LSD) and Tukey's HSD (*Honestly Significant Difference*) were performed. From the Table 20, we note that the multiple comparisons between means, performed two by two, give us experimental evidence that the difference between means is significant, accepting a risk of first kind $\alpha = 0.05$. We can conclude that all three levels of RRI-cost produce statistically different effects on invested capital. Therefore, the first subdivision into three ranges (*low, medium, high*) is acceptable.

Table 20: HSD & LSD Experiment 3.

	(I) RRI attractiveness	**(J) RRI attractive-ness**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	Upper Bound
LSD	30	50	-26,75*	,790	,000	-28,307	-25,2056
		80	-60,65*	,790	,000	-62,202	-59,1006
	50	30	26,75*	,790	,000	24,901	28,6115
		80	-33,83*	,790	,000	-35,750	-32,0399
	80	30	60,60*	,790	,000	58,796	62,5065
		50	33,89*	,790	,000	32,039	35,7500
HSD	30	50	-26,75*	,790	,000	-28,611	-24,9014
		80	-60,65*	,790	,000	-62,506	-58,7964
	50	30	26,75*	,790	,000	24,901	28,6115
		80	-33,83*	,790	,000	-35,750	-32,0399
	80	30	60,60*	,790	,000	58,796	62,5065

50	33,89*	,790	,000	32,039	35,7500

Besides, we asked whether the change in the cost of upholding RRI values has any significant effect on the number of agents undertaking innovative projects. The results of the simulation runs are reported in Table 21 and refer to the 30-th tick. As shown from the Table 21, the average number of agents involved in a network varies at the three levels of RRI-cost. An increase in the independent variable RRI-cost corresponds to a decrease in the number of agents involved in networks. Also, Figure 7 indicate that an increase in the independent variable RRI-cost corresponds to a decrease in the number of agents involved in the networks.

Table 21: Descriptive Statistics Experiment 3.

Descriptive Statistics								
RRI-attractive-ness	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
30	300	546,62	71,003	4,099	538,55	554,69	246	682
50	300	360,07	57,951	3,346	353,48	366,65	170	498
80	300	168,97	52,857	3,052	162,97	174,98	39	329
Total	900	358,55	165,891	5,530	347,70	369,41	39	682

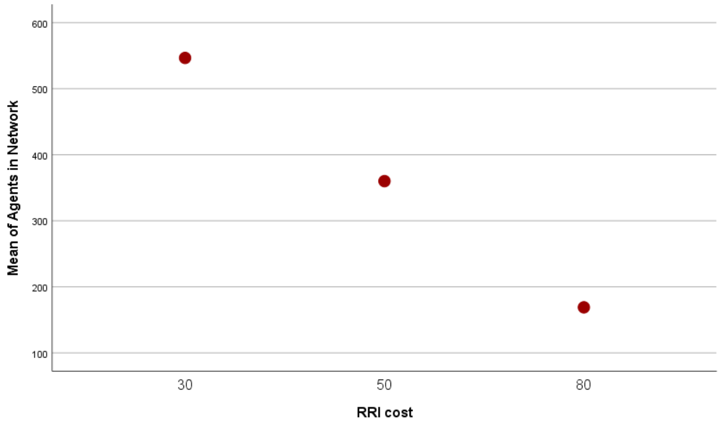

Figure 7: Plot averages Experiment 3.

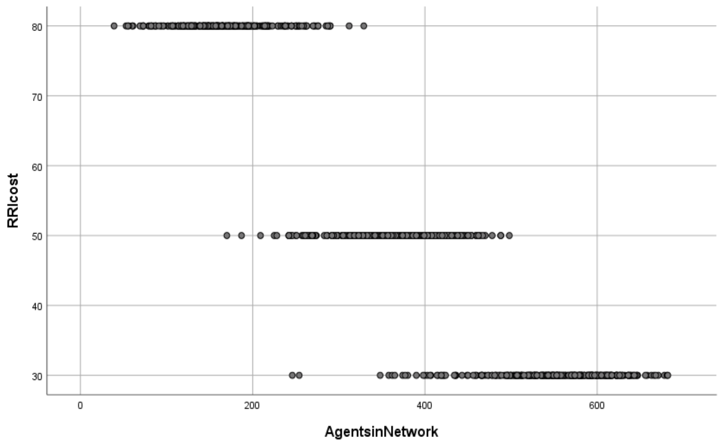

Figure 6: Scatter Plot Experiment 3.

Furthermore, the effectiveness of the RRI-cost factor on the number of agents involved in innovative networks was tested by means of a one-way ANOVA, the results of which are shown in Table 22.

Table 22: ANOVA Experiment 3.

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	21393581,30	2	10696790,65	2866,856	,000
Within Groups	3346879,133	897	3731,192		
Total	24740460,40	899			

The results show that the independent, or input variable, RRI-cost, affects the number of agents taking part in a network. Thus, accepting a risk of first kind $\alpha = 0.05$, we can reject H_0 of the RRI-cost factor's ineffectiveness.

The usual Post-hoc tests (Tukey and Fisher's LSD, reported in Table 23) conducted downstream of the ANOVA showed that their difference is significant, taking two by two averages. Also, in this case, considering the effect on the number of agents involved in the networks, the RRI-cost variable subdivision (*low, medium. high*) is acceptable.

Table 23: HSD & LSD Experiment 3.

	(I) RRI attractiveness	(J) RRI attractiveness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	30	50	186,553*	4,987	,000	176,76	196,34
		80	377,647*	4,987	,000	367,86	387,44
	50	30	-186,553*	4,987	,000	-196,34	-176,76
		80	191,093*	4,987	,000	181,30	200,88
	80	30	-377,647*	4,987	,000	-387,44	-367,86
		50	-191,093*	4,987	,000	-200,88	-181,30
HSD	30	50	186,553*	4,987	,000	174,84	198,26
		80	377,647*	4,987	,000	365,94	389,36
	50	30	-186,553*	4,987	,000	-198,26	-174,84
		80	191,093*	4,987	,000	179,38	202,80
	80	30	-377,647*	4,987	,000	-389,36	-365,94
		50	-191,093*	4,987	,000	-202,80	-179,38

*. The mean difference is significant at the 0.05 level.

The graph in Figure 8 summarises the above: an increase in the cost of supporting RRI corresponds to an increase in the capital invested in innovative projects, but a reduction in the agents involved.

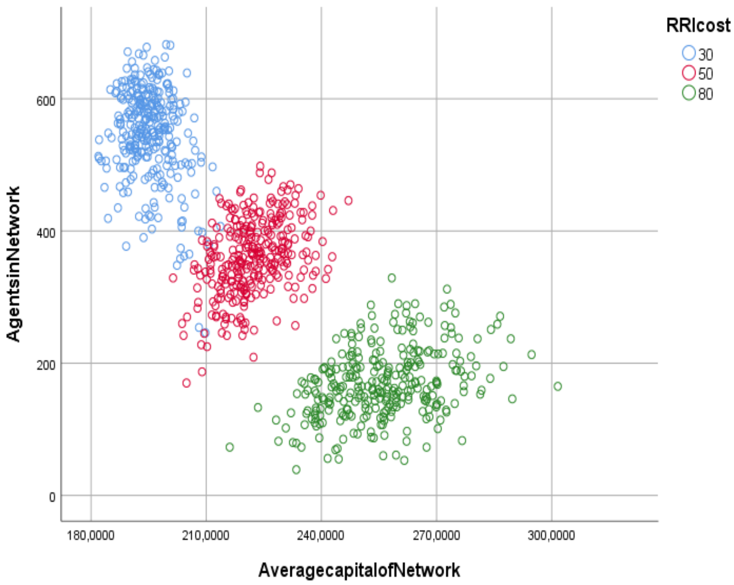

Figure 8: Scatter Plot Networks: Capital vs. # Agents.

In conclusion, after having exposed the principal methods of Verification, we have reported three experiments that apply the Relative Value Testing. This methodology allows us to investigate the relationship between an input variable and an output variable. The first experiment aims to verify the influence of the attractiveness threshold in the selection of partners on the number of created networks. Briefly, the results show that as the attractiveness threshold increases, the number of networks created decreases. The second experiment focuses on the role of regulators on the diffusion of RRI values. In short, at more stringent constraints on the RRI ethical-thinking key, the remaining keys spread faster while the number of networks decreases significantly. Finally, the third experiment explores the effect of a higher cost of supporting ethical values on the average capital of networks and the number of agents involved in networks.

It must be noted that the objective of these experiments is mainly to ensure rigor to the model and identify any bugs.

These experiments, finally, permitted to verify the adherence of the implemented first version of the model to the conceptual model developed in the deliverables D2.4 and D3.1.

Furthermore, through experimentation, it was possible to identify routes for refinements and fine tuning of the model, that will be described in the next section of this document and that derive also from the development of empirical WPs of the I AM RRI project.

4. Refinement of the I AM RRI SKIN model and presentation of the related simulation experiments

This section is devoted to describing some refinements introduced into the I AM RRI SKIN first version of the model, in order to take into account the developments of the project (as reported in deliverables D4.2 and D4.3) and also the richness of the conceptual model (as described firstly in D2.4 and then in D3.1). More than one refinement has been made to the model:

1) the knowledge base of the agents in the model was updated

2) a new key was added for the aspect of responsible research and innovation, which works as a proxy for ethical thinking

3) a new breed was studied and added for the characterisation of a new agent in the model.

4) a small change was made in the open-access key.

The new refined version of the model is available at https://github.com/GradoZeroTeam/IAMRRI, where it's possible find both versions of the model, the old one and the last one.

4.1 Kenes

According with conclusions coming from previous deliverables (D4.2 and D4.3), the first refinement required in I AM RRI SKIN concerns the characterization of knowledge bases of agents in the model. In fact, from use-cases discussed in the deliverables D4.2 and D4.3 it has emerged a richer identification of Capabilities and Abilities of agents involved in innovation value chains under analysis. This has allowed the enrichment of characterization of agents in the model.

In the following paragraph we will illustrate and explain kenes for each breed (class or family) of agents.

4.1.1 AM-techs

Starting from Table 5 on D3.2, the new Capabilities identified by deliverable D4.2 (Table 5) and deliverable D4.3 (Table 13) have been integrated or modified.

Table 24: AM-techs kenes development.

D3.2		D4.2 and D4.3		NOW	
Capabilities	Abilities	Capabilities	Abilities	Capabilities	Abilities
AM-technology (Including materials)	Ceramics	AM machine hardware development & design	Mechanic structure and movement	AM material knowledge & development & production	Ceramics
	Polymers		Integrate all R&D activities		Polymers
	Extrusion polymers		Guidelines for machine buying customers		Extrusion polymers
	R&D		Optics/lighting		R&D
	AM manufacturing	AM knowledge & development	Ceramics		Resin systems
	AM machine operating		Polymers		Binder materials
	AM materials		Metals		AM materials
	AM metals		Resin systems		AM materials
Software	AM design		Binder materials		AM material manufacturing
Hardware-machine	Ceramics printer	AM material production	AM material manufacturing	Software for AM	Software for AM manufacturability design

Business	Marketing	AM machine software development	Firmware (runs machine)		Software for AM design (cooperative with surgeons)*
	Customer research		Data/ job preparation software	AM machine software development	Firmware (runs machine)
	Customer knowledge		Job tracking/document software (especially for medical)		Data/job preparation software
	Supply chain connections	AM design software Development	Software for AM manufacturability design		Job tracking/document software
	Market knowledge		Software for AM design	AM machine hardware development & design	Mechanic structure and movement
		Sourcing	Sourcing AM material		Guidelines for machine buying customers
			Sourcing AM software		Optics/lighting
			Sourcing AM components		Integrate all R&D activities
		Cooperation	Product application Development	Ownership & operating hardware-machine	Ceramics printer
			Technological Development		Polymers printer
			Scientific Development		Metals printer
			Networks&networking skills		Resin systems printer
			Applying for funding	Sourcing	Sourcing AM material
		AM production (manufacturing Perspective)	AM machine+ceramics		Sourcing AM software
			AM machine+polymers		Sourcing AM components
			AM machine+metals	Cooperation	Product application development
			AM machine+resin systems		Technological development
			Ceramics		Scientific development
			Polymers		Networks&networking skills
		AM production (design perspective)	Design for AM manufacturability		Applying for funding
			Product design		Medical product development*
			Design for AM	Design for AM	Design for AM manufacturability
		Business development and sales	Selling		Product design
			Marketing		Design for AM
			Cooperation with potential customers		AM biomedical design*
			Customer research	Biomedical knowledge*	Knowledge and network for AM medical certifications
			Customer knowledge		Skills to go through the existing patent and scientific publications

	Supply chain connection Market knowledge	Clinical engineers Make manufacturing process traceable Knowledge about medical tenders Biomedical materials

* refers to medical manufacturer's Abilities and Capabilities

Starting from the deliverables D4.2 and D4.3 we're explaining how we built new kenes-set.

1) AM machine hardware development & design Capability have been added as new ones, and we mean skills in building an AM hardware-machine.
2) AM material knowledge & development and AM material production have been joined and integrated with the old Capability called "AM technology (including material)". This choice was made because these Capabilities have same Abilities of the old one. The new Capability name is "AM material knowledge & development & production" and we mean skills in doing research, having knowledge about materials and to manufacture them.
3) AM machine software development Capability has been added as new one, and we mean skills in coding software for running machine.
4) AM design software development Capability have been joined and integrated with the old Capability called "Software". This choice was made because they have the same meaning. The new Capability name is "Software for AM" and we mean skills to knowing how to use software design for AM.
5) Sourcing Capability has been added as new one, and we mean skills in sourcing material, software and so on.
6) Cooperation Capability has been added as new one, and we mean skills to collaborate with other entities.
7) AM production (manufacturing perspective) Capability has been divided and integrated in two Capabilities. Materials' Abilities have been added to "AM material knowledge & development & production", instead hardware-machine's Abilities have been related to the old Capability called "Hardware-machine". The new one name is "Ownership & operating Hardware- machine" and include skills to knowing how to use AM hardware-machine and own it.
8) AM production (design perspective) Capability has been added as new one, and it's called "Design for AM". We mean design skills.
9) Business development and sales have been integrated in the old Capability called "business". This choice was made because they have same Abilities.

In addition, we added other Abilities and one Capability (Biomedical knowledge) from Table 4 on deliverable D4.3 in biomedical sector in accordance with medical device manufacturer's kenes comments. In this regard it should be pointed out that medical device manufacturer's kenes have been merged with OEMs kenes, this choice was made after studying uses-cases from which the first kenes' table was derived. In fact, medical device manufacturer was linked to OEMs agents more times, this choice let us to complete kenes' of OEMs agents for both sectors.

The second step was allocating Capabilities into Biomedical (1), Automotive (2) or Broker (0) sector, the last one has Capabilities of both Biomedical and Automotive sector. For each Capability we will explain the difference between Biomedical and Automotive sector.

- "AM material knowledge & development & production" is the same for both Biomedical and Automotive agents, both doing research in order to develop and manufacture materials.

- "Software for AM" is characterized by one Ability called "AM design" that we can find in both areas. In addition, in Biomedical sector, we will find" Software for AM design" (cooperation with surgeons) and in Automotive sector we will find "Software for AM manufacturability". Considering this specificity, in this case we made explicit this difference with respect the industry.
- "Ownership & operating Hardware-Machine" has same Abilities for both sectors.
- "Business" Capability is the same for the two industries, apart Ability called "Patenting" which is present only in Biomedical sector. Even if this latter one is not a specific addition to Am-techs Kenes, as reported in Table 14 on deliverable D4.3, it has been decided to add it seeing as how Am-techs firms generate extra profit from licensing in case of good innovation.
- "AM machine software development" is the same in both industries, but in Biomedical one we can find one extra Ability called "Job tracking/document software", this last Ability is considered only in Biomedical industry (only for agents belonging specifically to this industry).
- Capabilities called "AM machine hardware development & design" and "Sourcing" are characterized by the same Abilities in both industries.
- "Cooperation" is associated with the same Abilities in Automotive and Biomedical industries, but in the last one we can find an extra Ability called "medical product development".
- "Design for AM" is characterized by "product design" and "design for AM" Abilities in both industries, then in Automotive there's "design for AM manufacturability "and in Biomedical there's "AM biomedical design".

The following table reports the new characterization of AM technology firms after the refinement of the Kenes, specifically it reports how Capabilities and Abilities are allocated between the two sectors.

Table 25: AM-techs kenes allocated between Automotive and Biomedical sectors.

BREED	SHAPE	INDUSTRY	INITIAL-CAPITAL	START-PROJECT	CAPABILITIES (1)	ABILITIES (1)	CAPABILITIES (2)	ABILITIES (2)
AM-techs AM-tech		1 Biomedical applications Industry. 2 Automotive Industry. 0 Broker Agent *This value will be unchanged during the simulation and it is randomly assigned in the initialization phase.	100 if small firms 1000 if big firms *depending on the big-firm-percent and number of agents (nAM-tech)	False True *randomly assigned	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) Extrusion Polymers (3) R&D (4) Resin systems (5) Binder materials(6) AM Materials (7) AM metals (8) AM material manufacturing (36)	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) Extrusion Polymers (3) R&D (4) Resin systems (5) Binder materials(6) AM Materials (7) AM metals (8) AM material manufacturing (36)
					Software for AM (2)	AM design (9) Software for AM design (cooperative with surgeons) (57)	Software for AM (2)	AM design (9) Software for AM manufacturability design (37)
					Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Resin systems printer (52)	Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Resin systems printer (52)
					Business (4)	Marketing (11) Customer research (12)	Business (4)	Marketing (11) Customer research (12) Customer Knowledge (13)

			Customer Knowledge (13) Supply chain connections (14) Market knowledge (15) Selling (19) Cooperation with potential customers (56) Patenting (61)		Supply chain connections (14) Market knowledge (15) Selling (19) Cooperation with potential customers (56)
		AM machine software development (7)	Firmware (runs the machine) (38) Data/job preparation software (39) Job tracking/document software (especially for medical, high quality parts) (40)	AM machine software development (7)	Firmware (runs the machine) (38) Data/job preparation software (39)
		AM machine hardware development & design (10)	Mechanic structure and movement (33) Guidelines for machine buying customers (34) Optics/lighting (35) Integrate all R&D activities (41)	AM machine hardware development & design (10)	Mechanic structure and movement (33) Guidelines for machine buying customers (34) Optics/lighting (35) Integrate all R&D activities (41)
		Sourcing (11)	Sourcing AM material (42) Sourcing AM software (43) Sourcing AM components (44)	Sourcing (11)	Sourcing AM material (42) Sourcing am software (43) Sourcing AM components (44)
		Cooperation (12)	Product application development (45) Technological development (46) Scientific development (47) Networks & networking skills (48) Applying for funding (49) Medical product development (60)	Cooperation (12)	Product application development (45) Technological development (46) Scientific development (47) Networks & networking skills (48) Applying for funding (49)
		Design for AM (13)	Product design (54) Design for AM (66) AM biomedical design (62)	Design for AM (13)	Product design (54) Design for AM (66) Design for AM manufacturability (58)
		Biomedical knowledge (16)	Knowledge and network for AM medical certifications (53) Skills to go trough the existing patents and scientific publications (63)		

		Clinical engineers (55) Make manufacturing process traceable (64) Knowledge about medical tenders (65) Biomedical materials (29)	

4.1.2 Suppliers

Beginning from Table 6 on deliverable D3.2, Suppliers kenes have been modified and added with Capabilities and Abilities of Table 7 on deliverable D4.2.

Table 26: Suppliers kenes development.

D3.2		D4.2 and D4.3		NOW	
Capabilities	Abilities	Capabilities	Abilities	Capabilities	Abilities
Material	Ceramics	Material	Cermics	AM material knowledge & development & production	Ceramics
	Polymers		Polymers		Polymers
	AM materials		AM materials		AM materials
	AM metals		AM metals		AM metals
	Resin systems		Resin systems		Resin systems
	Binder materials		Binder materials		Binder materials
Software	AM design				
	AM software integration	Software	Firmware	Software Coding	AM design AM software integration
			Data/job preparation software		
			Job tracking/document software		Software for AM manufacturability design
			Software for AM design (cooperative with surgeons)		
			Software for AM manufacturability design		AM design AM software integration
			Software for AM design		
Hardware-machine	Machine build	Hardware-Machine	AM machine+ ceramics		Software for AM manufacturability design
	Testing tools and parts		AM machine+ polymers	AM machine software development	Firmware (runs machine)
Business	Customer knowledge		AM machine+ metals		Data/job preparation softwaree
	Selling		AM machine+ resin systems		Job tracking/document software
				Ownership & operating Hardware-Machine	Ceramics printer Polymers printer
		Business	Selling		
			Marketing		metals printer
					resin systems printer machine build

	Cooperation with potential customers	Testing	testing tools and parts
		Business	Customer knowledge Selling Marketing Cooperation with potential customers

1) "Materials" Capability has been added to the new one called "AM material knowledge & development & production"
2) "Software" Capability has been divided and integrated into two different new Capabilities: "Software coding" and "AM machine software development". For software coding we mean skills to coding software for design.
3) "Hardware-machine" in D4.2 has been merged with the new Capability called "Ownership & operating hardware-machine" that we explained in AM-techs paragraph and with the old Capability "Hardware-Machine" in D3.2
4) The Abilities in "Business" Capability in Table 7 on deliverable D4.2 has been added with Abilities of "Business" Capability on Table 6 in deliverable D3.2. We decided to don't change the name of the Capability.
5) "Testing" Capability is a new one that we added.

In the case of Suppliers' Capabilities, the difference between Automotive and Biomedical industries is less pronounced that in the previous case (AM-technology firms). In fact, only "Software Coding" and "AM machine software development" are characterized by one extra Ability in Biomedical sector compared to Automotive one. To "Software Coding" it is associated the Ability called "Software for AM design (cooperative with surgeons)", instead in "AM machine software development" we can find the Ability called "Job tracking/document software (especially for medical, high-quality parts)".

In the following table (Table 27) we report the difference set of Capabilities and Abilities between Biomedical and Automotive sector.

Table 27: Suppliers kenes allocated between Automotive and Biomedical sectors.

BREED	SHAPE	INDUSTRY	INITIAL-CAPITAL	START-PROJECT	CAPABILITIES (1)	ABILITIES (1)	CAPABILITIES (2)	ABILITIES (2)
Suppliers Supplier		1 Biomedical applications Industry. 2 Automotive Industry. 0 Broker Agent *This value will be unchanged during the simulation and it is randomly assigned in the initialization phase.	100 if small firms 1000 if big firms *depending on the big-firm-percent and number of agents (nSupplier)	False True *randomly assigned	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) AM Materials (7) AM metals (8) Resin systems (5) Binder materials (6)	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) Resin systems (5) Binder materials(6) AM Materials (7) AM metals (8)
					Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Resin systems printer (52) Machine build (17)	Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Machine build (17) Resin systems printer (52)
					Business (4)	Customer knowledge (13)	Business (4)	Customer knowledge (13)

			Selling (19) Marketing (11) Cooperation with potential customers (56)		Selling (19) Marketing (11) Cooperation with potential customers (56)
		AM machine software development (7)	Firmware (runs the machine) (38) Data/job preparation software (39) Job tracking/document software (especially for medical, high quality parts) (40)	AM machine software development (7)	Firmware (runs the machine) (38) Data/job preparation software (39)
		Testing (8)	Testing tools and parts (18)	Testing (8)	Testing tools and parts (18)
		Software coding (15)	AM design (9) AM software integration (16) Software for AM manufacturability design (37) Software for AM design (cooperative design with surgeons) (57)	Software coding (15)	AM design (9) AM software integration (16) Software for AM manufacturability design (37)

4.1.3 Research-inst

From Table 9 in deliverable D3.2 and in accordance with Table 15 in deliverable D4.3, we identified a new set of Capabilities and Abilities.

Table 28: Research-insts kenes development.

D3.2		D4.2 and D4.3		NOW	
Capabilities	Abilities	Capabilities	Abilities	Capabilities	Abilities
AM technology (including materials)	AM manufacturing	AM machine hardware development & design	Mechanic structure and movement Optic/ lighting	AM material knowledge & development & production	Ceramics Polymers
		AM material knowledge & development	Ceramics Polymers Metals Resin systems Binder materials		metals resin systems binder materials AM material manufacturing Biomedical materials
Software	AM design Software research	AM material production	AM material manufacturing Data/job preparation software Job tracking/document software	Software Coding	AM design Software research Software for AM manufacturability design AM design Software research
		AM machine software development	Firmware (runs machine) Data/job preparation software		

			Job tracking/document software		
Biomedical	Surgical operations	AM design software development	Software for AM manufacturability design		
			Software for AM design	AM machine software development	Firmware (runs machine)
Materials	Biomedical materials	Cooperation	Product application development		Data/job preparation software
	Metals		Technological development		Job tracking/document software
			Scietific development		
			Networks& networking skills		
			Ability to push innovation		
			Applying for funding		
	Polymers			AM machine hardware development and design	Mechanic structure and movement
					Optic/lighting
Testing	Biomedical materials	AM prototyping and testing (manufacturing perspective)	AM machine+ ceramics		
			AM machine + polymers	Biomedical	Surgical operations
			AM machine + metals		
	Certificates		AM machine+ resin systems		
			ceramics	Testing	Biomedical materials
					Certificates
				Science	Publication
			Polymers	Cooperation	Product application development
					Technological development
Science	Publication		Metals		
					Scientific development
			Resin systems		
					Networks& networking skills
					Ability to push innovation
					Applying for funding
		AM production (design perspective)	Design for AM manufacturability	Design for AM	Design for AM manufacturability
			Product design		Product design
			Design for AM		Design for AM
			Interrelation between design and materials properties		Interrelation between design and material properties

1) "AM machine hardware development & design" has been added as new one.
2) "AM material knowledge & development" and "AM material production" have been integrated with "AM technology" (including materials), the new Capability name is "AM material knowledge & development & production".

3) “AM machine software development” has been added as new one.
4) “AM design software development” has been integrated with the old one called “Software”, the new Capability name is “Software coding”.
5) “Cooperation” has been added as new one.
6) “AM prototyping and testing” (manufacturing perspective) has been divided into “Ownership & operating hardware-machine” and “AM material knowledge & development & production”.
7) “AM production” (design perspective) has been added as new one, but now it’s called “Design for AM” and we mean design skills.
8) “Biomedical” and “Testing” Capabilities are unchanged.

Capabilities called “Software Coding”, “AM machine hardware development & design”, “Ownership & operating Hardware-Machine”, “Science” and “Cooperation” are characterized by the same Abilities for both industries.

In Biomedical one, we have two extra Capabilities. One of them is called “Design for AM”, as inferred from the Table 15 in the deliverable D4.3, the second one is called “Biomedical”. Furthermore, in Biomedical industry, the Capability called “AM material knowledge & development & production” has an additional Ability called “Biomedical materials”. Something similar happens for “AM machine software development” that is characterized by an Ability called “Job tracking/document software” that there’s not present in Automotive industry, because that’s medical specific, and for Capability called “Testing” which presents an Ability called “Biomedical materials”.

Table 29: Research-insts kenes allocated between Automotive and Biomedical sectors.

BREED	SHAPE	INDUSTRY	INITIAL-CAPITAL	START-PROJECT	CAPABILITIES (1)	ABILITIES (1)	CAPABILITIES (2)	ABILITIES (2)
Research-insts Research-inst		1 Biomedical applications Industry. 2 Automotive Industry. 0 Broker Agent *This value will be unchanged during the simulation and it is randomly assigned in the initialization phase.	100 if small firms 1000 if big firms *depending on the big-firm-percent number of agents (nResearch)	False True *randomly and assigned	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) Metals (8) Resin systems (5) Binder materials (6) AM material manufacturing (36) Biomedical materials (29)	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) Metals (8) Resin systems (5) Binder materials (6) AM material manufacturing (36)
					Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Resin systems printer (52)	Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Resin systems printer (52)
					Biomedical (6)	Surgical operations (27)	AM machine software development (7)	Firmware (runs the machine) (38) Data/job preparation software (39)
					AM machine software development (7)	Firmware (runs the machine) (38) Data/job preparation software (39) Job tracking/document software (especially for medical,	Testing (8)	Certificates (31)
							Science (9)	Publication (32)
							AM machine hardware development & design (10)	Mechanic structure and movement (33) Optics/lighting (35)

			high quality parts) (40)	Cooperation (12)	Product application development (45) Technological development (46) Scientific development (47) Networks & networking skills (48) Applying for funding (49) Abilitity to push innovation (59)
		Testing (8)	Biomedical materials (29) Certificates (31) Publication (32)		
		Science (9)	Mechanic structure and movement (33)	Software coding (15)	AM Design (9) Software research (28) Software for AM manufacturability design (37)
		AM machine hardware development & design (10)	Optics/lighting (35)		
		Cooperation (12)	Product application development (45) Technological development (46) Scientific development (47) Networks & networking skills (48) Ability to push innovation (59) Applying for funding (49)		
		Design for AM (13)	Design for AM manufacturability (58) Product design (54) Design for AM (66) Interrelation between design and material properties (76)		
		Software coding (15)	AM Design (9) Software research (28) Software for AM manufacturability design (37)		

4.1.4 Customers

In accordance with Table 8 on deliverable D3.2, the following table's kenes (Table 30) reports the new set of Capabilities and Abilities.

Table 30: Customers kenes development.

D3.2		D4.2 and D4.3		NOW (no sorting)	
Capabilities	Abilities	Capabilities	Abilities	Capabilities	Abilities
AM technology (including materials)	Manufacturing with tools Manufacturing tools			AM technology	Manufacturing with tools Manufacturing tools
Business	Customer knowledge Sourcing criteria			Business	Customer knowledge

Biomedical	Surgical operations			Biomedical	Sourcing criteria Surgical operations

Capabilities are unchanged.

In the Table 31 is underline the difference between Biomedical and Automotive industries. Specifically, it is only for the Capability called "Biomedical".

Table 31: Customers kenes allocated between Automotive and Biomedical sectors.

BREED	SHAPE	INDUSTRY	INITIAL-CAPITAL	START-PROJECT	CAPABILITIES (1)	ABILITIES (1)	CAPABILITIES (2)	ABILITIES (2)
Custom-ers Customer		1 Biomedical applica-tions Industry. 2 Automotive Indus-try. 0 Broker Agent *This value will be un-changed during the simulation and it is randomly assigned in the initialization phase.	100 if small firms 1000 if big firms *depending on the big-firm-percent and number of agents (nCustomers)	False True *randomly assigned	AM technology(14) Business (4) Biomedical (6)	Manufacturing with tools (24) Manufacturing tools (25) Customer Knowledge (13) Sourcing criteria (26) Surgical operations (27)	AM technology (14) Business (4)	Manufacturing with tools (24) Manufacturing tools (25) Customer Knowledge (13) Sourcing criteria (26)

4.1.5 OEMs

Starting from Table 7 on deliverable D3.2, from Table 6 on deliverable D4.2 and comments about Medical device manufacturer kenes on D4.3 (p. 39), the Table 32 reports the last version of OEMs kenes.

Table 32- OEMs Kenes development.

D3.2		D4.2 and D4.3		NOW (no sorting)	
Capabilities	Abilities	Capabilities	Abilities	Capabilities	Abilities
AM technology (including materials)	Moulding	Design	Product design for automotive Product design for medical	AM technology	Moulding
		Business	Selling Marketing Cooperation with potential customers Customer research Customer Knowledge Supply chain connections market knowledge Business case analysis		
		Sourcing	Sourcing AM components		
Business	Marketing Customer research	Cooperation	Product application development	Business	Marketing customer research

	Customer knowledge Selling Business case analysis Manufacturing	Networks & networking skills		Customer knowledge selling
OEM design	Car parts		Cooperation	Business case analysis Manufacturing Cooperation with potential customers Supply chain connections Market Knowledge Patenting* Marketing technological Development* Scientific development* Applying for funding* Medical product development* Product application development Networks&networking skills
			Software for am	Software for AM design (cooperative with surgeons)*
			Design	Car parts Product design for medical
			Design for AM	design for AM manufacturability* design for AM* product design* AM biomedical design*
			Biomedical knowledge*	Knowledge and network for AM medical certification* Skills to go trough the existing patents and scientific publications* clinical engineers* make manufacturing process traceable* biomedical materials*
			AM material knowledge & development & production	ceramics* polymers* metals* resin systems*
			Ownership & operating hardware-machine	ceramics printer* polymers printer* metals printer* resin systems printer*

* refers to medical manufacturer's Abilities and Capabilities that we added because OEMS are assimilated to Medical device manufacturer like we explained above

In line with what reported on page 29 of deliverable D4.3, Medical device manufacturer kenes can be merged with AM-techs firms or with OEMs. it was decided to assimilate them to OEMs following the study carried out on uses-cases from which the first tables Kenes for each breed were defined, as we explained in AM-techs paragraph (p. 26). Furthermore, we can characterize OEMs breed for both industries. About this, we have more difference between Kenes in Biomedical and Automotive industries.

In Biomedical industry there are 4 additional Capabilities, called “Ownership & operating Hardware-Machine”, “AM material knowledge & development & production”, “Biomedical knowledge”, and “Software for AM”.

Capability called “Design” is characterized, in the Automotive industry, by an Ability called “Car parts”. In Biomedical industry the same Capability is characterized by an Ability called “Product design for medical”.

“Cooperation” shows an extra Ability in Biomedical called “Medical product development” and Capability called “Design for AM” shows 3 additional Abilities in Biomedical sector that are: 1) “Design for AM manufacturability”, 2) “Design for AM”, 3) “AM biomedical design”.

These differences are reported in the Table 33, where is possible notice how we allocated Capabilities and Abilities in Automotive and Biomedical sector.

Table 33: OEMs kenes allocated between Automotive and Biomedical sectors.

BREED	SHAPE	INDUSTRY	INITIAL-CAPITAL	START-PROJECT	CAPABILITIES (1)	ABILITIES (1)	CAPABILITIES (2)	ABILITIES (2)
OEM OEMs		1 Biomedical applications Industry. 2 Automotive Industry. 0 Broker Agent *This value will be unchanged during the simulation and it is randomly assigned in the initialization phase.	100 if small firms 1000 if big firms *depending on the big-firm-percent number of agents (nOEM)	False True *randomly and assigned	AM material knowledge & development & production (1)	Ceramics (1) Polymers (2) Resin systems (5) AM metals (8)	Business (4)	Marketing (11) Customer research (12) Customer Knowledge (13) Supply chain connections (14) Market knowledge (15) Selling (19) Business Case analysis (20) Manufacturing (21) Cooperation with potential customers (56) Patenting (61)
					Software for AM (2)	AM design (cooperative with surgeons) (57)	Design (5)	Car parts (23)
					Ownership & operating Hardware-Machine (3)	Ceramics printer (10) Polymers printer (50) Metals printer (51) Resin systems printer (52)	Sourcing (11)	Sourcing AM material (42) Sourcing AM software (43) Sourcing AM components (44)
					Business (4)	Marketing (11) Customer research (12) Customer Knowledge (13) Supply chain connections (14) Market knowledge (15) Selling (19) Business Case analysis (20) Manufacturing (21) Cooperation with potential customers (56) Patenting (61)	Cooperation (12)	Product application development (45) Technological development (46) Scientific development (47) Networks & networking skills (48) Applying for funding (49)
					Design (5)	Product design for medical(30)	Design for AM (13)	Product design (54)

		Sourcing (11)	Sourcing AM material (42) Sourcing AM software (43) Sourcing AM components (44)	AM technology (14)	Moulding (22)
		Cooperation (12)	Product application development (45) Technological development (46) Scientific development (47) Networks & networking skills (48) Applying for funding (49) Medical product development (60)		
		Design for AM (13)	Product design (54) Design for AM (66) AM biomedical design (62) Design for AM manufacturability (58)		
		AM technology (14)	Moulding (22)		
		Biomedical knowledge (16)	Knowledge and network for AM medical certifications (53) Skills to go trough the existing patents and scientific publications (63) Clinical engineers (55) Make manufacturing process traceable (64) Knowledge about medical tenders (65) Biomedical materials (29)		

4.2 Gender equality

The second refinement introduced in the development of the I AM RRI SKIN model concerns the RRI keys characterizing the inclination of agents in the model towards RRI practices. Until now the I AM RRI SKIN model has implemented agents characterized by only 3 keys RRI: open access, public engagement and ethical thinking. According to the deliverable D3.2. p. 14, the RRI key ethical thinking “represents the inclination of the agent toward ethical values”. Ethical thinking is, as defined before, difficult to measure and therefore to set in the model. To overcome this problem and to enrich the representation of agents with another RRI inclination (easier to measure in the empirical settings), we decided to introduce a new RRI key as a variable characterizing the agents in the model: gender equality. Furthermore, gender equality was linked, in its variation, to changes in ethical thinking.

The gender equality key represents the inclination of the agents work for assuring gender balance in their organization and in innovation processes. As gender equality is an ethical value it is possible to link it to ethical thinking. In addition, this new RRI key is easier to measure and therefore to set in the I AM RRI SKIN model. At the moment, a reliable way to represent this variable is using a value ranging from 0 to 1 (according to the representation of other RRI variables in the model, where 0 means the lack of opening to gender-equality orientation, and 1 being related to the maximum opening and attention).

Since gender equality is representative of gender balance within the agents' business, this represents only a small part of the ethical values of agents. In particular, by setting the variable gender equality randomly in a range between 0 and 1, the variable ethical thinking no longer varies randomly as it previously happened in the model. These two variables are now related according to (1)

$$Ethical\ thinking\ = gender\ equality + 0.1 \tag{1}$$

If ethical thinking > 1 the final value will be settled equal to 1.

For clarity, the image below (Figure 9) shows the lines of code in set-up of each breed for setting up the 4 RRI keys.

```
set open-access random-float 1        ; set randomly in the absence of empirical data
set public-engagement random-float 1
set gender-equality random-float 1
set ethical-thinking gender-equality + 0.1    ;   ethical-thinking is linked to gender equality since set-up, but has an addition quota
if ethical-thinking > 1 [ set ethical-thinking 1]  ; max value is 1
set RRI-value  (list open-access public-engagement ethical-thinking gender-equality)
set open-access-publications 0        ; number of open access publications
```

Figure 9: Set-up code RRI keys.

In conclusion, although in the latest version of the model each breed (family agents) has 4 RRI keys the model works in the same way of the old version except for gender equality that's linked to ethical thinking and it condition ethical thinking key. In addition, during calibration each RRI key will be set differently for each breed according to the real data, except ethical thinking. This latter one will depend on set-up of gender equality key, according to (1).

4.3 NGO: a new agent

In accordance with previous I AM RRI deliverables (D2.4, D3.1, D3.2) and the literature on the subject, it is possible to identify a new type of agent to consider into the I AM RRI SKIN model. Indeed, "the European Commission has adopted a position that maintains that CSOs are vital components for realizing RRI (or a 'societal perspective') in current research and innovation processes, and that, therefore, the participation of CSOs in these processes needs to be fostered". (Ahrweiler et al., 2019, p. 29). This is reason why we studied how CSOs are linked to other agents in the model in order to integrate them in I AM RRI SKIN model.

First step towards the model refinement concerning the inclusion of CSOs in the model was to study who CSOs are and how they act. In general, it is possible to define Civil Society as an organization that refers to all forms of social action carried out by individual or groups who are neither connected to, nor managed by, the State[1]. Civil society organizations are organizational structures whose members serve the general interest through a democratic process, and which play the role of mediator between public authorities and citizens. Examples of such organizations include: social partners (trades union and employers' groups), non-governmental organizations (environmental and consumer protection) etc.

Table 34: CSOs/NGOs description.

AGENT	TYPE
CSOs/NGOs	Non-governmental, non-profit social organisation that focuses on the design and implementation of development-related projects and plays the role of mediator between public authorities and citizens.

4.3.1 CSOs why are important for EC and their role in an innovation project

In agreement with literature, CSOs are a central point to the Commission's RRI policy. In fact, civil society organisations play an important role as interlocutors between science and society. This makes it possible to apply the concept of "knowledge society", which means the recombination of all kinds of knowledge into a new, more inclusive one. "One of the challenges of RRI is to be more innovative and inclusive about embedding the involvement of the public within at all stages of research and innovation without wasting their time and other people's money" (Sutcliffe 2011, p. 10). In fact, the involvement of CSOs in innovation process is a key component of RRI concept.

Conforming to literature, Civil Society Organisations are becoming more and more important players in innovation process. In the future, they could operate as social entrepreneurs and as sources of societal innovation. This means that civil society organisations will have both behaviours typical of the corporate value system (e.g., efficiency, market requirements) and behaviours typical of their social mission (e.g. adherence to principles, ideological agendas).

What is the motivation for project consortia to include CSOs as partners? What do project partners expect to be CSOs specific contribution? Are CSOs the only drivers of RRI within projects?

As reported from "The role of civil society organisations in European responsible research and innovation" (p. 32) a quantitative online survey was undertaken under the Policy Support Programme (PSP) in the seventh Framework Programme of the European Commission. In particular, the survey was from projects funded within the Competitiveness and Innovation Programme (CIP) and in Information and Communication Technologies (ICT). These projects were *per se* innovation-oriented like as I AM RRI project so we can assume that the survey's results are quite significant for the characterization of CSOs, and so also of NGOs, in the future development of the model. The survey shows that CSOs can choose whether to take part or not in a project. If civil society organisations enter into a network project, there will always be more than 1 CSO involved. In addition, CSOs decide to participate in projects that are civil-oriented and work in the same field as themselves. When a CSO enters in a project its involvement in all phases is about the same. It's important to note that this survey highlights the fact that including CSOs as partners in consortia is only partly motivated by the expectation that these would provide RRI competence. More important is the expectation that they could contribute specific scientific Capabilities and expertise including data, not provided by other actor types. So, their presence in the network increases the diffusion and sharing knowledge due to new Capabilities and Abilities that other agents do not have (Sutcliffe 2011**,** Ahrweiler et al. 2019, Lang et al. 2015, Cavallaro et al. 2014, Böschen et al. 2014).

Since examples of CSOs include non-governmental organisations and since these two organisations are often juxtaposed in the literature, we consider these results to be valid for NGOs as well. From now on we will no longer refer to CSOs in general in the model, but we will consider non-governmental organisations.

4.3.2 NGO in I AM RRI SKIN model

The second step towards the model refinement was to introduce NGOs in I AM RRI SKIN code.

First, it was decided to add NGO agents as new breed (agent family in NetLogo) called NGOs. This new breed like the old ones is characterised by:

- Its own shape (visualisation of the agent in the world of NetLogo).
- Its own agent knowledge that is modelled through the Kene, which consists of triples of Capabilities, Abilities and Expertise levels. So will set-up with own Capabilities and Abilities set that have been deduced from the study of literature on how both CSOs and NGOs act.
- RRI keys.
- Specific values for initialisation of the model. For example, the number of NGO initially, the attractiveness-threshold that's how attractive an agent must be before it becomes a partner, initial-capital that is the capital that an agent start with and so on.

- Innovation Hypothesis (IH). This IH depends directly on the agent's kene. All the agents will generate an IH at the beginning of a simulation cycle, but only a part of them will be able to create an IH that can be further evaluated and refined.
- A variable called "attendance", that's represents the inclination level of an NGO to join in a network. It's modelled as a continuous variable with normal distribution and variance equal to 0.1, which average can be chosen by the user through the slider in the interface of NetLogo.

For clarity, the Figure 10 shows the initialise code for NGOs agents.

```
to initialise-NGOs
  create-NGOs nNGO[
    set shape "triangle 2"
    set size 3
    set color white
    setxy random-xcor random-ycor
    set initial-capital 100
    set capital initial-capital
    set industry random 2 + 1
    set ih []
   set max-veiled 1
   set start-project? false
   set partners no-turtles
   set max-partners 5
    set capabilities []
    set abilities []
    set expertises []
    set attendance random-normal ngo-attendance 0.1
   set open-access random-float 1
   set public-engagement random-float 1
   set gender-equality random-float 1
   set ethical-thinking gender-equality + 0.1    ;
   if ethical-thinking > 1 [ set ethical-thinking 1]  ;
   set RRI-value  (list open-access public-engagement ethical-thinking gender-equality)
   set open-access-publications 0
  ]

 ask n-of round  ((big-ngo-percent / 100) * nNGO) NGOs [
   set capital initial-capital * 4
    set max-partners 15 ]
  let n_start_project random nNGO
  ask n-of n_start_project NGOs [
    set start-project? true ]
end
```

Figure 10: NGOs initialise code.

NGOs are no- profit organisations, therefore we will consider them as such. Furthermore, in accordance with literature and the previous section on the role of these organisations in innovation process, we consider this new type of agent as providers of valuable data set for eventual partners. In fact, we recall that the major contribution NGOs make in a project is connected to the production of data available. NGOs are also specialised entities in sourcing of raw materials/software/goods needed for project purposes. In addition, they are by nature experts in public engagement, know the needs of society very well and cooperate with large banks and states to obtain funds for social purposes. (Fisher 97, Szarka 2013, Ahrwler et al. 2019, Aldashev et al. 2018).

In the following Table 35 it is possible see Capabilities and Abilities deduced from the literature about NGOs.

Table 35: NGOs kenes.

Breed	Capabilities	ID. num	Abilities	ID. num
NGOs	Software for AM	2	AM design	9
			Software for AM manufacturability design	37
	Sourcing	11	Sourcing AM material	42
			Sourcing AM software	43
			Sourcing AM components	44
			Sourcing AM hardware-machine	67
	Prevision Data	18	Data banking	68
			Society data provider	69
	Advocacy	17	Advising on governmental rules	70
			Knowledge of social legislation	71
	Business	4	Customer knowledge (social needs point of view)	72
			Cooperation with potential customer	56
	Cooperation	12	Applying for funding	49
			Network&networking skills	48
			Public mobisation	73
			Cooperation with banking/private funding	74
			Cooperation with customer (social needs point of view)	75

In the absence of specific knowledge about NGOs in the automotive and biomedical area, it was decided to set them up so that the Capabilities and Abilities would fit both sectors.

Based on data provided by some partners, we settled-up the last version of the model so that NGOs can start a process of network creation for the generation of an innovation idea and for its development. In particular, an NGO can start a project if it is focal agent. If not focal, it can join an existing Network. In fact, even if "no profit", these agents increase their capital when co-operating in a successful network delivering innovation to the market.

It is important to emphasise that if not focal an NGO can’t join in a Network during the phase called “IDEA-GENERATION-1”, but only when a Network is already created. If NGO is a focal agent, it can start the research for partners and create a Network or join with another focal agent in the creation of a Network. By their nature NGOs pursue social aim projects so an NGO joins a Network if its project is socially oriented. To simulate this operating of NGOs we decided to consider RRI keys as a proxy for the network’s inclination to carry out a social oriented project. Hence, at the beginning of the simulation phase named “IDEA-GENERATION-2”, before the update of RRI keys of partners of a formed network, the model calculates networks’ RRI keys average. At this point, each Network compares its RRI average values with the attendance value of each NGO agent: if Network RRI average is higher than this value the Network asks the NGO agent to join. In addition, Ahrweiler et al. (2019), shows that, if they are present, there are always more than 1 NGO in a Network. In our model version we set the constraint of 2 NGOs, the choice was made quite arbitrarily to have breed heterogeneity in a network since the model has the condition for a maximum of 5 partners in a network. It is possible to identify three cases in the model:

1) the Network includes an NGO (focal agent);
2) the Network has one NGO focal agent that joined to focal agent of the Network to create it;
3) the Network has no NGO among its partners.

In the first case, once the Network developed the Network asks to NGOs turtles to join. If there is at least one NGO agent with attendance value lesser than RRI average of the Network, so the Network add one NGO agent as net-partner. It updates its partners public-engagement and open access keys and then update its partners RRI value (each of the keys). If no one NGO has attendance value lesser than RRI average of the Network, the Network die. The second case occurs when during the IDEA-GENERATION-1 phase NGO focal agent research for possible partners and links to another focal agent who creates the Network. In this case, the Network ask to NGOs turtle to join. If there is at least one NGO agent with attendance value lesser than RRI average of the Network, the Network add one NGO as net-partner. After that it updates its partners public-engagement and open access keys and then update its partners RRI value (each of the keys). If there is no one NGO agent with attendance lesser than Network' RRI average, the Network die. In the last one, the Network look for two NGOs agent. If there are at least more than 2 NGO agents with attendance value lesser than RRI average of the Network, the Network add 2 NGO agents as net-partners. It updates its partners public-engagement and open-access keys and after that it updates its partners RRI value. If there is only 1 or no one NGO agent with attendance value lesser than RRI average of the Network, the Network update its partners RRI values.

According with Ahrweiler et al. (2019), open access and public engagement keys of partners increase when an NGO joins a Network. These two values increase each time the RRI update procedure is started. After the update procedure has been completed, Network goes to next phase called "IDEA-GENERATION-3". The following images show how the code has changed in IDEA-GENERATION-1 (Figure 11 and Figure 12) and in IDEA-GENERATION-2 (Figure 13, Figure 14 and Figure 15).

```
to find-partners
  let candidates no-turtles
  ;choose compatible agents
  ;ask other agents if I am compatible, if so I set them up as candidates
  set candidates turtles with [compatible? myself]
  if not any? candidates [stop]
 ;select exactly the number of partners I can afford
  if count partners < max-partners [
    set candidates up-to-n-of (max-partners - (count partners)) candidates
    set partners (turtle-set partners candidates)
    create-links-to partners
   ;ask the new partner to add me to the partners
    ask candidates [set partners (turtle-set myself partners)]]
end

;choice of compatible partners through a weighted average of the RRI values and capabilities of the
; potential partner. the weight given to the RRI values is set in the interface
;the potential partner with capabilities similar to mine and with a high RRI-value will have greater attractiveness;
to-report compatible? [possible-partner]
  let attractiveness 0
  ; (cannot partner with myself )
  if possible-partner = self  [ report false ]
  ;networks cannot partner
  if member? self Networks [report false]
  ; a possible partner cannot already be a partner of mine
  if member? self [partners] of possible-partner or member? possible-partner partners [report false]
  ; cannot have more than max-partners
  if count partners = max-partners [report false]
  set attractiveness ((length intersection advert [capabilities] of possible-partner / length capabilities) * (1 - RRI-attractiveness)
    + (mean [RRI-value] of possible-partner * RRI-attractiveness ))
  ;prefer agents from other breeds (exclude those of the same breed)
  if not member? possible-partner other breed    [set attractiveness attractiveness + 0.1]
  report attractiveness > attractiveness-threshold
end
```

Figure 11: IDEA-GENERATION-1 part of old version code.

```
to find-partners
  let candidates no-turtles
  ;choose compatible agents
  ;ask other agents if I am compatible, if so I set them up as candidates
  set candidates turtles with [compatible? myself]
  if not any? candidates [stop]
 ;select exactly the number of partners I can afford
  if count partners < max-partners [
    set candidates up-to-n-of (max-partners - (count partners)) candidates
    set partners (turtle-set partners candidates)
    create-links-to partners
   ;ask the new partner to add me to the partners
      ask candidates [set partners (turtle-set myself partners)]]
end

;choice of compatible partners through a weighted average of the RRI values and capabilities of the
; potential partner. the weight given to the RRI values is set in the interface
;the potential partner with capabilities similar to mine and with a high  will have greater attractiveness;
to-report compatible? [possible-partner]
  let attractiveness 0
  ; (cannot partner with myself )
  if possible-partner = self  [ report false ]
  ; a possible partner cannot be an NGOs
  if member? self NGOs [report false]
  ;networks cannot partner
  if member? self Networks [report false]
  ; a possible partner cannot already be a partner of mine
  if member? self [partners] of possible-partner or member? possible-partner partners [report false]
  ; cannot have more than max-partners
  if count partners = max-partners [report false]
  set attractiveness ((length intersection advert [capabilities] of possible-partner / length capabilities) * (1 - RRI-attractiveness)
    + (mean [RRI-value] of possible-partner * RRI-attractiveness ))
  ;prefer agents from other breeds (exclude those of the same breed)
  if not member? possible-partner other breed    [set attractiveness attractiveness + 0.1]
  report attractiveness > attractiveness-threshold
end
```

Figure 12: IDEA-GENERATION-1 code new version.

```
;; IDEA-GENERATION-2
to IDEA-GENERATION-2
  ask Networks with [[state] of focal = 1] [
    update-RRI
    make-RRI
  ]
 end

;network's partners procedure
to update-RRI
   ask net-partners[
    ;let RRI-network [RRI-net] of myself
    let difference (map - [RRI-net] of myself RRI-value)
    let project count Networks with [member? myself net-partners]
    foreach difference [ i ->
      if 0 = (position i difference) and open-access <= 1 [
        if (i < 0.3) and (i > 0) [set open-access (open-access + 0.2 / project) ]
        if (i > 0.3) and (i < 0.7) [set open-access (open-access + 0.14 / project)]
        if (i > 0.7) [set open-access (open-access + 0.07 / project)]]
      if 1 = (position i difference) and public-engagement <= 1 [
        if (i < 0.3) and (i > 0) [set public-engagement (public-engagement + 0.2 / project)]
        if (i > 0.3) and (i < 0.7) [set public-engagement (public-engagement + 0.14 / project)]
        if (i > 0.7) [set public-engagement (public-engagement + 0.07 / project)]]
      if 2 = (position i difference) and gender-equality <= 1 [
        if (i < 0.3) and (i > 0) [
          set gender-equality (gender-equality + 0.2 / project)
          set ethical-thinking (ethical-thinking + 0.1 / project)]
        if (i > 0.3) and ( i < 0.7) [
          set gender-equality (gender-equality + 0.14 / project)
          set ethical-thinking (ethical-thinking + 0.07 / project)]
        if (i > 0.7) [
          set gender-equality (gender-equality + 0.07 / project)
          set ethical-thinking (ethical-thinking + 0.04 / project)]]
    ]
  ]
end
```

Figure 13: IDEA-GENERATION-2 code old version.

```
;; IDEA-GENERATION-2
to IDEA-GENERATION-2
  ask Networks with [[state] of focal = 1] [
    find-ngo-partners
    update-RRI
    make-RRI
  ]
 end


to find-ngo-partners
ask Networks [
    let a mean RRI-net
    let o [who] of focal
    let d NGOs with [who != o]
    let c d with [ [attendance] of self <= a]
    let g count c
    let f count net-partners with [member? self NGOs]
    if focal = NGOs and f < 2 [
        if g = 0 [dissolve-network]
      if g >= 1 [
        set partners (turtle-set partners one-of c )]]
    if focal != NGOs and g >= 1 and f < 2 [
          set partners (turtle-set partners n-of (2 - f) c)]

]

end
```

Figure 14: IDEA-GENERATION-2 code new version (1).

```
to update-RRI
  if any? net-partners with [member? self NGOs] [
    ask net-partners [
      if self != NGOs  [
      set open-access open-access + 0.02
      set public-engagement public-engagement + 0.05 ]]
  ]

   ask net-partners[
    ;let RRI-network [RRI-net] of myself
    let difference (map - [RRI-net] of myself RRI-value)
    let project count Networks with [member? myself net-partners]
    foreach difference [ i ->
      if 0 = (position i difference) and open-access <= 1 [
        if (i < 0.3) and (i > 0) [set open-access (open-access + 0.2 / project) ]
        if (i > 0.3) and (i < 0.7) [set open-access (open-access + 0.14 / project)]
        if (i > 0.7) [set open-access (open-access + 0.07 / project)]]
      if 1 = (position i difference) and public-engagement <= 1 [
        if (i < 0.3) and (i > 0) [set public-engagement (public-engagement + 0.2 / project)]
        if (i > 0.3) and (i < 0.7) [set public-engagement (public-engagement + 0.14 / project)]
        if (i > 0.7) [set public-engagement (public-engagement + 0.07 / project)]]
      if 2 = (position i difference) and gender-equality <= 1 [
        if (i < 0.3) and (i > 0) [
          set gender-equality (gender-equality + 0.2 / project)
          set ethical-thinking (ethical-thinking + 0.1 / project)]
        if (i > 0.3) and ( i < 0.7) [
          set gender-equality (gender-equality + 0.14 / project)
          set ethical-thinking (ethical-thinking + 0.07 / project)]
        if (i > 0.7) [
          set gender-equality (gender-equality + 0.07 / project)
          set ethical-thinking (ethical-thinking + 0.04 / project)]]
    ]
   set RRI-value  (list open-access public-engagement ethical-thinking gender-equality)
    foreach RRI-value [i -> if i >= 1 [set i 1]]
  ]
end
```

Figure 15: IDEA-GENERATION-2 code new version (2).

For clarity, in Figure 16 Figure 17 Figure 18 and Figure 19 it is possible see the old flow chart and the new ones.

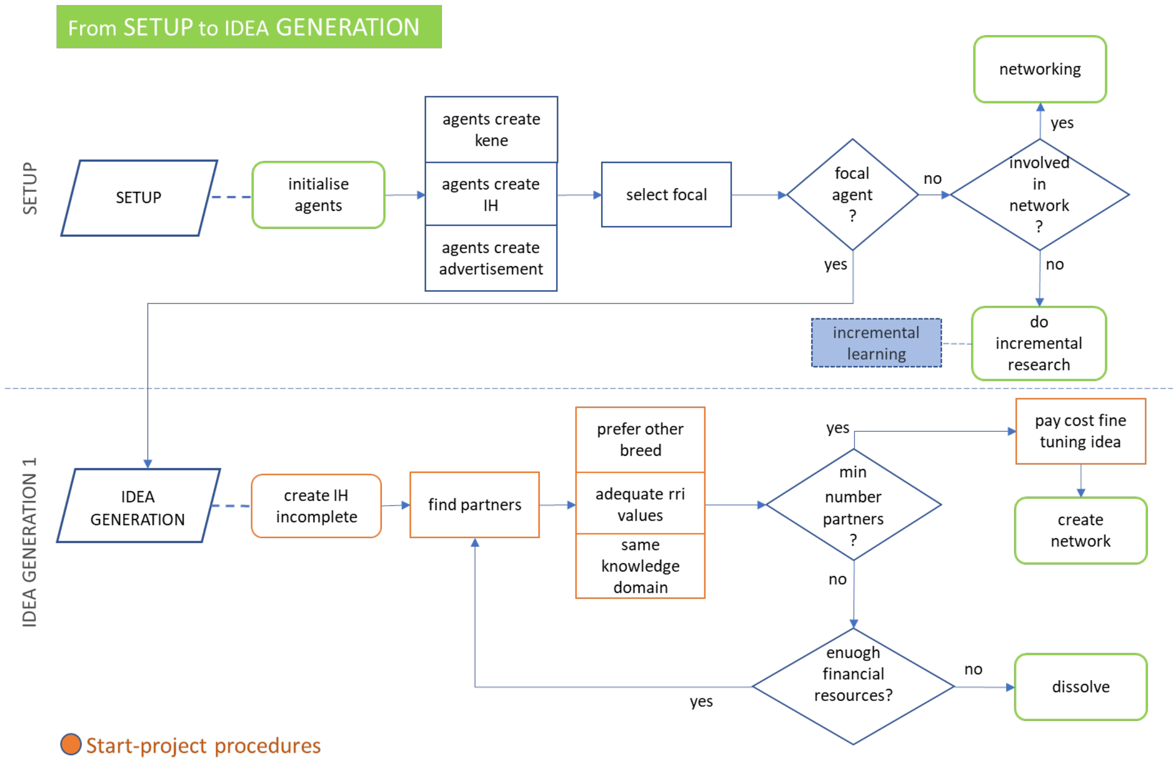

Figure 16: From Set-up to the Idea Generation - old version of the model.

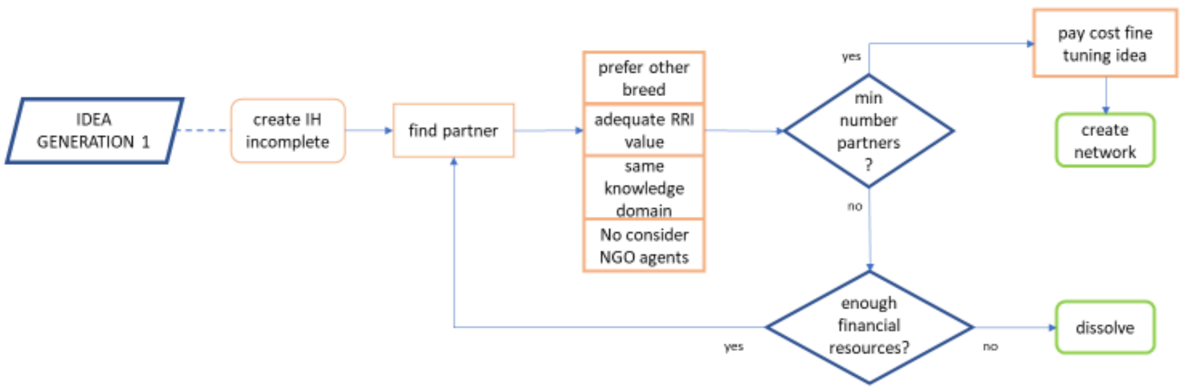

Figure 17: IDEA-GENERATION-1 - new version.

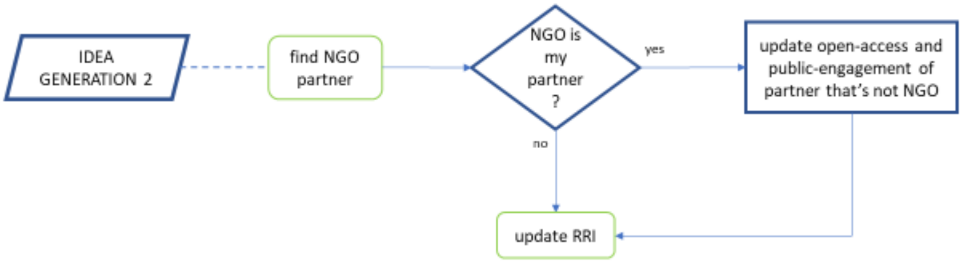

Figure 18: IDEA-GENERATION-2 - new version.

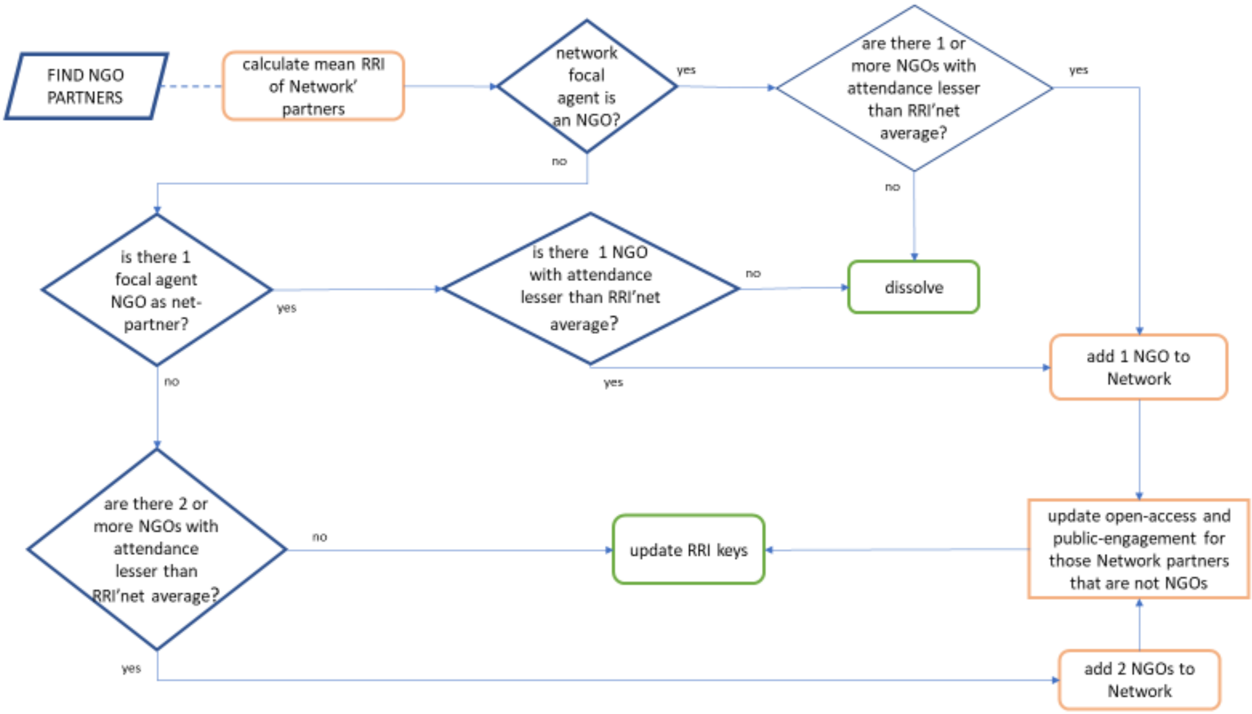

Figure 19: Find NGO partner procedure.

4.4 Open-access publication

The last refinement introduced in I AM RRI SKIN model concerns the update of open-access key. In the I AM RRI SKIN model, after the participative learning mechanisms, the agents involved in an IVC (Innovation Value Chain) or a Network increase their knowledge base. Furthermore, agents with a particular inclination to open access and with sufficient financial resources can publish in open access so to exploit the knowledge gained.

In order to give weight to the open access publications made during the simulation, we found it necessary to increase the open-access key value by an amount for those agents that are able to perform open-access publication.

In Figure 20, it is illustrated the previous code for the open access publication procedure.

```
; If the agent can afford to publish open access, the agent will then weigh open access orientation and will decide on whether to publish or not.
;While the weight has a strong effect on this decision, there is also an element of randomness to the decision, representing other factors
;influencing the decision maker, modelled by Bernoulli variable. If the decision is positive, the publication takes place, and the agent pays the open access fee.
to publish-open-access
  if [state] of focal = 14 [
  ask net-partners[
    let budget-for-publish 0.18 * initial-capital
    if (random-bernoulli open-access) and (capital > budget-for-publish) and (open-access > RRI-open-access-threshold) [
      set open-access-publications (open-access-publications + 1)
      set capital capital - budget-for-publish
      ask Networks with [member? myself net-partners] [set open-access-publications open-access-publications + 1]]
  ]]
end
```

Figure 20: Open access publication code, old version.

In the last version of the I AM RRI SKIN model if an agent made an open access publication its open access key increase, according to (2)

$$Open\ access\ =\ open\ access + 0.07 \qquad (2)$$

If open access > 1 the final value will be settled equal to 1.

For clarity, the image below (Figure 21) shows the lines of code in open-access publication.

```
; If the agent can afford to publish open access, the agent will then weigh open access orientation and will decide on whether to publish or not.
;While the weight has a strong effect on this decision, there is also an element of randomness to the decision, representing other factors
;influencing the decision maker, modelled by Bernoulli variable. If the decision is positive, the publication takes place, and the agent pays the open access fee.
to publish-open-access
  if [state] of focal = 14 [
  ask net-partners[
    let budget-for-publish 0.18 * initial-capital
    if (random-bernoulli open-access) and (capital > budget-for-publish) and (open-access > RRI-open-access-threshold) [
      set open-access-publications (open-access-publications + 1)
      set capital capital - budget-for-publish
      set open-access open-access + 0.07 ; if the agent make an open access publications its RRI value increase
      if open-access > 1 [set open-access 1]
      ask Networks with [member? myself net-partners] [set open-access-publications open-access-publications + 1]
        ]
  ]]
end
```

Figure 21: Open access publication code, last version.

5. Refined model "Verification"

After each refinement, all three experiments, illustrated in Section 3, were repeated to check how each refinement impacted on the results. By way of example, in this section we report the results for the model with all refinements implemented: Kenes, gender equality, NGO and open-access. The aim is to show how the results of the experiments vary with respect to the previous model (see Section 3).

The Table 36 shows the values used to set the variables of the new Breed NGOs: nNGO, ngo-attendance and big-ngo-percent.

Table 36: Control variable NGO.

Numbers of Agents	[value]	Firm's Variable	[value]	Environmental Variable	[value]
nNGO	[200]	ngo-attendance	[0.5]	big-ngo-percent	[5]

These values are the same for all three experiments.

EXPERIMENT 1

The aim of the experiment was to evaluate the number of Networks as the attractiveness threshold variable increases. In particular, we wonder how much the Networks decrease as the requirements for partners increase (attractiveness-threshold, see Section 3 Table 7). We expect that as the value of the latter variable increases, the number of Networks decreases. Variables are set according to Tables 6, 7 and 36.

RESULTS

The results of Verification Experiment 1 were analysed with the *One Way* Analysis of Variance (ANOVA) test. Analysis of variance is a technique for the division of experimental variance into statistically independent rates to isolate the variance attributable to the factor under investigation and thereby obtain information on the effects exerted. The results are consistent with what we expected.

ANOVA results are F(4, 1495)= 1187.69,p<0001.

More details on the results are given in the tables in the appendix (Table 37 and Table 38).

EXPERIMENT 2

The second experiment was designed to assess the social effect of regulators and what might be a better policy to adopt. The aim of this experiment is to investigate how the RRI keys vary as the value of the regulator variable increases. Variables are set according to Tables 11, 12 and 36. The experiment was run in manner to obtain the trend of the RRI keys over time, thus obtaining the RRI keys values at each individual step.

RESULTS

A graph of all four RRI keys can be found in the appendix (Figure 22).

Again, we used the one-way ANOVA test, comparing the regulator variable with each individual key. The results of the *One Way* ANOVA analysis show us that at higher value levels of the regulator variable we have an increase of the ethical-thinking key, we report the values for steps 4 6 and 30 and the remaining keys[17].

1) Step 4: F(2,897)=60170,70,p<0001.

[17] Gender equality Step4: F(2,897)= 50314,452,p<0001 ; Step6: F(2,897)= 4644,32,p<0001 ; Step30: F(2,897)= 50314,45,p<0001.
Open access Step4: F(2,897)= 1,69,p<185 ; Step6: F(2,897)= 278,64,p<0001 ; Step30: F(2,897)=0,755,p<470.
Public Engagement Step4:F(2,897)=0,156,p<855 ; Step6: F(2,897)= 81,57,p<0001 ; Step30: F(2,897)=2,09,p<124.

2) Step 6: F(2,897)=2306,73,p<0001.
3) Step 30: F(2,897)=17786,05,p<0001.

More details on the results are given in the tables in the appendix (Tables from 39 to 62).

EXPERIMENT 3

The purpose of this experiment is to assess how the number of partners in a network varies as the RRI-cost variable increases. The model works in such a way as to expel agents from a network if they are unable to bear the cost of investing in RRI keys. Moreover, the increase of the RRI-cost variable should also increase the value of the average capital invested in innovation projects. Therefore, the average capital invested in the innovation project by the network is also evaluated as the variable RRI-cost increases. Variables are set according to Tables 16, 17 and 36.

RESULTS

We used the one-way ANOVA test, comparing the RRI-cost variable first with the output "average capital invested by Networks" and then with the second output of interest which is " dimension of Networks". The results show that as the RRI-cost variable increases, there is an increase in capital investment, as we expected, and a decrease in the size of the Network. We report both ANOVA results:

- Average capital invested by Networks: F(2,897)=2203,94,p<0001
- Dimension of Network: F(2,897)=4067,01,p<0001.

More details on the results are given in the tables in the appendix (Tables 63,64 and 65).

6. Conclusions

After having illustrated the methodologies of "Verification" more affirmed in literature, the deliverable illustrates the experiments conducted and the relative results. These experiments are to be considered fundamental, even if time consuming, as they ensure rigor to the model and represent the only debugging strategy for an ABM. Moreover, all the refinements and extensions to the model illustrated in the deliverable D3.3 have been illustrated, with particular attention to the increase of the Capabilities of the agents, the introduction of the gender-equality and the NGOs.

As mentioned in Section 3, "Validation" experiments will be the subject of D5.2. Validation is the process of determining how well the implemented model corresponds to reality. "Validation" process has always played an essential role in modelling issues (Conway et al., 1959), especially computational models (Carley, 1996; Garcia et al., 2007). We could say that the biggest problem related to "Validation" process is that there is no universally accepted approach. For this reason, we will illustrate the various methodologies in the literature and the Validation strategy used to ensure model rigor. The main purpose was to test the correspondence between RRI keys' effect on the performance of IVCs in our model and the effect of RRI keys on the performance of IVCs in the real world. The results obtained substantiate the correspondence between the real world and our model and provide useful insights for improvement.

Finally, in D5.2 we will describe the methodology and the steps that make up the "Calibration" process. In general, we could say that the "Calibration" aims to regulate the individual parameters and behaviours of the agents up to the achievement of a behaviour assimilable to the real data. Therefore, after filtering and refining the data provided by the partners, an iterative process of fine-tuning of the parameters and individual behaviours begins.

7. Appendix 1: tables of the "Verification" process on the model refined (v0.2)

Table 37: Descriptive Statistics Experiment 1.

Descriptive Statistics								
RRI-attractive-ness	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0.2	300	188,29	24,504	1,415	183,51	189,08	83	252
0.4	300	184,00	23,554	1,360	181,33	186,68	95	241
0.6	300	168,03	24,133	1,393	165,28	170,77	82	246
0.8	300	139,80	29,470	1,701	136,45	143,15	36	211
1.0	300	64,76	24,523	1,416	61,97	67,54	17	143
Total	1500	148,58	51,700	1,335	145,96	151,20	17	252

Table 38: LSD test Experiment 1.

	(I) RRI attractiveness	(J) RRI attractive-ness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0.2	,4	2,290	2,068	,268	-1,77	6,35
		,6	18,267*	2,068	,000	14,21	22,32
		,8	49,490*	2,068	,000	42,43	50,55
		1,0	121,537*	2,068	,000	117,48	125,59
	,4	,2	-2,290	2,068	,268	-6,35	1,77
		,6	15,977*	2,068	,000	11,92	20,03
		,8	44,200*	2,068	,000	40,14	48,26
		1,0	119,247*	2,068	,000	115,19	123,30
	,6	,2	-18,267*	2,068	,000	-22,32	-14,21
		,4	-15,977*	2,068	,000	-20,03	-11,92
		,8	28,223*	2,068	,000	24,17	32,28
		1,0	103,270*	2,068	,000	99,21	107,33
	,8	,2	-46,490*	2,068	,000	-50,55	-42,43
		,4	-44,200*	2,068	,000	-48,26	-40,14
		,6	-28,223*	2,068	,000	-32,28	-24.17
		1,0	75,047*	2,068	,000	70,99	79,10
	1,0	,2	-121,537*	2,068	,000	-125,59	-117,48
		,4	-119,247*	2,068	,000	-123,30	-115,19
		,6	-103,270*	2,068	,000	-107,33	-99,21
		,8	-75,047*	2,068	,000	-79,10	-70,99

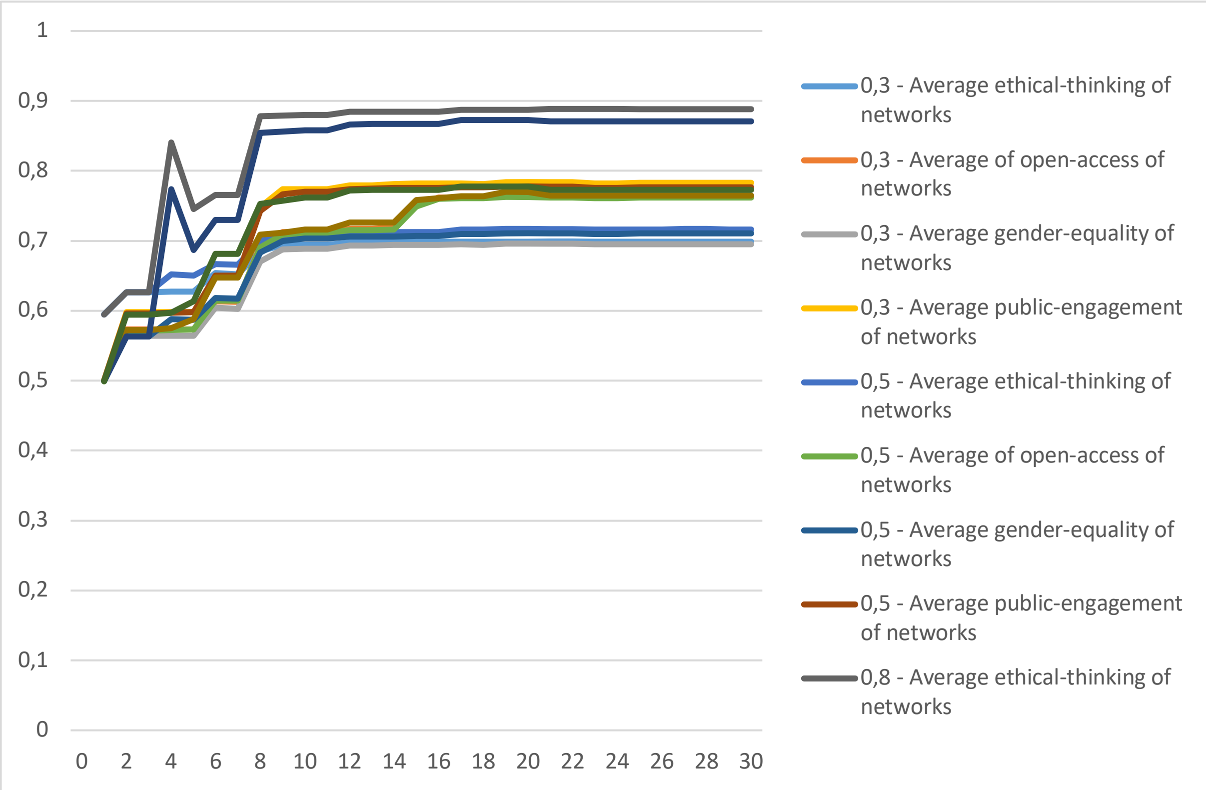

Figure 22: Experiment 2 - average of RRI keys plot.

Table 39: Descriptive Statistics - ethical thinking step 4.

Descriptive Statistics								
Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,627	,010	,001	,626	,628	,599	,661
,5	300	,652	,007	,000	,651	,653	,635	,670
,8	300	,840	,007	,000	,840	,841	,822	,869

Table 40: Tukey test - ethical thinking step 4.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,02474468891730*	,000672946474571	,000	-,02632450116607	-,0231648767
		,8	-,21340431710254*	,000672946474571	,000	-,21498412935130	-,2118245049

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
	,5	,3	, 02474468891730*	,000672946474571	,000	,023164876668534	, 0263245012
		,8	-,18865962818524*	,000672946474571	,000	-,19023944043400	-,1870798159
	,8	,3	, 21340431710254*	,000672946474571	,000	,21182450485377	,2149841294
		,5	, 18865962818524*	,000672946474571	,000	, 18707981593647	,1902394404

Table 41: Descriptive Statistics Experiment 2 - ethical thinking step 6.

Descriptive Statistics								
Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,6535965	,01075444568	,0006209082	,6523745874	,6548183948	,62506632	,681032113
,5	300	,6668813	,01076352054	,0006214322	,6656583689	,6681042384	,64377699	,779140708
,8	300	,7651123	,03487259458	,0020133702	,7611501625	,7690745044	,67487053	,844104637

Table 42: Tukey test - ethical thinking step 6.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,01328481258*	,00179357454	,000	-,01749541644	-,0090742087
		,8	-,11151584234*	, 00179357454	,000	-,1572644620	-,1073052385
	,5	,3	,01328481257*	, 00179357454	,000	,00907420872	,017495416
		,8	-,09823102976*	, 00179357454	,000	-,1024416336	-,094020426
	,8	,3	, 21340431710254*	, 00179357454	,000	, 10730523848	, 1157264462
		,5	, 18865962818524*	, 00179357454	,000	, 09402042590	, 1024416336

Table 43: Descriptive Statistics Experiment 2 - ethical thinking step 30.

Descriptive Statistics								
Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,6989765	,0121042726	,0006988405	,697601209	,7003517470	,666508788	,751409335
,5	300	,7168461	,0135681462	,0007833573	,715304509	,7183876934	,690849911	,874254288
,8	300	,8880407	,0148564092	,0008577352	,886352683	,8897286077	,734495288	,930088838

Table 44: Tukey test - ethical thinking step 30.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,0178696233*	, 00110686835	,000	-,02046811256	-,0152711341
		,8	-,1890641671*	, 00110686835	,000	-,191662656391	-,1864656779
	,5	,3	, 0178696233*	, 00110686835	,000	, 015271134051	,0204681126

	,8	-,1711945438*	, 00110686835	,000	-,173793033084	-,1685960546
,8	,3	, 1890641671*	, 00110686835	,000	, 186465677879	, 1916626564
	,5	, 1711945438*	, 00110686835	,000	, 168596054573	, 173793033

Table 45: Descriptive Statistics Experiment 2 - gender equality step 4.

Descriptive Statistics

Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
,3	300	,5640012	,010680477	,0006166376	,562787648	,565214647	,533882432	,602613697
,5	300	,5883143	,007336088	,0004235492	,587480784	,589147814	,571209038	,613251125
,8	300	,7737070	,008212411	,0004741438	,772773962	,774640125	,753507843	,810050703

Table 46: Tukey test - gender equality step 4.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	,3	,5	-,0243131516*	,0007231635	,000	-,0260108536	-,0226154496
		,8	-,2097058956*	, 0007231635	,000	-,2114035976	-,2080081936
	,5	,3	, 0243131516*	, 0007231635	,000	, 0226154496	,0260108536
		,8	-,1853927441*	, 0007231635	,000	-,1870904461	-,1836950421
	,8	,3	,2097058956*	, 0007231635	,000	,2080081936	,2114035976
		,5	, 1853927440*	, 0007231635	,000	, 1836950421	, 1870904461

Table 47: Descriptive Statistics Experiment 2 - gender equality step 6.

Descriptive Statistics

Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
,3	300	,6045826	,010190752	,000588363	,603424694	,605740410	,57730720	,630537568
,5	300	,6181714	,010832042	,000625388	,616940744	,619402184	,59363485	,738687888
,8	300	,7297855	,026332893	,001520330	,726793633	,732777439	,63090441	,792128094

Table 48: Tukey test - gender equality step 6.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	,3	,5	-,013588912*	,0014256428	,000	-,0169357578	-,0102420665
		,8	-,125202984*	, 0014256428	,000	-,1285498296	-,1218561384
	,5	,3	,013588912*	, 0014256428	,000	, 0102420665	,0169357578
		,8	-,11161407*	, 0014256428	,000	-,1149609175	-,1082672263

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
	,8	,3	,12520298*	, 0014256428	,000	, 1218561384	, 1285498296
		,5	, 11161407*	, 0014256428	,000	, 1082672263	, 1149609175

Table 49: Descriptive Statistics Experiment 2 - gender equality step 30.

Descriptive Statistics

Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Min	Max
,3	300	,5640011	,010680477	,0006166376	,562787648	,565214647	,5338824317	,6026136967
,5	300	,5883143	,007336088	,0004235492	,587480784	,589147814	,5712090376	,6132511249
,8	300	,7737070	,008212411	,0004741437	,772773962	,774640125	,7535078425	,8100507034

Table 50: Tukey test - gender equality step 30.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,0243131516*	,0007231635	,000	-,02601085356	-,0226154496
		,8	-,2097058956*	, 0007231635	,000	-,21140359763	-,2080081936
	,5	,3	,0243131515*	, 0007231635	,000	, 02261544958	,0260108536
		,8	-,1853927441*	, 0007231635	,000	-,18709044606	-,1836950421
	,8	,3	,2097058956*	, 0007231635	,000	,20800819364	,2114035976
		,5	,1853927441*	, 0007231635	,000	,18369504207	,1870904461

Table 51: Descriptive Statistics Experiment 2 - open access step 4.

Descriptive Statistics

Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Min	Max
,3	300	,5734225	,012043877	,00069535356	,5720540975	,57479091128	,5422879228	,6056157752
,5	300	,5722677	,011503676	,00066416501	,5709606306	,57357469064	,5402878716	,5998473791
,8	300	,5748068	,024167478	,00139530998	,5720609617	,57755270548	,5138892120	,6462359767

Table 52: Tukey test - open access step 4.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	,3	,5	,0011548438	,00138359958	,682	-,0020933010	, 004402989
		,8	-,0013843291	, 00138359958	,577	-,0046324739	, 001863816
	,5	,3	-, 0011548438	, 00138359958	,682	-, 0044029885	, 002093301
		,8	-,0025391730	, 00138359958	,159	-,0057873177	, 000708972
	,8	,3	, 0013843291	, 00138359958	,577	-,0018638156	, 004632474

		,5	, 0025391730	, 00138359958	,159	-,0007089718	, 005787318

Table 53: Descriptive Statistics Experiment 2 - open access step 6.

Descriptive Statistics

Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,6137970	,015320266	,0008845160	,6120563438	,6155376743	,5730313439	,6514918183
,5	300	,6146314	,015688863	,0009057970	,6128488669	,6164139563	,5740888329	,6523526352
,8	300	,6474619	,026642935	,0015382305	,6444348473	,6504891064	,5648528401	,7019204245

Table 54: Tukey test - open access step 6.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,000834403	, 0016266509	,865	-,0046531358	, 0029843307
		,8	-,033664968*	, 0016266509	,000	-,0374837010	-,0298462346
	,5	,3	, 000834403	, 0016266509	,865	-, 0029843307	, 0046531358
		,8	-,032830565*	, 0016266509	,000	-,0366492985	-,0290118321
	,8	,3	, 033664968*	, 0016266509	,000	, 0298462346	, 0374837010
		,5	, 032830565*	, 0016266509	,000	, 0290118321	, 0366492985

Table 55: Descriptive Statistics Experiment 2 - open access step 30.

Descriptive Statistics

Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,7627632	,0216035983	,0012472843	,760308597	,7652177331	,7003391046	,8170326687
,5	300	,7615863	,0200520960	,0011577083	,759308048	,7638646252	,7110976608	,8071913457
,8	300	,7641794	,0337667212	,0019495226	,760342912	,7680159592	,6631343801	,8663596635

Table 56: Tukey test - open access step 30.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	, 001176829	,0021129198	,843	-,0037834717	, 0061371287
		,8	-,001416271	, 0021129198	,781	-,0063765709	, 0035440295
	,5	,3	-, 001176829	, 0021129198	,843	-, 0061371287	, 0037834717
		,8	-,002593099	, 0021129198	,437	-,0075533994	, 0023672010
	,8	,3	,001416271	, 0021129198	,781	-,0035440295	, 0063765709

	,5	, 002593099	, 0021129198	,437	-, 0023672010	, 0075533994

Table 57: Descriptive Statistics Experiment 2- public engagement step 4.

Descriptive Statistics								
Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,5980560	,0210906227	,00121766767	,5956597540	,6004523227	,5444523826	,6423700302
,5	300	,5968975	,0212293403	,00122567653	,5944854239	,5993095143	,5416851345	,6413371207
,8	300	,5974946	,0321715557	,00185742563	,5938393491	,6011499151	,4575795651	,6786844766

Table 58: Tukey test - public engagement step 4.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	,001158569209	,0020712359	,842	-,0037038738	,00602101226
		,8	,00056140 6249	,0020712359	,960	-,0043010368	,00542384930
	,5	,3	-, 001158569209	, 0020712359	,842	-,0060210123	,00370387385
		,8	-,000597162960	, 0020712359	,955	-,0054596060	,00426528010
	,8	,3	-,000561406249	, 0020712359	,960	-,0054238493	,00430103681
		,5	, 000597162960	, 0020712359	,955	-,0042652801	,00545960602

Table 59: Descriptive Statistics Experiment 2 - public engagement step 6.

Descriptive Statistics								
Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,6493272	,030578707	,0017654625	,6458528695	,6528014814	,5807131206	,7154511185
,5	300	,6504991	,032552829	,0018794384	,6468005069	,6541977122	,5766006117	,7232993126
,8	300	,6812007	,040114044	,0023159854	,6766429910	,6857583838	,5530229586	,7652080145

Table 60: Tukey test - public engagement step 6.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	-,001171934	, 0028299511	,910	-,0078155404	, 0054716722
		,8	-,031873512*	, 0028299511	,000	-,0385171183	-, 0252299057
	,5	,3	, 001171934	, 0028299511	,910	-,0054716722	, 0078155404
		,8	-,030701578*	, 0028299511	,000	-,0373451842	-,0240579716
	,8	,3	, 031873512*	, 0028299511	,000	, 0252299057	, 0385171183
		,5	, 030701578*	, 0028299511	,000	, 0240579716	, 0373451842

Table 61: Descriptive Statistics Experiment 2 - public engagement step 30.

Descriptive Statistics								
Regulator	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
,3	300	,7817615	,05289778	,003054055	,7757513288	,7877716586	,6759295786	,9030333625
,5	300	,7769659	,05131648	,002962758	,7711354062	,7827964062	,6618640805	,8807996603
,8	300	,7730374	,05270482	,003042914	,7670491182	,7790256010	,6165990486	,9008063378

Table 62: Tukey test - public engagement step 30.

	(I) Regulator	(J) Regulator	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	,3	,5	, 004795588	,0042711837	,500	-,0052314630	, 0148226380
		,8	, 008724134	, 0042711837	,103	-,0013029164	, 0187511846
	,5	,3	-, 004795588	, 0042711837	,500	-,0148226380	, 0052314630
		,8	, 003928547	, 0042711837	,628	-,0060985039	, 0139555971
	,8	,3	-,008724134	, 0042711837	,103	-,0187511846	, 0013029164
		,5	-,003928547	, 0042711837	,628	-, 0139555971	, 0060985039

Table 63: Descriptive Statistics Experiment 3 - average of network invested capital.

Descriptive Statistics								
RRI-attractive-ness	Run	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
30	300	181,652	7,70695	,44496097	180,77655	182,52785	166,28137	202,31256
50	300	206,014	9,34652	,53962150	204,95169	207,07559	175,30122	237,79613
80	300	236,999	12,94094	,74714558	235,52870	238,469361	200,98118	281,59751
Total	900	208,222	24,86084	,82869461	206,59522	209,84802	166,28137	281,59751

Table 64: LSD and Tukey test Experiment 3.

	(I) RRI attractiveness	(J) RRI attractive-ness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	30	50	-24,36*	,836	,000	-26,001	-22,72141
		80	-55,35*	,836	,000	-56,987	-53,70682
	50	30	26,75*	, 836	,000	22,721	26,00143
		80	-33,83*	, 836	,000	-32,625	-29,34540
	80	30	55,35*	, 836	,000	53,707	56,98683

		50	30,99*	, 836	,000	29,345	32,62542
	30	50	-24,36*	, 836	,000	-26,323	-22,3997
		80	-55,35*	, 836	,000	-57,309	-53,3852
	50	30	24,36*	, 836	,000	22,400	26,32314
HSD		80	-30,99*	, 836	,000	-32,947	-29,02369
	80	30	55,35*	, 836	,000	53,385	57,30855
		50	30,99*	, 836	,000	29,024	32,94713

Table 65: Descriptive Statistics Experiment 3 - dimension of network.

Descriptive Statistics								
RRI-attractive-ness	**Run**	**Mean**	**Std. Dev.**	**Std. Error**	**95% Confidence Interval for Mean**		**Min**	**Max**
					Lower Bound	Upper Bound		
30	300	766,27	75,493	4,359	757,70	774,85	500	943
50	300	504,58	73,928	4,268	496,18	512,98	330	720
80	300	241,11	63,978	3,694	233,84	248,38	86	428
Total	900	503,99	226,034	7,534	489,20	518,78	86	943

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