Governance of Responsible Innovation

GREAT – 321480

Agent-based Model Prototype – Technical Report			
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Table of Contents

Figures

Tables

Glossary

Term	Determination
RRI	Responsible Research and Innovation
SCI	Scientific
INFSO-SKIN	Information Society and Media - Simulating Knowledge Dynamics in Innovation Networks
ICT-PSP	Information and Communication Technology for Policy Support Programme
CIP	Competitiveness and Innovation framework Programme
DFI	Diversified Firm
RES	Research Institute
SME	Small and Medium Enterprise
CSO	Civil Society Organisation

1. Overview

The GREAT simulation prototype is an agent-based model designed to simulate and analyse responsible research and innovation (RRI) aspects of research and innovation projects. The GREAT prototype is based on the INFSO-SKIN model used for simulating scenarios for collaborative research and innovation networks under various policy conditions using real-world data.

The GREAT model builds on INFSO-SKIN's main definitions in the following ways:

- Actors, represented by the 'agents' in the model, include research institutes, large diversified firms (DFI's), SME's and Civil Society Organizations (CSO's). Distinct classes of agents are used to define those four types of agents and characterize differences among them. The class definitions used in the model describe the agents and their behaviours in terms of their (different) initial knowledge profiles and their (different) capacities to contribute to research proposals and projects.
- Instruments and Calls for proposals are defined in the model, characterizing (only) one type of instrument: the ICT Policy Support Programme (ICT-PSP), which is part of the EU Competitiveness and Innovation framework Programme (CIP). The definition of the CIP ICT-PSP instrument that is used in the model describes the 'rules' for participation in the Programme. The Call definitions used in the model specify the requirements for participation in more detail, for example the orientation of certain Calls to certain thematic research areas.
- Proposals are created in simulation by consortia that are formed by the agents in response to the Calls. The proposals are submitted to the Commission. After a Call is closed, the submitted proposals are evaluated using eligibility and ranking criteria, which include scientific (SCI) criteria as well as RRI criteria (the latter is optional). Only the top ranking eligible proposals are awarded funding and become actual projects.
- Projects: The consortia carry out the proposed research. Distinct deliverables are produced in sub-projects, each dedicated to a particular innovative aspect of the research project. Learning among the project partners happens primarily within the sub-projects. A particular effect of this learning, relevant to RRI, may be a strategy change (this is optional and not implemented yet in the current prototype).

New features

For the GREAT application, new features have been added to the INFSO-SKIN model:

- The CSO agents are designed to realistically describe the individual knowledge profiles of CSO's and their capacities to participate in the CIP ICT-PSP Programme. For this purpose, the model's definition of the structure of the knowledge space is extended to include 'special' capabilities that only CSO's have.
- The CIP instrument and Calls are designed to realistically describe the rules for participation in the CIP ICT-PSP Programme. These descriptions are extended, in order to experiment with new modified designs for the instrument, for example through Calls that require the participation of CSO's and the inclusion of their 'special' capabilities in the proposals.
- The RRI-based evaluation rules for proposals and projects are designed and implemented conform the four dimensions of RRI: 'anticipation', 'participation', 'reflexivity' and 'responsiveness'. The overall simulation strategy with respect to these dimensions is explained in the next section.

Simulation strategy with respect to RRI dimensions

The simulation strategy used for this prototype is to measure all four RRI dimensions of the research and innovation process:

- Anticipation is the extent to which the utilisation of special capabilities (exclusively held by CSO's) required by the Call is matched by the proposals.
- Participation is the extent to which the participation of CSO's required by the Call is matched by the proposals.
- Reflexivity is the extent to which the diversity of capabilities required by the Call is matched by the proposals.
- Responsiveness is the extent to which strategy change is implemented during the projects.

Measurements of these four RRI dimensions may be performed for the evaluation of proposals and projects, as part of the eligibility and ranking criteria, together with the scientific criteria:

- The anticipation, participation and reflexivity scores are used for the evaluation of proposals. The three scores are computed while performing the eligibility check and are also used for the ranking of eligible proposals.
- The responsiveness score is used for the evaluation of projects. This score is computed while a project is doing the research, measuring the instances of strategy change (this is not implemented in the current prototype).

All RRI scores are numbers between 0 and 100 and plotted in histograms (Figure 1).

Balance between RRI and scientific criteria

The GREAT simulation prototype uses the same scientific (SCI) criteria for evaluation of proposals as the INFSO-SKIN model:

- Capability match is the extent to which the range of capabilities required by the Call is matched by the proposals.
- Expertise level is the average level of expertise that consortia members have in relation to the capabilities that they are contributing to the proposals.

Both scores are used for the evaluation of proposals. The scores are computed while performing the eligibility check and are also used for the ranking of eligible proposals.

Total balanced scores are derived, using weighted average, from the RRI and SCI scores (a parameter allows the user to alter the balance between the two sets).

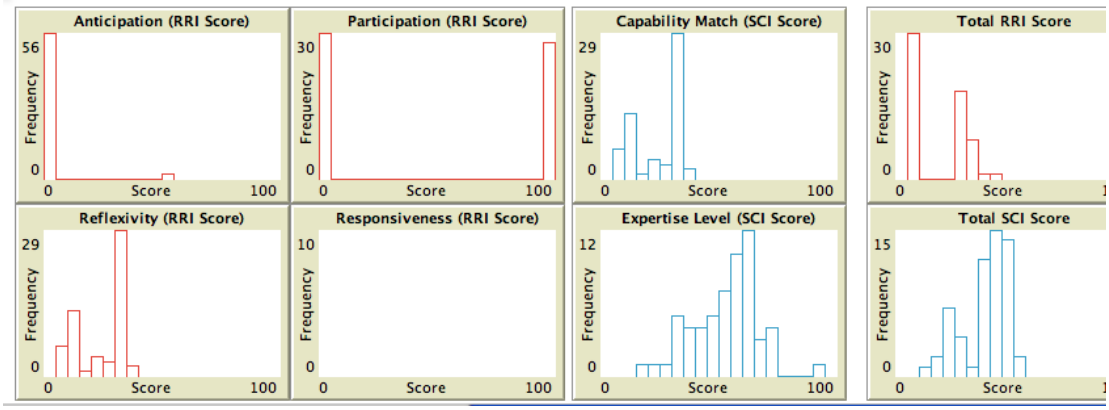

Figure 1: SCI and RRI score histograms

2. Model narrative

The model narrative tells the full story of the process that is simulated. The narrative is summarized by Figure 2 (model setup) and Figure 4 (a flowchart of the simulation).

2.1. Setup of the agents

The initialisation procedure of the simulation model sets up all the agents first. The agent population represents the number and types of actors that can be participants in EU-funded projects. Agents are R&D organisations (universities and research institutes (RESs)), R&D departments in large diversified firms (DFIs), small and medium sized enterprises (SMEs) and civil society organisation (CSOs).

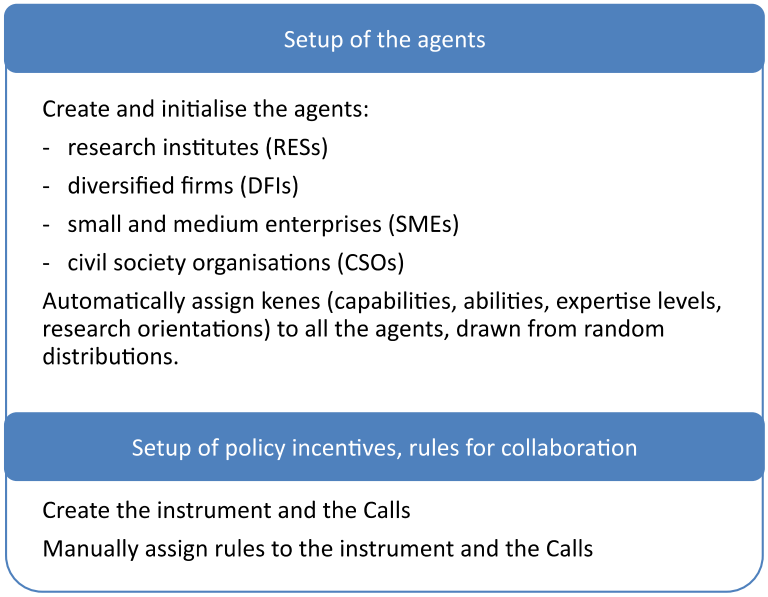

Figure 2: The initialisation of the simulation model

For representation of individual knowledge base of an agent we draw on the kene concept, introduced by Gilbert (1997), containing a number of "units of knowledge". Each unit of knowledge is represented as a quadruple of an agent's capability *C* (an integer), an ability *A* (a real number), an expertise level *E* (an integer) and a research orientation *R* (an integer).

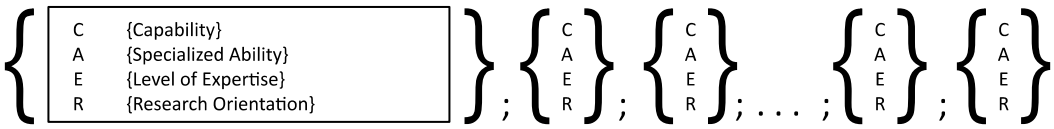

Figure 3: The kene structure

- The vector C (capabilities) represents different knowledge areas and technological disciplines, e.g. biochemistry, telecommunications or mechanical engineering. In order to cover all potential research areas encompassed in the CIP ICT-PSP call, the number of different capabilities needs to be chosen sufficiently large. The knowledge space is set up to contain 1000 different capabilities, within which 100 capabilities are allocated to a specific theme, resulting in 10 different themes.

- The vector *A* (abilities) represents the specialisation of the agent in these specific fields. In software development, for instance, abilities are front-end development, graphical user interface development, back-end development, etc.

- The advancement of the skills the agent possesses with respect to these abilities is represented with the vector *E* (expertise levels).

- The vector *R* (research orientations) represents the agent's general orientations, which can be related to basic or applied research. Values range from 0, indicating entirely theoretical knowledge (i.e. basic research) to 9, which indicates exclusively applied research. Values in between represent a mix of basic and applied research.

The four types of agents are all implemented in the GREAT prototype; see Table 1.

Agent types	Contribution (indicated by length of kene)	Objectives	Research orientation	Capacity for partnerships
RES's	Variety of knowledge	Publications, Patents	Basic or Applied	Large (>2)
DFI's	Variety of knowledge	Patents	Applied	Large (>2)
SME's	Rare knowledge	Patents, Publications	Applied	Small (1 or 2)
CSO's	Special knowledge	Publications	Applied	Small (1 or 2)

Table 1: Agent types and attributes

2.2. Setup of policy incentives and rules for collaboration

The EU provides funding for collaborative research. The rules for collaboration are defined in the Framework Programmes (e.g. the rules for project consortia, research topics, time span of the FP etc.). Actors (research institutes, firms etc.) want to apply for funding. The Calls of the Commission specify:

- the type of instrument under which the project is financed (CIP IPC-PSP). This specifies the minimum and maximum number of partners in a consortium, the composition of partners (e.g. the minimum number of SMEs and CSOs), and the duration of the project.
- the date of Call (to determine the deadline for submission)
- a range of capabilities, a sufficient number of which must appear in eligible proposals
- the thematic research areas and 'special' capabilities that appear in the Call's capability range
- the funding available for this Call
- the desired basic or applied orientation

For the instrument it can also be specified:

- whether eligible proposals should fulfil the RRI criteria
- the minimum scores of eligible proposals with regard to the RRI criteria and the scientific (SCI) criteria
- the weighting of the RRI criteria vs. the SCI criteria

2.3. Running the simulation model

A simulation run iterates over four main stages (Figure 4). The first stage is triggered when a Call is still open, the second stage when a Call is closed, the third and fourth depending on start and end date of projects. We define an iteration of the simulation to correspond to one month. This allows us to represent all processes in a reasonable order. For example, when a new Call is published, the deadline for a proposal is six months away, i.e. agents have six time steps to set up a consortium and to "write a proposal". The number of iterations is set to 120 iterations/months (10 years).

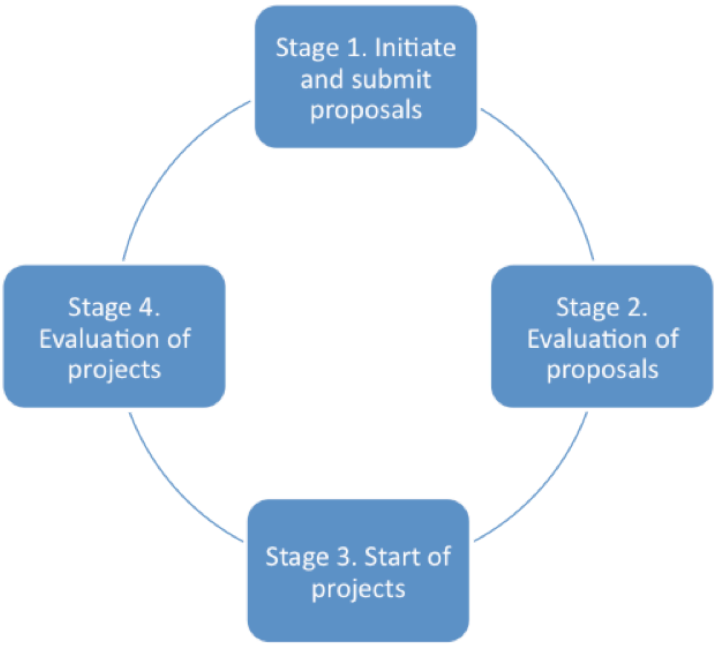

Figure 4: The main stages of the simulation

Stage 1. Initiate and submit proposals

Agents chose their partners in order to form project consortia based on partner choice mechanisms: firstly, previous partners are considered, secondly, any previous partner which is in the proposal may invite their previous partners, thirdly, new partners will be considered.

New partners are chosen based on the Call's requirements, which is a range (list) of capabilities. A sufficient number of these capabilities need to appear in the proposal for eligibility (i.e. "capability match"). If none of the agents' previous partners is able to contribute one of the capabilities required, in the next iteration step, the partners' previous partners are considered. If they cannot contribute, the search continues within the entire population of agents, randomly. In each step, *n* agents are checked for relevant capabilities and, if fitting, they are asked whether they wanted to join the consortium. The invited agents subsequently check their capacity for joining new proposals, which depends on the length of their kenes and the number of proposals and projects that they have already committed themselves to. An SME or a CSO, for example, both having kenes of minimum length, may therefore not be able to join another consortium in case they happen to be in one already. The same rules apply for the initiation of projects.

After all partners are selected, a proposal is produced, containing the relevant knowledge contributed by each partner (one or more capabilities per partner) and submitted to the Commission. A partner may only contribute as many capabilities as she has, and only the ones that are required by the Call. The proposal is submitted once a sufficient number of required capabilities are in the proposal.

Stage 2. Proposal evaluation and selection

The procedure for stage 2 of the simulation, in which the Commission evaluates the submitted proposals, depends on the user's inputs for model setup:

Option #1 - Evaluation using scientific criteria only

The Commission evaluates the submitted proposals based on scientific (SCI) scores only:

- The proposal has to be eligible, which means that it has to satisfy certain user-specified thresholds in terms of its number of consortium members (minimum and maximum), research orientation (basic or applied), etc.

- All eligible proposals are then ranked according to their SCI scores:

  - The expertise level score is the mean of the expertise levels of the partners in the proposal.
  - The capability match score is the ratio of the number of 'matching' capabilities of the proposal (i.e. those matching the Call's specifications) to the total number of capabilities in the Call's full capability range.

First, proposals are ranked according to their expertise level score. Proposals on the same ranking position are then ranked according to their capability match score.

Option #2 - Evaluation using scientific and RRI criteria:

The Commission evaluates the submitted proposals based on both scientific (SCI) scores and RRI scores:

- The proposals need to satisfy certain user-specified eligibility thresholds for the SCI scores (cf. Option #1) and also for RRI scores:

  - The anticipation score is the ratio of the number of matching 'special' capabilities of the proposal (i.e. exclusively held by CSOs) to the number of special capabilities specified in the Call.
  - The participation score is the ratio of the number of CSOs in the proposal's consortium to the minimum number of CSOs required by the Call.
  - The reflexivity score is the ratio of the number of non-special (matching or non-matching) capabilities of the proposal to the total number of non-special capabilities in the Call's capability range.

- All eligible proposals are then ranked according to their total balanced SCI/RRI score, with weights chosen by the user.

Selection of proposals

From the first position in the ranking downward, proposals are selected based on the available funding. Only the proposals that are selected can start their projects, all other proposal consortia are dissolved.

Stage 3. Cooperation and R&D

After a proposal is selected to be funded, the project stage starts. In projects, agents start to work on a project's innovation hypothesis, i.e. they interact and engage in collaborative research and learning activities trying to make the project's potential innovation a reality.

Doing the research in subprojects

The descriptions of the research and learning during the project stage follow the ideas of the INFSO-SKIN model, which means that at the start of the project all the consortium members are allocated to subprojects (if possible – it is assumed that for each subproject at least three partners need to be available). Within each subproject, the kenes of the partners involved are combined to form a subproject's innovation hypothesis, based on which every three months a research output is produced. For simplicity a subproject's innovation hypothesis is referred to as a 'deliverable' in the

following description. A deliverable is a vector of locations in the subproject's kene. So, for example, a deliverable might be [1 3 4 7], meaning the second (counting from 0 as the first), fourth, fifth and eighth quadruple in the kene of the subproject. The deliverable, however, cannot be longer than the length of the kene, nor shorter than 2, but is of random length between these limits.

Learning processes and knowledge sharing

The descriptions of the learning processes and knowledge sharing in projects follow a version of the SKIN model called SKEIN ("Simulating Knowledge Dynamics in EU-funded Innovation Networks", Scholz, Nokkala, Ahrweiler, Pyka and Gilbert 2010). Accordingly the research and learning undertaken in sub-projects is incremental (abilities are substituted, expertise levels are increased). Radical innovation, on the other hand, may occur in the moment when the proposal is put together, meaning that new combinations of capabilities may appear in the consortia. SMEs and CSOs are important candidates for contributing rare and special capabilities respectively:

- The involvement of SMEs increases the likelihood for radical innovation. Entirely new knowledge is injected into the system by the emergence of small, sophisticated companies. In order to allow the SMEs to play their special role we define 10 capabilities per theme as "rare" capabilities, giving these capabilities in the starting distribution exclusively to SMEs.

- Similarly, "special" capabilities are exclusively given to CSOs. Their involvement may be expected to increase the likelihood for responsible innovation.

The work on deliverables in subprojects has an impact on the expertise levels of the partners involved. Each iteration, whenever capabilities are used in subprojects, the expertise levels in relation to these capabilities are increased by 1.

Knowledge transfer in subprojects happens by exchange of capabilities used among the partners involved in the work on the deliverable.

When a project ends, it is delivered to the Commission. The project is then evaluated by the Commission.

Stage 4. Evaluation of projects

When the model is setup in accordance with option #2 of stage 2 (evaluation of proposals), the Commission uses both RRI scores and SCI scores for the evaluation of the projects. In contrast to the evaluation of proposals, however, the projects are now evaluated based on all four dimensions of responsible research and innovation, thus adding the responsiveness aspect. Responsiveness is the ability to learn from past experience and hence to adapt individual behaviour and strategies.

The RRI-score of a project can be computed as:

- The project's anticipation score is simply the proposal's anticipation score.
- Same for the project's participation score.
- Same for the project's reflexivity score.

- The responsiveness score is the extent to which strategy change is implemented during projects. This score can be computed while a project is carrying out the research, measuring the instances of strategy change.

Based on this evaluation the simulation model provides a detailed set of information on the RRI aspects in projects. The information can be used for example as criteria for strategy changes within projects, strategy changes for future proposals and finally also for changes regarding the specifications of a Call.

3. Conclusions

With the adaptation of the INFSO-SKIN for the GREAT project we designed an agent-based model to simulate and analyse responsible research and innovation (RRI) aspects of research and innovation projects. The INFSO-SKIN model was developed for simulating scenarios for collaborative research and innovation networks under various policy conditions using real-world data.

For analysing the different aspects of RRI the simulation prototype draws on the RRI concept introduced by Stilgoe et al. (2013) by implementing RRI as a process which can be measured and described based on the four dimensions: 'anticipation', 'participation', 'reflexivity' and 'responsiveness'. RRI in this context affects all actors within the system and hence cannot simply be reduced to one measure. Instead the implementation of RRI aspects must be based on a sound understanding on the processes involved and the liability and possibilities actors within the system. For this purpose, each RRI dimension is measured separately in the simulation and hence can be tracked and analysed throughout a simulation run on an aggregated level but also on an agent or project level.

The GREAT simulation model is designed as a policy laboratory, where the user can systematically alter simulation parameters and by this analyse the effects of different policy measures on the four dimensions of RRI. Using the RRI and SCI indicators, policy experiments can be implemented. The model outlined allows for testing the effect of for instance, various thresholds concerning the RRI score on the SCI score of projects. The complexity of the model however, calls for an intense sensitivity analysis where the prototype is tested and crucial and important key

mechanisms are identified. For this reason the simulation model provides a set of scenario settings where we can systematically compare and analyse the simulations outcome.

In a second step the simulation will be supplemented by a rich set of empirical data that can provide actionable information to calibrate the agent-based simulation.

We encourage you to run the simulation prototype using the instructions given in the appendix.

References

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ii. Scholz, R., Nokkala, T., Ahrweiler, P., Gilbert, N., Pyka, A. (2010): The agent-based Nemo-model (SKEIN): Simulating European Framework Programmes, in: Ahrweiler, P. (Hrsg.), Innovation in Complex Social Systems, Routledge Studies in Global Competition, 2010, 300-314.

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Appendix

The instructions for running the prototype are the following:

1) Running the model without CSO's, using only the SCI criteria:

Participant-settings	Small (no CSOs)
Instrument-settings	Baseline (0% RRI)
Calls-settings	Baseline (CIP)
Themes-settings	Baseline
Other-settings	Baseline

Table 2: Interface settings for the baseline scenario

2) Running the model with CSO's, using the SCI criteria and also the RRI criteria:

Participant-settings	Small with CSOs
Instrument-settings	Balanced (50% RRI)
Calls-settings	with special capabilities
Themes-settings	Baseline
Other-settings	Baseline

Table 3: Interface settings for the CSO scenario