Supplementary materials

1. Results and questions of survey 'Evaluation on INSPIRE's governance at the European level'

Welcome and thank you for your interest in this survey!

The goal of this survey is to measure the (perceived) governance of INSPIRE at the European level. This survey focuses on a broad range of governance aspects. When answering this survey we would like you to focus on the governance of INSPIRE at the European level (*). This means focusing on e.g. the set regulations by the EU (e.g. on data, technology and standards) and the interactions between INSPIRE stakeholders, such as member states, with EU institutes. The governance of INSPIRE within a national member state is not in scope of this survey (e.g. coordination and collaboration between regional bodies within a country).

Answering the survey takes approximately 10-15 minutes. Your answers will be processed anonymously. Please provide an answer how you experience the governance of INSPIRE. When you do not have an opinion on a subject, you can skip the question.

The survey will give an overview of potential issues on the governance of INSPIRE. As respondent you will get the opportunity to provide your e-mail address to receive the survey results at an early stage.

This research is independently conducted by the Wageningen University and KU Leuven. You can provide your answers through this survey until Thursday 26 November.

(*) We intentionally use 'European level' instead of 'European Union level' as we do not want to suggest that this survey is about how the EU is governing INSPIRE.

Information about your role in INSPIRE

1.) What is your organisation's role in INSPIRE? Multiple answers are possible.	**Executive:** e.g. busy with coordinating, policy making, managing, legal aspects, standards	**Data provider:** e.g. busy with collecting, transforming, harmonising and delivering data	**Platform provider:** e.g. busy with hosting INSPIRE webservices, delivering data to users, delivering technological building blocks	**Data user:** e.g. busy with using INSPIRE or developing products based on INSPIRE data and services	**Researcher**: e.g. busy with monitoring or analyzing INSPIRE and its progress	**Other**
Response	38	32	26	13	8	0

2.) Years of involvement in INSPIRE	**Absolute**	**Relative**
Less than 1 year	1	1.8%
Between 2 and 3 years	5	9.1%
Between 4 and 5 years	5	9.1%
Between 5 and 10 years	10	18.2%
More than 10 years	34	61.8%
Total	**55**	**100.0%**

3.) Do you currently work on EU-level or on member state level on INSPIRE?	**Absolute**	**Relative**
Member state level	48	87.3%
Non-member state level	2	3.6%

EU level	4	7.3%
Other, namely	1	1.8%
Total	**55**	**100.0%**

This question was only presented when respondents chose 'member state level' in question 3.

4.) At which member state do you work?	**Response**
Countries with 0 response	Ireland, Lithuania, Poland
Countries with 1 response	Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Hungary, Italy, Malta, Romania, Slovakia, Slovenia, Sweden
Countries with 2 responses	Greece, Latvia, Luxembourg, Netherlands
Countries with 3 responses	Germany, Spain
Countries with 5 responses	Portugal
Countries with 13 responses	Czech Republic

This question was only presented when respondents chose 'non-member state level' in question 3.

5.) At which non-member state do you work?	**Response**
Countries with 0 response	Iceland, Liechtenstein, North Macedonia, Serbia, Turkey, United Kingdom
Countries with 1 response	Norway, Switzerland, unknown*

**this respondent indicated in question 3 to work at a EEA member, but because the respondent did fill in 'other' instead of non-member state, the country is unknown.*

This question was only presented when respondents chose 'EU-level' in question 3.

6.) At which EU department or agency do you work?	**Response**
Agencies/departments with 0 response	European Environment Agency (EEA), DG Communications Networks, Content and Technology (DG Connect)
Agencies/departments with 1 response	DG Environment (DG Env), Joint Research Centre (JRC)
Agencies/departments with 2 responses	Eurostat

View of INSPIRE

7.) How satisfied are you with INSPIRE? 10= Very satisfied, 1= not satisfied at all	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Frequency	1	0	1	2	9	8	21	11	1	1

Descriptive statistics	**N=**	**Avg.**	**Med.**	**Mode**
	55	6.5	7	7

The scale for answering was as follow: 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

8.) What is your overall view on the governance of INSPIRE at the European level?	**Governing aspect (image)**	**1**	**2**	**3**	**4**	**5**	**N=**	**Avg.**	**Med.**	**Mod.**
INSPIRE is adequately governed	Satisfaction	1	6	22	24	2	55	3.4	3	4
INSPIRE has a clear goal and vision	Goal/ Vision	1	3	11	30	10	55	3.8	4	4
I support the goal and vision of INSPIRE	Goal/ Vision	1	0	4	30	19	54	4.2	4	4
Opinions on INSPIRE are aligned among its stakeholders	Alignment	2	18	24	8	0	52	2.7	3	3
There is room for feedback in the INSPIRE governance	Feedback	1	2	12	37	1	53	3.7	4	4
The INSPIRE governance responds to feedback	Feedback	1	7	17	27	1	53	3.4	4	4
Important decisions on INSPIRE are made collaboratively	Collaborative	1	4	15	30	4	54	3.6	4	4

9.) Any additional comments on your view on the governance of INSPIRE?
Although there's room for feedback within the INSPIRE Governance, the detailed legal framework leaves little room for adjustment.

Goal and Vision stands for years! But the execution should be more actual and accept new standards and technology
I like the basic idea of INSPIRE ... sharing data with own responsibility ;-) But... it is sometimes forgotten...
INSPIRE governance is not very agile. There is room for improvement.
INSPIRE is 100% top down. Imposition by geospatial standardisation bodies and companies controlling EU decision processes.
Since the very beginning of INSPIRE I would support "stronger" and "more direct" obligations. Member states would be against, but EU should have been much stricter. (the easiest example - metadata obligatory in English). Being stricter, I think, the results would have been much earlier, better for use etc.
Stable user-supporting validation tools (provided by the European governance) were missing for too long. This was a weak part of the governance feedback. Some technical changes have not been supported by needed specification up-dates.
The governance could be communicated better.
The INSPIRE knowledge base web has been set up too late and is not very user-friendly (even though it's much better than the previous web). Too many sources of information and platforms are confusing for data providers, who do not have the full capacity just to work on INSPIRE.
The strong binding to legislative aspect does not allow the suitable flexibility for technical implementation that would reach to better operable solutions. Highlighting best practices is a limited way for improvement. Adaptation to new rules and guidelines are too slow.

Instruments of INSPIRE

10.) What kind of governance form is the most dominant in INSPIRE's governance at the European level? Rank from most dominant to least dominant	Hierarchical governance (top down governance, e.g. governing by legal obligations and requirements)	Network governance (horizontal governance, e.g. collaboration in working groups with a mix of stakeholders, exchanging knowledge and ideas)	Laissez-faire governance (central governance is absent, which gives room for e.g. self-organized public and private bottom-up initiatives)
First choice	32	13	8
Second choice	8	32	13
Third choice	13	8	32

Question	**Average**	**Median**	**Mode**	**N=**
11.) Estimate how much hierarchical governance is used in the governance of INSPIRE at the European level? Please express in percentages (%).	52.0%	50.0%	50.0%	53
12.) Estimate how much network governance is used in the governance of INSPIRE at the European level? Please express in percentages (%).	39.5%	40.0%	50.0%	53
13.) Estimate how much laissez-faire governance is used in the governance of INSPIRE at the European level? Please express in percentages (%).	17.9%	10.0%	10.0%	53

14.) Any additional comments on the governance types used at the European level of INSPIRE?
I am an advocate of governed and to some extent centralised way of building INSPIRE. Otherwise we do not have any standards.
I do know the answer to questions 8-11. I don't have knowledge/overview about it. But I cannot leave the answer empty - so I just tip 50% everywhere.
I think laissez faire is not desirable for an infrastructure such as INSPIRE but too many aspects of INSPIRE were unclear at the beginning.
INSPIRE is ruled by comitology that is driven by the regulation. The Commission and the Member States discuss the evolution of the legal framework in the INSPIRE Committee. Furthermore INSPIRE is governed by the MIF (Maintenance and Implementation Framework) that has two pilars, the INSPIRE Committee and the INSPIRE expert group (MIG). The INSPIRE MIG governs the technical evolution and implementation of the Directive.
Pseudo consultations where only the voice of standardisation bodies and companies are listened. Target users are totally absent. without users involvement and feedback, no possible good result.
The European Commission bodies should be the first to comply with the INSPIRE Directive and therefore comply with the regulations.
The legal obligation has been the key motor for implementation and the biggest constraint.
The network governance was dominant (and appreciated) at the preparatory stage of INSPIRE. The hierarchical form was the basis for the implementation stage, but still accompanied with the network form to some extent. Unfortunately, the future planning - built nowadays on ambitious studies of consultancy companies - seems to underestimate the realisation perspective. This turns the governance to the hierarchical approach even more.

INSPIRE in action

The scale for answering this question was as follow: 1 = Very absent; 2 = Absent; 3 = Not present/absent; 4 = Present; 5 = Very present

15.) Which of the following aspects do you see in practice regarding INSPIRE?	Governing aspect	1	2	3	4	5	N=	Avg.	Med.	Mode
Leadership	Leadership	0	6	12	29	6	53	3.7	4	4
Corodination	Coordination	1	2	6	39	6	54	3.9	4	4
Self-organisation (e.g. emergence of spontaneous initiatives around INSPIRE)	Self-Organisation	2	7	9	28	6	52	3.6	4	4
Collaboration	Collaboration	2	1	8	35	8	54	3.9	4	4

16.) Any additional comments on these aspects?
All these aspects are present and relevant to specific situations.
it is worse than expected
strong leadership, but not by the right type of persons. Need for user-oriented approach. Listen to target users. The most important at least.
There should be stronger emphasis on holding up to INSPIRE principles of interoperability and standardization. However, INSPIRE must provide simple yet more powerful tools and software development toolkits to do so in the future.

INSPIRE's structures

The scale for answering this question was as follow: 1 = Very constraining; 2 = Constraining; 3 = Not enabling/constraining; 4 = Enabling; 5 = Very enabling

17.) Indicate if the following aspects of INSPIRE's governance at the European level are enabling or constraining INSPIRE implementation.	Governing aspect	1	2	3	4	5	N=	Avg.	Med.	Mode
Roles and responsibilities	Roles & Responsibilities	1	6	8	30	4	49	3.6	4	4
Ownership	Ownership	4	10	11	17	2	44	3.1	3	4
Law	Law	3	8	9	23	7	50	3.5	4	4
Budget resources (availability or access to financial resources)	Budget	14	18	9	8	3	52	2.4	2	2
Time resources (capacity)	Time	8	23	9	9	2	51	2.5	2	2
Knowledge resources (availability or access to knowledge)	Knowledge	5	15	7	18	7	52	3.1	3	4
Political capital (easy access to political power)	Political capital	4	13	22	9	0	48	2.8	3	3
Social capital (easy access to social network)	Social capital	0	8	22	16	2	48	3.3	3	3
Standards	Standards	2	7	2	26	14	51	3.8	4	4
Technology	Technology	2	8	5	23	14	52	3.8	4	4
Political support	Support	3	10	19	14	2	48	3.0	3	3
Support from INSPIRE stakeholders	Support	4	8	13	16	8	49	3.3	3	4
Trust	Trust	3	10	17	14	4	48	3.1	3	3
National cultures	Culture	4	10	22	9	2	47	2.9	3	3
Organizational cultures	Culture	2	15	15	13	3	48	3.0	3	3

18.) Any additional comments on these aspects?
Currently low usage of the INSPIRE datasets. The factors are worth for a analysis.

INSPIRE is open to all and stands up to the visions of free Europe and the European Union. In my opinion, it tries treating providers/users in that way. On the other hand, INSPIRE is very burdened with bureaucracy as are other institutions and initiatives in the EU. INSPIRE should more emphasise national data providers to remove barriers from obtaining their (often tax-funded data) data.
not sure what to answer here
Sorry, I don't understand the question very well...
The answers apply to the current situation as certain aspects have changed since the beginning of the INSPIRE framework.
There were different needs and constrains during the nearly 2 decades of INSPIRE. The political support was needed at the beginning to establish the legislation framework. The expert knowledge, capacities of various sorts are needed to implement successfully.

INSPIRE's results

The scale for answering this question was as follow: 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

19.) How do you rate the following aspects of INSPIRE?	**Governing aspect**	**1**	**2**	**3**	**4**	**5**	**N=**	**Avg.**	**Med.**	**Mode**
Data provision	Data provision	1	7	27	16	4	55	3.3	3	3
Data sharing	Data provision	2	5	22	17	7	53	3.4	3	3
Data availability	Data availability	2	6	11	23	11	53	3.7	4	4
Data access	Data availability	2	5	18	21	8	54	3.5	4	4
Data content	Data content	2	14	21	11	5	53	2.9	3	3
Data use	Data use	10	18	13	10	2	53	2.5	2	2
Data usefulness	Data content	6	12	19	10	5	52	2.9	3	3

20.) Any additional comments on the results of INSPIRE?
Currently low usage of the INSPIRE datasets. The factors are worth for a analysis. INSPIRE data content does not reflect the identified datasets content.
As an example of data use: Viewers of European Commission should use official WMS/WNTS and not Google Earth or open Street Map information.
Cadastral data - good example for the others (CUZK nr. 1) ;-)
I support the goal of INSPIRE but the data specifications and means of provision of data are too complicated for data providers and not very useful for the users in my opinion. The whole process should probably have been done in more stages with different levels of harmonization - first the terminology (a BIG step), then the structure, then the provision. But I think that big progress has been achieved in data discoverability by metadata, so probably the rest will follow as well. It just takes a lot of time (the obligation of metadata provision has been here for 10 years now, so the data will probably take this time as well, or even more...).
inspire is not helping. a burden only. no usage. no added value
INSPIRE provided a common formal framework for building up SDIs in MSs and across EU. It supported a coordinated approach. It enforced the provision and usage of standardized metadata and a broad application of webmap services. It introduced the data sharing approach. The INSPIRE datasets originally were planned for technology-independent data exchange for cross-border (even EU wide) solutions. They were not thought to replace the national products and services. Expecting their everyday use everywhere is not needed and such expectations lead to disappointments.
It is unclear what is the meaning of the data in this case. Is it information as documents, protocols, meetings information or data as spatial data, schemas?
sharing only helps if really all data owners participate
technical and content interpretation of INSPIRE left open too many essential aspects and at the same time was over ambitious, this lead to many interoperability and data quality issues.
The data usefulness for public and private sector is high, certainly in view of the green and digital twin transition. Few MS provide direct access to source systems. Data sharing obstacles and reuse limitations still exist impeding data access. A lot of data has been documented showing high data availability in MS. The data offer across the EU is diverse and still lacks comparability and compatibility, limiting pan-EU reuse.
There is non-efficient way in filtering data. When INSPIRE states so many requirements in metadata, why these are not utilized in, e.g. improved filtering in INSPIRE web interface and so on? Not everyone is a programmer, who can connect to API, ATOM and such services...

Concluding remarks

The scale for answering was as follow: 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

21.) How do you rate the following concluding statements?	1	2	3	4	5	N=	Avg.	Med.	Mode
Considering all aspects I am satisfied with INSPIRE	2	2	20	28	3	55	3.5	4	4
Considering all aspects I am satisfied with the governance of INSPIRE at the European level	0	11	20	22	1	54	3.2	3	4
I worry about the future of INSPIRE	2	9	21	19	4	55	3.3	3	3
I worry about the future governance of INSPIRE at the European level	2	7	24	17	3	53	3.2	3	3

22.) Do you have any recommendations on INSPIRE's current governance state or its future?
be more prescriptive and simple in the way INSPIRE should be implemented.
Demand should be central in the governance. INSPIRE is supply-oriented. The Commission is on the right track by linking INPISRE with the green deal data space.
Future governance is unclear to me, will current governance be continued or changed? Basically governance could be more agile in the future.
I was very surprised at a WS on future of INSPIRE, where some of the EU countries expressed that their governments consider INSPIRE being a project with given deadlines. These countries are not planning any development or follow up. They believe, that they are asked to publish harmonised data sets in 2021 and "that's it". They are not planning to keep the data updated etc. Hope my description is clear. If not, please do not hesitate to ask me.
in fact, I do not worry about inspire future because it has no future and that is a good thing
Less bureaucracy, more effective requirements enforcement but be open to changing them. Better propagation of INSPIRE to become somewhat famous. In other words, do an INSPIRE marketing, like if you were a private company (yes, I am saying that :)).
More PR, even constant PR; more support from political and professional bodies is essential
The European Commission should set an example by using official data, and not asking Member States for shapefile data. Only interoperable formats such as gml should be used The European Commission should provide tools to publish the data and thus facilitate the publication of the data in an interoperable way. For example, to publish INSPIRE spatial data on the European Data Portal. What is the tool for migrating INSPIRE metadata to GeoDCAT-AP?
The SDI approach adopted in inspire is obsolete and can only bring complex solutions to a simple problems. We need more centralisation, not only for governance but for the entire GI management processes.
There are still tasks to be finalized by MIG-T and the MSs to reach an entire INSPIRE. The lessons learned by the ELF and ELS pilot projects have shown, that there is no strong actor in this stage to run a stable EU+wide infrastructure for interoperable seamless spatial data and services in a sustainable way (relevant formal competence, finances, capacities). Each of the players provides some parts but faces limitations to enable the complex/entire infrastructure to happen and to sustain as a reliable data service.
There is a tremendous work done till now. It´s very important to give a strong bust right now to achieve the most important objective, to have seamless datasets across Europe. The benefits will be great.
To build upon the efforts already provided by the MS. This should not be lost. The main positive point is the setup of the INSPIRE infrastructures, enabling access and availability to the data. In that perspective INSPIRE should remain a standard for the future. The INSPIRE geoportal is a success (Thanks to JRC!). However the INSPIRE data and specifications need to be deeply revised with new concepts and approaches, which probably means a revision of the legal aspect as well. In that perspective, the European leadership and governance has to be very strong with close collaboration with the MSs Proposal: Regarding the INSPIRE compliancy of the datasets, the 'All' datasets should be better defined at European level and not only at MS level. A specific selection of datasets usable at Pan-European level should be setup with priory for INSPIRE compliancy. The data specifications should therefore be refined accordingly. Therefore, SEVERAL DATA SCHEMAs and CONTENTs might be created for a SAME THEME depending of the identified datasets . This does not necessarily implicate additional burden to reach INSPIRE compliancy, but should lead to DECREASE the CONSTRAINTS on order to meet INSPIRE COMPLIANCY at legal and guideline rules level. For example: LIMITING DATA INSPIRE COMPLIANCY to ontologies, semantics and registries and basics for data modelling (legal obligations). DATA SCHEMA, CONTENT and ENCODING will be OUT of Scope of INSPIRE COMPLIANCY. The DATA SPECIFICATIONS (schema, content and encoding) will be customised in a case to case situation to fit to the IDENTIFIED pan-European DATASETS and NOT to a DATA THEME. However, the INSPIRE COMPLIANCE keeps the way the DATA SPECIFICATIONS will be defined.

This approach might decrease the burden to formally reach the INSPIRE data compliancy with the advantage to provide more usefull datasets adapted to new tendancies and needs by the fact that their data specifications as such might evolve outside INSPIRE.
we hope that activities in INSPIRE spirit will continue

Results of the questionnaire

Below you can provide any additional comments or your e-mail address to receive updates on the research results. Please hit the submit button (in your own language) to submit your answers. Otherwise your answers are not stored!

23.) Do you want to place any remarks on INSPIRE or this questionnaire?
Building up any infrastructure requires a lot of time; some times it returns in cycles (dependent on resources and/or new technical tools). It will happen.
I like INSPIRE ;-) but I am afraid of the future of it ;-)
I was involved in the INSPIRE awareness rising and early implementation. Since 2016 I have been following the INSPIRE activities "from the distance". My answers can be slightly shifted due to this fact. Thanks for keeping INPSIRE going!
INSPIRE is GREAT, but improve FLEXIBILITY and ADAPTABILITY.
It is OK!
maybe a general questionnaire on inspire should be good. governance is not the main issue here. Would be good to have it translated, for better impact.
No
NO
Some of the questions should be followed up with further clarification and interpretation. Different interpretations may lead to different answers.
The SDI approach adopted in inspire is obsolete and can only bring complex solutions to a simple problems. We need more centralisation, not only for governance but for the entire GI management processes.
Meaningful research!

2. Overview, Design Concepts, Details – SDI Governance Model applied on INSPIRE

The model description follows the ODD (Overview, Design concepts, Details) protocol for describing individual- and agent-based models ((Grimm et al. 2006; Grimm et al. 2010)). This ODD accompanies the research article *The future of INSPIRE: Exploring governance scenarios for the European Spatial Data Infrastructure.* As this article uses the model from Sjoukema et al. ((Sjoukema et al. 2021)) only with a few modifications, the same ODD is used. Modifications to the ODD, and thus the model, in order to better fit the context of INSPIRE are highlighted.

1. Purpose

The purpose of Spatial data infrastructure (SDI) governance model is to provoke discussion among SDI governors by simplifying and simulating SDI governance. It contains three important governance processes: interactions between actors, interactions between actors and resources and interactions between actors and the SDI. These governance processes are simulated in an agent-based model. The purpose is not to predict SDI governance or to imply all factors which influence SDI governance, but to better understand SDI governance and to gain insight for actions for proper steering of SDI governance in the future.

2. Entities, state variables, and scales

There are four actors in the model, each with specific properties and different roles. The actor's roles represent the (group of) organisations involved in the process of SDI governance and should be seen as aggregations for the actor group they represent. The four actor roles are:

1. SDI executive: this actor role represents the executive branch of government that has authority and responsibility for the SDI. In many cases, the SDI executive has the role of 'policy maker' or coordinator, and determines the mission and vision of the SDI. The SDI executive is in many cases the most influential actor in SDI governance (see e.g. Coetzee et al. 2018; Coetzee et al. 2019).
2. SDI Data Providers: This actor role represents the organisation(s) who delivers spatial data to the SDI. It can also be seen as data producer.
3. SDI Platform Provider: This actor role represents the organisation(s) who maintains and updates the infrastructure and plays a central role in bridging data from SDI data providers to SDI users. It can have the role of provider or broker.
4. SDI users: This actor role represents the organisations(s) who uses the spatial data from the SDI. SDI users use spatial data as end-user or as value added re-seller.

All actors own two main attributes which will change over time: satisfaction and resources (budget). Both budget and satisfaction range from 0 to 10, where 0 means 'not satisfied at all' or 'no resources at all' and 10 means 'very satisfied' or 'a lot of resources'.

The satisfaction represents the satisfaction of the actor with the SDI and its governance in a broad sense. When all actors are dissatisfied (their mean satisfaction is below 1), the model will stop running. When the amount of budget of the SDI executive increases its satisfaction will also increase and vice versa.

The SDI Data Provider and SDI platform provider will spend their resources to maintain the SDI which is represented by a data quality flow. This data quality flow also uses a 0 to 10 scale, representing the availability and quality of spatial data through the SDI. The value of 0 represents no data available or at a very poor quality, the value of 10 represents high quality/availability of data.

The allocation of budget to the SDI data provider and SDI platform provider has been defined with four different scenarios: 1) piecemeal funding in which the budget is allocated project-based (every 5 time steps) by the SDI executive; 2) continuous funding in which there is a steady and stable budget allocation by the SDI executive; 3) pay-per-use funding in which SDI-user will pay the SDI data provider and SDI provider provided that the quality of used data is good and acceptable; 4) INSPIRE financing in which the SDI data provider and SDI platform provider cover their own costs for the SDI until they cannot afford it anymore. When the data quality decreases, they gain extra resources so they can spend it again on the SDI.

There is no spatial scale in SDI governance model. SDI governance can be evaluated within different temporal scales (e.g., daily, monthly and yearly scales). The ticks (time steps) resemble the development of the model over time and its relation with real time is not specific. Thus, ticks should not interpreted in temporal scale of weeks or months but results should be assessed relatively.

3. Process overview and scheduling

At every time step, the following flow is followed subsequently:

Actor interactions

First the type of message (hierarchy, network or no message) is determined. Every message has an equal 1/3 chance of being selected. However, depending on input sliders set by the observer, the chance on a certain message can be affected. When a message is selected a random number is created which will be compared with the setting of the input slider for this message type. When the random number is higher than the setting of the slider, the procedure is started over. When the random number is lower, the sender of the message is selected.

It is possible for the observer to change this fixed mode to adaptive mode. In adaptive mode, the input sliders which influence the chance on a message can be automatically adjusted. It works as follow:

After 15 ticks the average satisfaction of actors is evaluated. If it is higher than 7.5, the settings remain the same. If it is lower than 7.5, the distribution of sent message types is compared. For example, if the amount of sent hierarchy messages is higher than the amount of sent network messages, the slider which influences the chance on hierarchy messages is set -10. If the amount of hierarchy messages is also higher than the amount of no messages, again the slider is set -10. However, if the amount of hierarchy messages is lower than the amount of network messages, the slider is set +10. The same mechanisms apply to the other type of messages.

In order to prevent a message type to become overly dominant or underrepresented, two boundary conditions are set: if the chance on a message type goes over a setting of 80, the setting is set back -20. If a setting goes under the 20, the setting is set +20.

If the selected message is a hierarchy message, then the SDI executive is selected as message sender. Else (the selected message is a network or no-message), one of the four actors is selected randomly and determined as message sender.

Then the receiver of the message is selected. This is done by selecting a random actor which is not the sender of the message. The message receiver is also called the feedback sender.

Before the message is send, the actor checks its budget. If it is budget = 0, the actor will override the message with a no message.

Then the message is (visually) send to the selected receiver.

The actor who receives the message will assess it:

- If the message is a hierarchy message and the previous received message is also a hierarchy message, the satisfaction of the receiver is set -2 and its feedback is set to -0.5. Else, the satisfaction of the actor is set to +2 and the feedback is set to +0.5.

- If the message is a network message and the previous and before previous message were also network messages, the satisfaction of the receiver is set to -2 and its feedback is set to -0.5. Else, the satisfaction is set to +1 and its feedback to +0.5.

- If the message is a no message and the previous and before previous message were also no messages, the satisfaction of the receiver is set to -2 and its feedback is set to -0.5. Else, there is no change in the satisfaction or the feedback of this receiver.

Then the receiver will remember the message and store the previous message (message-1) as before previous message (message-2). The actually received message will be stored as previous message (message-1).

If the satisfaction of message receiver is greater than 5, +1 is added to the feedback. If the satisfaction of the message receiver is smaller than 5, -1 is added to the feedback. If the satisfaction of the message receiver equals 5, then the content is not effected (feedback = 0).

Together with the feedback based on the received message, the total feedback is send to the message sender. If this feedback affects the message sender is dependent on the 'susceptibility to feedback' input slider. With this slider, the chance of feedback getting to the message sender can influenced on a 0 to 100% scale.

Budget interactions

At every time step, budget interactions also occur. The SDI executive gains budget based on the selected budget scenario. In the model there are four budget scenarios: piecemeal funding, continuous funding, pay-per-use funding and INSPIRE financing.

- Piecemeal funding: With piecemeal funding, budget is provided without a coherent long term vision or strategy, for example by projects. This funding is implemented in the model as such in every 5 ticks 2.5 amount of money goes to the SDI executive. Every time step, the SDI executive allocates 0.25 to the SDI data provider and 0.25 to the SDI platform provider.
- Continuous funding: With continuous funding, there is a stable flow of budget covering the main costs of the SDI. In this type of funding, in every tick 0.5 amount of money is sent to the SDI executive. Every time step, the SDI executive allocates 0.25 to the SDI data provider and 0.25 to the SDI platform provider.

- Pay-per-use funding: In this scenario, not the SDI executive but the SDI users will recover the costs of the SDI data provider and SDI platform provider by paying for the data if the quality is good enough (data quality > 5). In this model, budget is divided from the SDI user to the SDI platform provider (0.25) and the SDI data provider (0.25) if the data quality is greater than 5.
- INSPIRE financing: In this policy, the SDI data and SDI platform provider pay the maintenance costs until they cannot afford this anymore (budget is < 0.25). If the data quality is still good according to the data user, this situation remains. However, when they get negative data feedback (feedback-data) from the user, they will invest extra to improve the data quality. When their budget hits 0, they gain +3 budget to make these investments.

The amount of budget of the SDI executive also affects his satisfaction. If the amount of budget is higher than 6, his satisfaction increases + 0.5. If the amount is between 3 and 6, his satisfaction is not affected. If it is below 3, satisfaction is decreased with – 1. Other actors are not affected by the amount of budget they possess.

Data interactions

Then the model enters the phase of data dissemination. The SDI data provider and SDI platform provider send data to the SDI user.

- If the satisfaction of SDI data provider is greater than 5, then quality of data is increased by 0.5.
- If satisfaction of SDI data provider and SDI platform provider is smaller than 5, then data quality decreases by 0.5.
- If satisfaction of SDI data provider and SDI platform provider is equal 5, then data quality will not change.

The same mechanism applies to the SDI platform provider, increasing or decreasing the total data quality.

The SDI user will send feedback to the SDI data provider and SDI platform provider based on the data quality. This is separate stream of feedback, called feedback-data. If the data quality is greater than 5, positive feedback is sent (+1). If data quality is smaller than 5, negative feedback is sent (-1). If data quality is equal 5, then the feedback equals 0 and no feedback is sent.

The SDI data provider and SDI platform provider have to spend budget to maintain the data quality. If they have enough budget (> 0.25), they pay 0.25 each. Else, the data quality diminishes by - 0.25 per actor.

When the data feedback is negative, the SDI data provider and SDI platform provider can improve the quality of data if they have enough budget. In the model, if the data feedback is negative (< 0) and SDI data provider and SDI platform provider both have more than 0.2 budget, then they both allocate 0.25 of money and the data quality increases by 0.5. If one of the actors has less budget than 0.2, than the other actor allocates 0.5 budget and increases the data quality by 0.5. If both actors have less budget than 0.2, the data quality decreases with -1.

In case of good quality of data, SDI user will increase its budget and satisfaction. If the data quality is greater than 5 than the SDI user will gain 0.5 budget. If the data quality greater than

8, the satisfaction of the SDI user increases by 1.5 in the model. If the data quality is between the range of 5 to 8, then the satisfaction of SDI user increases by 1. If the data quality equals 5, this will not influence the satisfaction of SDI user. If the data quality is between the range of 5 to 3, then the satisfaction of the SDI user decreases by -1. If the data quality is between the range of 2 and 0 will decrease the satisfaction of SDI user by -1.5. And if the data quality equals 0 then satisfaction of SDI user will decreases by -2.

To end the time step, a time penalty is set where the satisfaction of all actors decreases with 0.2 at the end of each time step.

4. Design concepts

Basic principles.
The idea to design the model was taken from the signalling game modelling approach (reference: Netlogo library). In this approach, the involved actors communicate with each other in order to understand their current state of environment. In the context of SDI governance, the four actors (SDI executive, SDI provider, SDI data provider and SDI user) interact in order to achieve a successful governance of the SDI system. The model was initiated with the two actors of SDI executive and SDI user and later on, more complexity was introduced including SDI platform provider and SDI data provider actors. Later on, the budget interaction and data flow within the SDI system (SDI platform provider, SDI data provider and SDI user) were added, which still can be switched off with a switch. The purpose of the added complexity is to simulate the interactions among the four actor roles involved in the process of SDI governance, while maintaining the SDI system.

Emergence
Based on the inputs set by the observer at the start of the model (chance on hierarchy messages, network messages and no-messages, the susceptibility to feedback and the budget policy) the governance interactions of the actors are influenced. In the model we look at how sustainable these interactions are by looking at the life span of the SDI. As the observer can influence only the chances on interaction types, it is still unpredictable how long the model will run each time. As the interactions are based on the inputs (i.e. the actors cannot adapt by applying a different interaction strategy) all models will fail inevitably.

Adaptation
The original modus of the model contains little adaptive behaviour. The actors do not change their strategies depending on the state of the system. The strategies are based on chances and input settings of these chances by the observer.

An exception is the data flow. In order to keep a reasonable flow of data (data availability and high quality) within SDI system, a kind of adaptive behaviour has been implemented in the model. The SDI user will send negative feedbacks in case of a poor data flow (data flow < 5). To improve the flow of data, the SDI platform provider and SDI data provider spend 0.5 budget (0.25 per each actor) and the data quality increases with 0.5. If SDI platform provider or SDI data provider do not have any budget, the one that that has budget spend the full 0.5 budget to improve the data quality. These costs come above the normal costs for maintaining the SDI.

When the model is put in adaptive mode, the dynamics of the simulation may be adaptively influenced after a period of 15 ticks. If then the average satisfaction is less than 7.5, the chances on a certain message are automatically influenced, based on the distribution of sent messages. If one message type was overrepresented, the chances on this message type are lowered. The

chance on an underrepresented message type are increased. In this way, the model dynamics try to adjust the governance mix in order to become more sustainable.

Interaction.
There is direct interactions among SDI executive, SDI platform provider, SDI data provider and SDI user. The direct interactions consist of sending hierarchy, network and no messages and receiving feedback. These interactions are represented as sets of links in the model among the different actors. There is also another set of indirect interaction in which the data flows from the SDI platform provider and SDI data provider to the SDI user. The SDI user responds with direct feedback to this. The communications in this interaction are also represented with sets of links. The last form of interaction is between the actor and its budget. As some actors will give budget (depending on the budget policy) and others spend budget, the spending actors are dependent on a source of income from these other actors.

Stochasticity.
In the SDI governance model, there are three processes in which random selection are implemented. First, a random process of selecting a hierarchy, network or no message occurs of which the chances can be influenced by sliders. Second, one actor among four actors to send the message is selected. The third random process is the selection of an actor to receive the randomly selected message. Also the susceptibility of feedback can be changed, which changes the chance the actor will listen to the feedback and change its satisfaction. As this are the main principles of the model, running the model shows a lot of stochastic behaviour.

Observation.
The graphic user interface provides several types of graphs and monitors in order to follow the dynamics of the model. The graphs provide visual interpretation of variables such as: 1) satisfaction of SDI executive, SDI platform provider, SDI data provider, SDI user and also their overall (mean) satisfaction; 2) data quality over time, and 3) budget of SDI executive, SDI platform provider, SDI data provider and SDI user. Monitors provide information about the number of a certain type of selected message. The model stops running if the mean satisfaction of the actors equals 1 or less. This output (the amount of time steps the run took before it failed) is also collected.

5. Initialization

At initialization all data from previous runs is deleted, the time is reset and the four actors are created. The messages and the previous message (message-1) and before previous message (message-2) are set to the neutral 'not yet messaging'. The global and actors own-variables such as data quality, satisfaction and budget are set by default to 5. This setting is fixed on initialization to make outcomes in the dynamics of the model better comparable. However, these values can be easily changed in the code if necessary. These initial values were chosen as they are the middle values of their range.

Before running the model, the observer can modify four sliders and one chooser:

- Slider to determine the chances on hierarchy messages (0 to 100)
- Slider to determine the chances on network messages (0 to 100)
- Slider to determine the chances on no messages (0 to 100)
- Slider to determine the susceptibility to feedback (0 to 100)
- Button for switching adaptive mode on or off
- Chooser for determining the budget policy:
    - Piecemeal funding

- Continuous funding
- Pay per use funding
- INSPIRE financing

6. Input data

External sources were not used to develop the SDI governance model.

7. Submodels

There are no sub models used in this agent-based model. All processes are mentioned in the 'process overview and scheduling'.

8. References

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