From insight network to open policy practice: practical experiences
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Appendix S1: Open assessments performed

A number of open assessments have been performed in several research projects (see the funding declaration) and health assessments since 2004. Some assessments have also been done on international Kuopio Risk Assessment Workshops for doctoral students in 2007, 2008, and 2009 and on a Master's course Decision Analysis and Risk Management (6 credit points), organised by the University of Eastern Finland (previously University of Kuopio) in 2011, 2013, 2015, and 2017.

More assessments can be found at Opasnet page Category:Assessments.

Table S1-1. Some environmental health assessments performed using open assessment. References give links to both an assessment page and a scientific publication as applicable.

| Topic | # | Assessment | Year | Project |
|-------|---|------------|------|---------|
| Vaccine effectiveness and safety | 1 | Assessment of the health impacts of H1N1 vaccination[1] | 2011 | In-house, collaboration with Decision Analysis and Risk Management course |
| | 2 | Tendering process for pneumococcal conjugate vaccine[2] | 2014 | In-house, collaboration with the National Vaccination Expert Group |
| Energy production, air pollution and climate change | 3 | Helsinki energy decision[3] | 2015 | In-house, collaboration with city of Helsinki |
| | 4 | Climate change policies and health in Kuopio[4] | 2014 | Urgenche, collaboration with city of Kuopio |
| | 5 | Climate change policies in Basel[5] | 2015 | Urgenche, collaboration with city of Basel |
| | 6 | Availability of raw material for biodiesel production[6] | 2012 | Jatropha, collaboration with Neste Oil |
| | 7 | Health impacts of small scale wood burning[7] | 2011 | Bioher, Claih |
| | 8 | Climate strategy of Helsinki: Carbon neutral Helsinki 2035 action plan[8] | 2018 | In-house, collaboration with city of Helsinki |
| | 9 | Climate mitigation of the social affairs and health sector in Finland[9] | 2020 | In-house, commissioned by the Prime Minister |
| Health, climate, and | 10 | Gasbus - health impacts of Helsinki bus traffic[10] | 2004 | Collaboration with Helsinki Metropolitan Area |
| Topic | #  | Assessment                                                                 | Year | Project                                      |
|-------|----|---------------------------------------------------------------------------|------|----------------------------------------------|
|       | 11 | Cost-benefit assessment on composite traffic in Helsinki[11]               | 2005 | In-house                                     |
|       | 12 | Benefit-risk assessment of Baltic herring in Finland[12]                  | 2015 | Collaboration with Finnish Food Safety Authority |
|       | 13 | Benefit-risk assessment of methyl mercury and omega-3 fatty acids in fish[13] | 2009 | Beneris                                      |
|       | 14 | Benefit-risk assessment of fish consumption for Beneris[14]               | 2008 | Beneris                                      |
|       | 15 | Benefit-risk assessment on farmed salmon[15]                              | 2004 | In-house                                     |
|       | 16 | Benefit-risk assessment of Baltic herring and salmon intake[16]           | 2018 | BONUS GOHERR                                 |
|       | 17 | TCDD: A challenge to mechanistic toxicology[17]                           | 1999 | EC ENV4-CT96-0336                            |
|       | 18 | Comparative risk assessment of dioxin and fine particles[18]               | 2007 | Beneris                                      |
|       | 19 | Compound intake estimator[19]                                             | 2014 | Plantlibra                                   |
|       | 20 | Paakkila asbestos mine[20]                                                | 1999 | In-house                                     |
|       | 21 | Model for site-specific health and ecological assessments in mines[21]    | 2013 | Minera                                       |
|       | 22 | Risks of water from mine areas[22]                                        | 2018 | Kaveri                                       |
|       | 23 | Water Guide for assessing health risks of drinking water contamination[23] | 2013 | Conpat                                       |
|       | 24 | Bathing Water Guide for assessing health risks of bathing water contamination[24] | 2019 | Water Guide update                           |
|       | 25 | Analysis and discussion about research strategies or organisational changes within THL | 2017 | In-house                                     |
|       | 26 | Transport and communication strategy in digital Finland[25]               | 2014 | Collaboration with the Ministry of Transport and Communications of Finland |
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Appendix S2: Examples of insight networks

Figure S2-1. Insight network about dioxins in Baltic fish. The focus is on reasoning and value judgements and their connections to causal chains about dioxins and health.
Figure S2-2. Legend for main object types used in insight networks. The actual colours and formatting depend on the capabilities of the software used.
Figure S2-3. Items in open policy ontology shown in an insight network format. All relations are of types 'has subclass' or 'has part'.
Figure S2-4. Relations in open policy ontology shown in an insight network format. In this graph, relations are shown as nodes, and the arcs between relations are of types 'has subclass', 'has part', or 'inverse'.
Figure S2-5. Structured discussion about risks of open governance. The original discussion was held in Finnish and can be found from http://fi.opasnet.org/fi/Keskustelu:Jaettu_ymm%C3%A4rrys. Trapezoids are statements. Light blue is an opening fact statement (‘Openness causes serious problems to the quality of policy making.’), and blue is closing fact statement that is updated based on the discussion (‘Openness causes serious problems to the quality of policy making, if it is too tightly connected to impulsive thinking in social media.’). Orange arguments are true and gray are false. Red arrow is an attack, green is a defense, and gray is irrelevant (Accessed 1 Feb 2020).
Figure S2-6. Structured discussion at an argumentation tool (https://dev.tietokide.fi/?Q10. Accessed 1 Feb 2020)
Figure S2-6. Insight network about the assessment model for Helsinki energy decision 2015.
Appendix S3: Open policy ontology

Shared understanding aims at producing a description of different views, opinions, and facts related to a specific topic such as a decision process. The open policy ontology describes the information structures that are needed to document shared understanding of a complex decision situation. The purpose of the structure is to help people identify hidden premises, beliefs, and values and explicate possible discrepancies. This is expected to produce better understanding among participants.

The basic structure of a shared understanding is a network of items and relations between them. This network uses Resource description framework, which is an ontology standard used to describe many Internet contents. Items and relations (aka properties) are collectively called resources. Each item is typically of one of the types mentioned below. This information is documented using property instance of (e.g. Goherr assessment is instance of assessment).

Items are written descriptions of the actual things (people, tasks, publications, or phenomena), and on this page these descriptions rather than the actual things are discussed. Different item types have different levels of standardisation and internal structure. For example, knowledge crystals are web pages that always have headings question, answer and rationale, and the information is organised under those headings. Some other items describe e.g. statements that are free-text descriptions about how a particular thing is or should be (according to a participant), and yet some others are metadata about publications. A common feature is that all items contain information that is relevant for a decision.

In the open policy ontology, each item may have lengthy texts, graphs, analyses or even models inside them. However, the focus here is on how the items are related to each other. The actual content is often referred to as one key sentence only (description). Each item also has a unique identifier URI that is used for automatic handling of data.

The most important items are knowledge crystals and they are described here.

- **Assessment** describes a particular decision situation and focuses on estimating impacts of different options. Its purpose is to support the making of that decision. Unlike other knowledge crystals, assessments typically have a defined start and end dates and they are closed after the decision is made. They also have contextually and situationally defined goals to be able to better serve the needs of the decision makers of the decision.
- **Variable** answers a particular factual or ethical question that is typically needed in one or more assessments. The answer of a variable is continually updated as new information arises, but its question remains constant in time. Variable is the basic building block of assessments. In R, variables are typically implemented using ovariable objects from OpasnetUtils package.
- **Method** tells how to systematically implement a particular information task. Method is the basic building block for describing the assessment work (not reality, like variables). In practice, methods are "how-to-do" descriptions about how information should be produced, collected, analysed, or synthesised in an assessment. Typically, methods contain a software code or another algorithm to actually perform the method easily. In R, methods are typically ovariables
that require some context-specific upstream information about dependencies before it can be calculated.

There are also other important classes of items:

- **Publication** is any documentation that contains useful information related to a decision. Publications that are commonly used at Opasnet include encyclopedia article, lecture, nugget, and study. Other publications at Opasnet are typically uploaded as files.
  - **Encyclopedia article** is an object that describes a topic like in Wikipedia rather than answers a specific research question. They do not have a predefined attribute structure.
  - **Lecture**: Lecture contains a piece of information that is to be mediated to a defined audience and with a defined learning objective. It can also be description of a process during which the audience learns, instead of being a passive recipient of information.
  - **Nugget** is an object that is not editable by other people than a dedicated author (group) and is not expected to be updated once finalised. They do not have a predefined attribute structure.
  - **Study** describes a research study and its answers, i.e. observational or other data obtained in the study. The research questions are described as the question of the information object, and the study methods are described as the rationale of the object. Unlike in an article, introduction or discussion may be missing, and unlike in a variable, the answer and rationale of the study are more or less fixed after the work is done; this is because the interpretations of the results typically happen elsewhere, e.g. in variables for which a study contains useful information.

- **Discussion** is a hierarchically structured documentation of a discussion about a defined statement or statements.

- **Stakeholder** page is used to describe a person or group that is relevant for a decision or decision process; they may be an actor that has an active role in decision making or is a target of impacts. Contributors of Opasnet are described on their own user pages; other stakeholders may have their page on the main namespace.

- **Process** describes elements of a decision process.

- **Action** describes what, who and when should act to e.g. perform an assessment, make a decision, or implement policies.

Relations show different kinds of connections between items.

- **Causal link** tells that the subject may change the object (e.g. affects, increases, decreases, prevents).

- **Participatory link** describes a stakeholder's particular role related to the object (participates, negotiates, decides).

- **Operational link** tells that the subject has some kind of practical relation to the object (executes, offers, tells).

- **Evaluative link** tells that the subject shows preference or relevance about the object (has truthlikeness, value, popularity, finds important).
• **Referential link** tells that the object is used as a reference of a kind for the subject (makes relevant; associates to; has reference, has tag, has category).

• **Argumentative link** occurs between statements that defend or attack each other (attack, defend, comment).

• **Property link** connects an evaluative (acceptability, usability), a logical (opposite, inverse) or set theory (has subclass, has part) property to the subject.

### Item types

This ontology is specifically about decision making, and therefore actions (and decisions to act) are handled explicitly. However, any natural, social, ethical or other phenomena may relate to a decision and therefore the vocabulary has to be very generic.

| Class | English name | Finnish name | Description |
|-------|--------------|--------------|-------------|
| resource | resource | resurssi | All items and relations are resources |
| resource | item | asia | Relevant pieces of information related policy making. Sometimes also refers to the real-life things that the information is about. Items are shown as nodes in insight networks. |
| resource | relation | relaatio | Information about how items are connected to each other. Relations are shown as edges in insight networks. |
| item | substance | ilmiö | Items about a substantive topic or phenomenon itself: What issues relate to a decision? What causal connections exist between issues? What scientific knowledge exist about the issues? What actions can be chosen? What are the impacts of these actions? What are the objectives and how can they be reached? What values and preferences exist? |
| item | stakeholder | sidosryhmä | Items about people or organisations who have a particular role in a policy process, either as actors or targets of impacts: Who participates in a policy process? Who should participate? Who has necessary skills for contributing? Who has the authority to decide? Who is affected by a decision? |
| item | process | prosessi | Items about doing or happening in relation with a topic, especially information about how a decision will be made: What will be decided? When will it be decided? How is the decision prepared? What political realities and restrictions exist? |
| Class      | English name | Finnish name | Description                                                                                                                                 |
|------------|--------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| item       | action       | toiminta     | Items about organising decision support (impact assessment, decision making, implementation, and evaluation): What tasks are needed to collect and organise necessary information? How is information work organised? How and when are decisions implemented? Actions are also important afterwards to distribute merit and evaluate the process: Who did what? How did information evolve and by whom? |
| item       | information object | tieto-olio | A specified structure containing information about substance, stakeholders, processes, methods, or actions.                                        |
| information object | knowledge crystal | tietokide | Information object with a standardised structure and contribution rules                                                                         |
| knowledge crystal | assessment | arviointi | Describes a decision situation and typically provides relevant information to decision makers before the decision is made (or sometimes after the decision about its implementation or success). It is mostly about the knowledge work, i.e. tasks for decision support. |
| knowledge crystal | variable | muuttuja | Describes a real-world topic that is relevant for the decision situation. It is about the substance of the topic.                              |
| knowledge crystal | method   | metodi      | Describes how information should be managed or analysed so that it answers the policy-relevant questions asked. How to perform information work? What methods are available for a task? How to participate in a decision process? How to use statistical and other methods and tools? How to motivate participation? How to measure merit of contributions? |
| information object | discussion part | keskustelun osa | Information object that is used to organise discussions into a specified structure. The purpose of the structure is to help validation of statements and facilitate machine learning. |
| information object | discussion | keskustelu | Discussion, or structured argumentation, describes arguments about a particular statement and a synthesis about an acceptable statement. In a way, discussion is (a documentation of) a process of analysing the validity of a statement. |
| discussion | fact discussion | faktakes-kustelu | Discussion that can be resolved based on scientific knowledge.                                                                                  |
| discussion | value discussion | arvokes-kustelu | Discussion that can be resolved based on ethical knowledge.                                                                                   |
| discussion part | statement | väite       | Proposition claiming that something is true or ethically good. A statement may be developed in a discussion by adding and organising related argumentation (according to pragma-dialectics), or by organising premises and inference rules (according to Perelman). |
| Class          | English name           | Finnish name | Description                                                                                                                                 |
|---------------|------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| statement     | value statement        | arvoväite    | Proposition claiming that something is ethically good, better than something else, prioritised over something, or how things should be.         |
| statement     | fact statement         | faktaväite   | Proposition claiming how things are or that something is true.                                                                               |
| value statement | true value statement   | tosi arvoväite | A statement that has not been successfully invalidated.                                                                                    |
| value statement | false value statement  | epätosi arvoväite | A statement that has been successfully invalidated.                                                                                      |
| fact statement | true fact statement    | tosi faktaväite |                                                                                                                                             |
| fact statement | false fact statement   | epätosi faktaväite |                                                                                                                                             |
| statement     | true statement         | tosi väite   |                                                                                                                                             |
| statement     | false statement        | epätosi väite |                                                                                                                                             |
| statement     | opening statement      | avausväite   | A statement that is the basis for a structured discussion, a priori statement.                                                              |
| statement     | closing statement      | lopetusväite | A statement that is the resolution of a structured discussion, a posteriori statement. Closing statement becomes an opening statement when the discussion is opened again. |
| opening statement | fact opening statement | avausfaktaväite |                                                                                                                                             |
| closing statement | fact closing statement | lopetusfaktaväite |                                                                                                                                             |
| opening statement | value opening statement | avausarvoväite |                                                                                                                                             |
| closing statement | value closing statement | lopetusarvoväite |                                                                                                                                             |
| discussion part | argument               | argumentti   | A statement that has also contains a relation to its target as an integral part. Due to this relation, arguments appear inside discussions and target directly or indirectly the opening statement. |
| discussion part | argumentation          | väittely     | Hierarchical list of arguments related to a particular statement.                                                                             |
| Class                  | English name            | Finnish name    | Description                                                                                                                                                                                                 |
|-----------------------|-------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| information object    | knowledge crystal part  | tietokideoa     | This is shown separately to illustrate that the objects are actually linked by has part rather than has subclass relation.                                                                                     |
| knowledge crystal part| question                | kysymys         | A research question asked in a knowledge crystal. The purpose of a knowledge crystal is to answer the question.                                                                                             |
| knowledge crystal part| answer                  | vastaus         | An answer or set of answers to the question of a knowledge crystal, based on any relevant information and inference rules.                                                                              |
| knowledge crystal part| rationale               | perustelut      | Any data, discussions, calculations or other information needed to convince a critical rational reader that the answer of a knowledge crystal is good.                                                      |
| knowledge crystal part| answer part             | vastausosa      | This is shown separately to illustrate that the objects are actually linked by has part rather than has subclass relation.                                                                              |
| answer part            | result                  | tulos           | The actual, often numerical result to the question, conditional on relevant indices.                                                                                                                     |
| answer part            | index                   | indeksi         | A list of possible values for a descriptor. Typically used in describing the result of an ovariable.                                                                                                     |
| answer part            | conclusion              | päätelmä       | In an assessment, a textual interpretation of the result. Typically a conclusion is about what decision options should or should not be rejected and why based on the result. |
| knowledge crystal part | ovariable               | ovariable       | A practical implementation of a knowledge crystal in modelling code. Ovariable takes in relevant information about data and dependencies and calculates the result. Typically implemented in R using OpasnetUtils package and ovariable object type. |
| ovariable              | key                     | avainovariable  | An ovariable that is shown on an insight network even if some parts are hidden due to practical reasons.                                                                                               |
| information object    | publication             | julkaisu        | Any published report, book, web page or similar permanent piece of information that can be unambiguously referenced.                                                                                  |
| publication            | nugget                  | tiedomuru       | An object that is not editable by other people than a dedicated author (group).                                                                                                                         |
| substance              | topic                   | aihe            | A description of an area of interest. It defines boundaries of a content rather than defines the content itself, which is done by statements. When the information structure is improved, a topic often develops into a question of a knowledge crystal, while a statement develops into an answer of a variable. |
| priority               | objective               | tavoite         | A desired outcome of a decision. In shared understanding description, it is a topic (or variable) that has value statements attached to it.                                                           |
| substance              | risk factor             | riskitekijä     |                                                                                                                                                                                                          |
| Class       | English name | Finnish name | Description                                                                                                                                 |
|-------------|--------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| substance   | indicator    | indikaattori | Piece of information that describes a particular substantive item in a practical and often standard way.                                   |
| indicator   | risk indicator | riski-indikaattori | Indicator about (health) risk or outcome                                                                                                   |
| information object | data     | tietoaineisto |                                                                                                                                            |
| information object | graph    | kuvaaja      | Graphical representation of a piece of information. Typically is related to an information object with describes relation.               |
| work        | data work    | tietotyö     |                                                                                                                                            |
| work        | data use     | tiedon käyttö |                                                                                                                                            |
| substance   | priority     | prioriteetti |                                                                                                                                            |
| substance   | expense      | kustannus    |                                                                                                                                            |
| substance   | health impact | terveysvai-kutus |                                                                                                                                            |
| stakeholder | decision maker | päätäjä     |                                                                                                                                            |
| stakeholder | public officer | virkamies   |                                                                                                                                            |
| stakeholder | assessor     | arvioiija    |                                                                                                                                            |
| stakeholder | expert       | asiantuntija |                                                                                                                                            |
| stakeholder | citizen      | kansalainen  |                                                                                                                                            |
| stakeholder | agent        | toimija      |                                                                                                                                            |
| action      | task         | toimenpide   | action to be taken when the option has been selected                                                                                       |
| action      | decision     | päätös       | action to be taken when the option is yet to be selected. Describes a particular event where a decision maker chooses among defined alternatives. This may also be a part of an assessment under heading Decisions and scenarios. |
| action      | work         | työ          | continuous actions of the same kind and typically independent of the decision at hand. If the decision changes work routines, the action to make this change happen is called task. |
| work        | prevention   | ennaltaehkäisy | trying to prevent something                                                                                                                  |
| work        | treatment    | hoito        | trying to fix something when something has already happened                                                                                 |
| Class       | English name | Finnish name                          | Description                                                                                                                                 |
|------------|--------------|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| work       | support      | tuki                                  | work that aids in the completion of the selected option, in whatever way.                                                                 |
| method     | open policy practice | avoin päättöksen-tekokäytäntö | framework for planning, making, and implementing decisions.                                                                                       |
| method     | open assessment | avoin arviointi                     | method answering this question: How can factual and value information be organised for supporting societal decision making when open participation is allowed? |
| method     | analysis      | analyysi                              |                                                                                                                                                  |
| method     | reporting     | raportointi                           |                                                                                                                                                  |
| method     | measuremen t  | mittaus                               |                                                                                                                                                  |
| publication| study         | tutkimus                              |                                                                                                                                                  |
| publication| encyclopedi a article | ensyklopedia-artikkeli | An object that describes a topic rather than answers a specific research question.                                                               |
| publication| lecture       | luento                                | Contains a piece of information that is to be mediated to a defined audience and with a defined learning objective.                                |
| method     | procedure     | toimintamalli                         |                                                                                                                                                  |
| method     | principle     | periaate                              | a short generic guidance for information work to ensure that the work is done properly. They especially apply to the execution phase.            |
| principle  | intentionali ty | tavoitteellisuus                     | See Table 3 for explanations.                                                                                                                    |
| principle  | causality     | syysuhteiden kuvaus                  |                                                                                                                                                  |
| principle  | criticism     | kritiikki                             |                                                                                                                                                  |
| principle  | permanent resource locations | kohteellisuus                      |                                                                                                                                                  |
| principle  | openness       | avoimuus                              |                                                                                                                                                  |
| principle  | reuse          | uusio käyttö                          |                                                                                                                                                  |
| principle  | use of knowledge crystals | tietokiteiden käyttö | Facilitation methods are used to promote the participants' feeling of being an important member of a group that has a meaningful purpose.       |
| principle  | grouping       | ryhmäytyminen                         |                                                                                                                                                  |
| Class     | English name | Finnish name | Description                                                                                                                                 |
|-----------|--------------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| principle | respect      | arvostus     | Contributions are systematically documented and their merit evaluated so that each participant receives the respect they deserve based on their contributions. |
| objective | expense      | kustannus-   | one of sequential time intervals when a particular kind of work is done in decision support. In the next step, the nature of the work changes.   |
|           | objective    | tavoite      |                                                                                                                                            |
| process   | step         | jakso        | the first step in a decision process. Helps in collecting necessary information for making a decision.                                       |
| step      | impact       | vaikutus-    | the second step in a decision process. When the decision maker actually chooses between options.                                           |
|           | assessment   | rviointi     |                                                                                                                                            |
| step      | decision     | päättöksen-  | the third step in a decision process. When the chosen option is put in action.                                                            |
|           | making       | teko         |                                                                                                                                            |
| step      | implementa-   | toimeen-     | the fourth step in a decision process. When the outcomes of the implementation are evaluated.                                                |
|           | tion         | pano         |                                                                                                                                            |
| step      | evaluation   | evaluointi   | one part of a decision work process where focus is on particular issues or methods. Typically phases overlap temporally.                      |
|           |              |              |                                                                                                                                            |
| process   | phase        | vaihe        | documenting of all relevant views, facts, values, and opinions about a decision situation in such a way that agreements and disagreements can be understood |
| phase     | shared       | jaettu       | production of necessary information for a decision at hand                                                                                  |
|           | understanding| ymmärrys     | ensuring that all work related to a decision will be, is, and has been done properly                                                         |
| phase     | evaluation   | seuranta     | helping people to participate, contribute, and become motivated about the decision work                                                    |
|           | and management| ja ohjaus    |                                                                                                                                            |
| phase     | co-creation  | yhteiskehit- |                                                                                                                                            |
|           |              | täminen      |                                                                                                                                            |
Relation types

Relations are edges between items (or nodes). A relation I is said to be an inverse of relation R, iff, for all items subject and object, claim "subject R object" is always equal to claim "object I subject".

Table S3-2. Relation types used in open policy ontology.

| Class           | English name       | Finnish name       | English inverse | Finnish inverse | Description                                           |
|-----------------|--------------------|--------------------|-----------------|-----------------|-------------------------------------------------------|
| relation        | participatory link | osallisuus-linkki  |                 |                 | The subject is a stakeholder that has a particular role related to an object |
| relation        | operational link   | toiminto-linkki    |                 |                 | The subject has some kind of practical relation to the object (a fairly wide class) |
| relation        | evaluative link    | arvostus-linkki    |                 |                 | The subject shows preference or relevance about the object |
| relation        | referential link   | viitelinkki        |                 |                 | The subject is used as a reference of a kind for the object |
| relation        | argumentative link | argumentaatiolinkki|                 |                 | The subject is used as an argument to criticise the object |
| relation        | causal link        | syllylinkki        |                 |                 | The subject has causal effect on the object (or vice versa in the case of an inverse relation) |
| relation        | property link      | ominaisuus-linkki  |                 |                 | The object describes a defined property of the subject |
| causal link     | negative causal link| negatiivinen syyllylinkki |     |                 | The subject reduces or diminishes the object |
| causal link     | positive causal link| positiivinen syllylinkki |     |                 | The subject increases or enhances the object |
| negative causal link | decreases     | vähentää            | is decreased    | vähentyy        |                                                       |
| positive causal link | increases    | lisää               | is increased    | lisääntyy      |                                                       |
| negative causal link | worsens       | huonontaa           | is worsened     | huonontuu      |                                                       |
| positive causal link | improves      | parantaa            | is improved     | parantuu       |                                                       |
| negative causal link | prevents      | estää               | is prevented    | estyy          |                                                       |
| positive causal link | enhances      | edistää             | is enhanced     | edistyy        |                                                       |
| Class                      | English name | Finnish name | English inverse | Finnish inverse | Description                  |
|----------------------------|--------------|--------------|-----------------|-----------------|-----------------------------|
| negative causal link       | impairs      | heikentää    | is impaired by  | heikentyy        |                             |
| positive causal link       | sustains     | ylläpitää    | is sustained by | ylläpitäytyy    |                             |
| causal link                | affects      | vaikuttaa    | is affected by  | vaikuttuu        |                             |
| causal link                | indirectly affects | vaikuttaa epäsuorasti | indirectly affected by | vaikuttuu epäsuorasti |                             |
| causal link                | cause of     | syy          | caused by       | johtuu           | Wikidata property P1542     |
| causal link                | immediate cause of | välitön syy | immediately caused by | johtuu välittömästi | Wikidata property P1536     |
| causal link                | contributing factor of | vaikuttava tekijä | caused by | Wikidata property P1537 |                             |
| participatory link         | performs     | toteuttaa    | performer        | toteuttajana     | who does a task?            |
| participatory link         | decides      | päätätä      | decider          | päätäjänä        |                             |
| participatory link         | asks         | kysyy        | asker            | kysyjänä         |                             |
| participatory link         | participates | osallistuu   | participant       | osallistujana    |                             |
| participatory link         | accepts      | hyväksyy     | accepted by      | hyväksyjänä      |                             |
| participatory link         | develops     | kehittää     | developed by     | kehittäjänä      |                             |
| participatory link         | proposes     | ehdottaa     | proposed by      | ehdottajana      |                             |
| participatory link         | answers      | vastaa       | answered by      | vastaajana       |                             |
| participatory link         | responsible for | vastuussa   | responsibility of | vastuullisena    |                             |
| participatory link         | negotiates   | neuvottelee  | negotiated by    | neuvotteli-jana  |                             |
| participatory link         | recommend s  | suosittelee  | recommended by   | suosittelijana   |                             |
| participatory link         | controls     | kontrolloi   | controlled by    | kontrolloijana   |                             |
| participatory link         | claims       | väittää      | claimed by       | väittäjänä       |                             |
| Class                  | English name | Finnish name | English inverse | Finnish inverse | Description                                                                 |
|------------------------|--------------|--------------|----------------|-----------------|-----------------------------------------------------------------------------|
| participatory link     | owns         | omistaa      | owned by       | omistajana      |                                                                             |
| participatory link     | does         | tekee        | done by        | tekijänä        |                                                                             |
| participatory link     | maintains    | ylläpitää    | maintained by  | ylläpitäjänä    |                                                                             |
| participatory link     | oversees     | valvoo       | overseen by    | valvojana       |                                                                             |
| operational link       | has option   | omistaa      | option for     | vaihtoehtona    |                                                                             |
| operational link       | has index    | omistaa indeksin | index for indeksinä |                  |                                                                             |
| operational link       | tells        | kertoo       | told by        | kertojana       |                                                                             |
| operational link       | describes    | kuvaa        | described by   | kuvaajana       |                                                                             |
| operational link       | maps         | kartoittaa   | mapped by      | kartjoittajana  |                                                                             |
| operational link       | contains data| sisältää dataa | data contained in | data sisältyy   |                                                                             |
| operational link       | data for     | on datana    | gets data from | saa datansa     |                                                                             |
| operational link       | uses         | käyttää      | is used by     | on käytettävänä | an input (object) for a process (subject)                                  |
| operational link       | produces     | tuottaa      | is produced by | tuottajana      | Object is an output of a process produced by a stakeholder (subject)       |
| operational link       | provides     | varustaa     | is provided by | varustajana     |                                                                             |
| property link          | logical link | looginen linkki |                | Relations based on logic                                                  |
| property link          | set theory link | joukko-oppilinkki |            | Relations based on set theory                                             |
| set theory link        | part of      | osana        | has part       | sisältää osan   | is a part of a bigger entity, e.g. Venus is part of Solar System. Wikidata property P361 (part of) & P527 (has part). |
| set theory link        | context for  | kontekstina  | has context    | omistaa kontekstin |                                                                             |
| Class                  | English name | Finnish name | English inverse | Finnish inverse | Description                                                                 |
|------------------------|--------------|--------------|----------------|----------------|-----------------------------------------------------------------------------|
| set theory link        | has subclass | omistaa alajoukon | subclass of | alajoukkona      | Wikidata property P279 Object belongs to a set defined by the subject and inherits the properties of the set. Sysnonyym for has item, which is depreciated. Wikidata property P31 |
| set theory link        | has instance | omistaa instanssin | instance of | instanssina      | subject is opposite of object, e.g. black is opposite of white. Wikidata property P461; it is its own inverse |
| logical link           | opposite     | vastakohta   |                |                | a sentence is equal to another sentence where subject and object switch places and has the inverse relation. This is typically needed in preprocessing of insight networks, and it rarely is explicitly shown of graphs. Wikidata property P1696; it is its own inverse |
| logical link           | inverse      | toisinpäin   |                |                | If subject is true, then object is true. Also the negation is possible: if - then not. This links to logical operators and, or, not, equal, exists, for all; but it is not clear how they should be used in an insight network. |
| operational link       | prepares     | valmistelee  | prepared by    | valmistelijana  |                                                                             |
| operational link       | pays         | kustantaa    | paid by        | kustantajana    |                                                                             |
| operational link       | rationale    | perusteele   | has rationale  | perusteltuu     |                                                                             |
| operational link       | offers       | tarjoaa      | offered by     | tarjoajana      |                                                                             |
| operational link       | executes     | suorittaat   | executed by    | suorittajana    |                                                                             |
| Class               | English name                  | Finnish name                  | English inverse | Finnish inverse | Description                                                                                                                                 |
|---------------------|-------------------------------|-------------------------------|-----------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| operational link    | irrelevant to                 | epärelevantti asiassa         |                 |                 | If there is no identified relation (or chain of relations) between a subject and an object, it implies that the subject is irrelevant to the object. However, sometimes people may (falsely) think that it is relevant, and this relation is used to explicate the irrelevance. |
| evaluative link     | finds important               | kokee tärkeäksi               | is found        | tärkeäksi kokijana |                                                                                                                                               |
|                     |                               |                               | important       |                 |                                                                                                                                               |
| evaluative link     | makes relevant                | tekee relevantiksi            | is made         | relevantiksi tekijänä | if the subject is valid in the given context, then the object is relevant. This typically goes between arguments, from a variable to value statement or from a value statement to a fact statement. This is a synonym of 'valid defend of type relevance'. |
| evaluative link     | makes irrelevant              | tekee epärelevantiksi         | is made         | epärelevantiksi tekijänä | Opposite of 'makes relevant'. Synonym of 'valid attack of type relevance'.                                                                   |
| evaluative link     | makes redundant               | tekee turhaksi                | is made         | turhaksi tekijänä | Everything that is said in the object is already said in the subject. This depreciates the object because it brings no added value. However, it is kept for archival reasons and to demonstrate that the statement was heard. |
| evaluative link     | has opinion                   | on mieltä                     |                 |                 | Subject (typically a stakeholder) supports the object (typically a value or fact statement). This is preferred over 'values' and 'finds important' because it is more generic without loss of meaning. |
| evaluative link     | values                        | arvostaa                      | valued by       | arvostajana      | A stakeholder (subject) gives value or finds an object important. Object may be a topic or statement. Deprecated, use 'has opinion' instead.       |
| Class                          | English name          | Finnish name          | English inverse | Finnish inverse | Description                                                                                                                                 |
|-------------------------------|-----------------------|-----------------------|-----------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| evaluative link               | has truthlike-ness    | on totuudellinen     |                 |                 | A subjective probability that subject is true. Object is a numeric value between 0 and 1. Typically this has a qualifier 'according to X' where X is the person or archetype who has assigned the probability. |
| evaluative link               | has preference        | mieltymys            | preference of   | mieltyymysenä   | Subject is better than object in a moral sense.                                                                                                   |
| evaluative link               | has popularity        | on suosiossa         | objective of    | tavoitteena     | A measure based on likes given by users.                                                                                                                                 |
| evaluative link               | has objective         | omaa tavoitteen      | objective of    |                 |                                                                                                                                                |
| argumentative link            | agrees                | samaa mieltä         |                 |                 |                                                                                                                                                |
| argumentative link            | disagrees             | eri mieltä           |                 |                 |                                                                                                                                                |
| argumentative link            | comments              | kommentoi            | commented by    | kommentoi-jana  |                                                                                                                                                |
| argumentative link            | defends               | puolustaa            | defended by     | puolustajana    |                                                                                                                                                |
| argumentative link            | attacks               | hyökkää              | attacked by     | hyökkääjänä     |                                                                                                                                                |
| argumentative link            | relevant argument     | relevantti argumentti|                 |                 | Argument is relevant in its context.                                                                                                                                 |
| argumentative link            | irrelevant argument   | epärelevanti argumentti|                 |                 | Argument is irrelevant in its context.                                                                                                                                 |
| argumentative link            | joke about            | vitsi aiheesta       | provokes joke   | kirvoittaa vitsin| This relation is used to describe that the subject should not be taken as information, even though it may be relevant. Jokes are allowed because they may help in creating new ideas and perspectives to an issue. |
| Class         | English name | Finnish name | English inverse | Finnish inverse | Description                                                                                                                                 |
|--------------|--------------|--------------|----------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| referential  | topic of     | aiheena      | has topic       | aiheesta       | This is used when the object is a publication and the subject is a (broad) topic rather than a statement. In such situations, it is not meaningful to back up the subject with references. Useful in describing the contents of a publication, or identifying relevant literature for a topic. |
| referential  | discussed in | kerrotaan    | discusses       | kerto          | Subject is a reference that backs up statements presented in the object. Used in the same way as references in scientific literature are used. |
| referential  | reference for | viitteenä    | has reference   | viite          | Describes the source of a statement; may also refer to a person.                                                                                   |
| referential  | states       | väittää      | stated in       | väitetään kohteessa |                                                                                                                                                  |
| referential  | tag for      | täginä       | has tag         | omistaa tägin  | Subject is a keyword, type, or class for object. Used in classifications.                                                                      |
| referential  | category for | kategoriana  | has category    | kuuluu kategoriaan |                                                                                                                                                  |
| referential  | associates   | liityy       |                 |                | Subject is associated with object in some undefined way. This is a weak relation and does not affect the outcomes of inferences, but it may be useful to remind users that an association exists and it should be clarified more precisely. This is its own inverse. |
| referential  | answers      | vastaa       | has answer      | vastaus        | Used between a statement (answer) and a topic (question). In knowledge crystals, the relation is embedded in the object structure.               |
| irrelevant   | argument     | epärelevantti| Kommentti       |                | Inverses are not needed, because the relation is always tied with an argument (the subject).                                                     |
| irrelevant   | argument     | epärelevantti| Hyökkäys        |                |                                                                                                                                                  |
| irrelevant   | argument     | epärelevantti| Puolustus       |                |                                                                                                                                                  |
| Class                  | English name                  | Finnish name                  | English inverse | Finnish inverse | Description                                                                                                                                 |
|-----------------------|-------------------------------|-------------------------------|-----------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| relevant argument     | relevant comment              | relevantti kommentti         |                 |                 | characteristic of a product or work that tells whether it is fit for its purpose. Especially used for assessments and assessment work.          |
| relevant argument     | relevant attack               | relevantti hyökkäys          |                 |                 |                                                                                                                                             |
| relevant argument     | relevant defense              | relevantti puolustus         |                 |                 |                                                                                                                                             |
| property link         | evaluative property           | arviointi-ominaisuus         |                 |                 |                                                                                                                                             |
| evaluative property   | property of decision support  | päätöstuen ominaisuus        |                 |                 | What makes an assessment or decision support process fit for its purpose?                                                                     |
| evaluative property   | setting of assessment         | arvioinnin kattavuus         |                 |                 | See Table 5.                                                                                                                                  |
| setting of assessment | impacts                      | vaikutukset                  |                 |                 |                                                                                                                                             |
| setting of assessment | causes                       | syyt                         |                 |                 |                                                                                                                                             |
| setting of assessment | problem owner                | asianomistaja                |                 |                 |                                                                                                                                             |
| setting of assessment | target users                 | kohderyhmä                   |                 |                 |                                                                                                                                             |
| setting of assessment | interaction                  | vuorovai-kutus               |                 |                 |                                                                                                                                             |
| interaction           | dimension of openness         | avoimuuden ulottuvuus        |                 |                 | See Table 6.                                                                                                                                  |
| dimension of openness | scope of participation       | osallistumisen avoimuuus     |                 |                 |                                                                                                                                             |
| dimension of openness | access to information        | tiedon avoimuus              |                 |                 |                                                                                                                                             |
| dimension of openness | timing of openness           | osallistumisen ajoitus       |                 |                 |                                                                                                                                             |
| dimension of openness | scope of contribution        | osallistumisen kattavuus     |                 |                 |                                                                                                                                             |
| Class                        | English name                  | Finnish name                | English inverse | Finnish inverse | Description                                                                 |
|------------------------------|-------------------------------|-----------------------------|-----------------|-----------------|----------------------------------------------------------------------------|
| dimension of openness        | impact of contribution        | osallistumisen vaikutus    |                 |                 | See Table 2. How does assessment interact with the intended use of its results? Possible values: isolated (eristetty), informing (tiedottava), participatory (osallistava), joint (yhteistyöhakuinen), shared (jaettu). |
| interaction                  | category of interaction       | vuorovaikutuksen luokka    |                 |                 |                                                                            |
| property of decision support | quality of content            | sisällön laatu             |                 |                 | See Table 4.                                                               |
| quality of content           | informativeness               | tarkkuus                   |                 |                 |                                                                            |
| quality of content           | calibration                  | harhattomuus               |                 |                 |                                                                            |
| quality of content           | coherence                    | sisäinen yhdenmukaisuus    |                 |                 |                                                                            |
| property of decision support | applicability                | sovelletavuus              |                 |                 |                                                                            |
| applicability                | relevance                    | merkitykselisyyys          |                 |                 |                                                                            |
| applicability                | availability                 | saatavuus                  |                 |                 |                                                                            |
| applicability                | usability                    | käytettävyys               |                 |                 |                                                                            |
| applicability                | acceptability                | hyväksytävyys              |                 |                 |                                                                            |
| property of decision support | efficiency                   | tehokkuus                  |                 |                 |                                                                            |
| efficiency                   | intra-assessment efficiency  | sisäinen tehokkuus        |                 |                 |                                                                            |
| efficiency                   | inter-assessment efficiency  | ulkoinen tehokkuus         |                 |                 |                                                                            |
Appendix S4: Workspace tools: OpasnetUtils package and Opasnet Base

Ovariable

Ovariable is an object class that is used in R to operationalise knowledge crystals. In essence, impact assessment models are built using ovariables as the main tool to organise, analyse, and synthesise data and causal relations between items. The purpose of ovariables is to offer a standardised, generalised, and modular solution to modelling. Standardised means that all ovariables have the same overall structure, and this makes it possible to develop generalised functions and processes to manipulate them. Modular structure of a model makes it possible to change pieces within the model without braking the overall structure of functionality. For example, it is possible to take an existing health impact model, replace the ovariable that estimates the exposure of the target population with a new one, and produce results that are otherwise comparable to the previous results but differ based on exposure.

What is the structure of an ovariable such that

- it complies with the requirements of variable and
- it is able to implement probabilistic descriptions of multidimensional variables and
- it is able to implement different scenarios?

An ovariable contains the current best answer in a machine-readable format (including uncertainties when relevant) to the question asked by the respective knowledge crystal. In addition, it contains the information needed to derive the current best answer. The respective knowledge crystal typically has an own page at Opasnet, and the code to produce the ovariable is located on that page under subheading Calculations.

It is useful to clarify terms here. Answer is the overall answer to the question asked (including an evaluated ovariable), and it is the reason for producing the knowledge crystal page in the first place. Answer is typically located near the top of the page to emphasise its importance. An answer may contain text, tables, or graphs on the web page. It typically also contains an R code for evaluating the respective ovariable. Output is the key part (technically a slot) of the answer within an ovariable and contains the details of what the reader wants to know about the answer. All other parts of the ovariable are needed to produce the output or understand its meaning. Finally, Result is the key column of the Output table (technically a data frame) and contains the actual numerical values for the answer.

Slots

The ovariable is a class S4 object defined by OpasnetUtils in R software system. An ovariable has the following separate slots that can be accessed using X@slot (where X is the name of the ovariable):

@name
• Name of `<self>` (the ovariable object) is useful since R's S4 classes doesn't support self reference. It is used to identify relevant data structures as well as to set up hooks for modifiers such as scenario adjustments.

@output

• The current best answer to the question asked.
• A single data frame (a 2D table type in R)
• Not defined until `<self>` is evaluated.
• Possible types of columns:
  • *Result* is the column that contains the actual values of the answer to the question of the respective knowledge crystal. There is always a result column, but its name may vary; it is of type `<self>`:Result.
  • *Indices* are columns that define or restrict the Result in some way. For example, the Result can be given separately for males and females, and this is expressed by an index column *Sex*, which contains locations *Male* and *Female*. So, the Result contains (at least) one row for males and one for females. If there are several indices, the number of rows is typically the product of numbers of locations in each index. Consequently, the output may become very large with several indices.
  • *Iter* is a special kind of index used in Monte Carlo simulations. Iter contains the number of the iteration. In Monte Carlo, the model is typically run 1000 or 10000 times.
  • *Unit* contains the unit of the Result. It may be the same for all rows, but it may also vary from one row to another. Unit is not an index.
• Other, non-index columns can exist. Typically, they are information that were used for some purpose during the evolution of the ovariable, but they may be unimportant in the current ovariable if they have been inherited from parent ovariables. Due to these other columns, the output may sometimes be rather wide.

@data

• A single data frame that defines `<self>` as such.
• *data* slot contains data about direct measurements or estimates of the output. Typically, when data is used, the output can be directly derived from the information given, with possibly some manipulations such as dropping out unnecessary rows or interpreting given ranges or textual expressions as probability distributions.
• Probability distributions are interpreted by *OpasnetUtils/Interpret*.

@marginal

• A logical vector that indicates full marginal indices (and not parts of joint distributions, result columns, or units or other row-specific descriptions) of output.

@formula
• A function that defines <self> using objects from dependencies as inputs.
• Returns either a data frame or an ovariable, which is then used as the output of the ovariable.
• Formula and dependencies slots are always used together. They estimate the answer indirectly in cases when there is knowledge about how this variable depends on the results of other variables (called parents). The slot dependencies is a table of parent variables and their identifiers, and formula is a function that takes the outputs of those parents, applies the defined code to them, and in this way produces the output for this variable.

@dependencies

• A data frame that contains names and tokens or identifiers for model runs of variables required for <self> evaluation (list of causal parents). The following columns may be used:
  • Name: name of an ovariable or a constant found in the global environment (.GlobalEnv).
  • Key: the run key (typically a 16-character alphanumeric string) of a model run that is stored to Opasnet server. Key to be used in objects.get() function to fetch the dependent object.
  • Ident: Page identifier and rcode name to be used in objects.latest() function where the newest run contains the dependent object. Syntax: "Op_en6007/answer".
  • Also other columns are allowed (e.g. Description), and they may contain additional information about parents.
• Dependencies is a way of enabling references in ovariables by using function OpasnetUtils/ComputeDependencies. It creates variables in .GlobalEnv environment so that they are available to expressions in formula.
• Dependent ovariables are fetched and evaluated (only once by default) upon <self> evaluation.

@ddata

• A string containing an Opasnet identifier e.g. "Op_en1000". May also contain a subset specification e.g. "Op_en1000/dataset".
• This identifier is used to download data from the Opasnet database for the data slot (by default, only if empty) upon <self> evaluation.
• By default, the data defined by ddata is downloaded when an ovariable is created. However, it is also possible to create and save an ovariable in such a way that the data is downloaded only when the ovariable is evaluated.

@meta

• A list of descriptive information of the object. Typical information include date created, username of the creator, page identifier for the Opasnet page with the ovariable code, and identifier of the model run where the object was created.
• Other meta information can be added manually.
OpasnetUtils and operations with ovariables

OpasnetUtils is an R package found in CRAN repository (cran.r-project.org). It contains tools for open assessment and modelling at Opasnet, especially for utilising ovariables as modelled representations of knowledge crystals. Typically, ovariables are defined at Opasnet pages, and their data and evaluated output are stored to Opasnet server. There are also special user interface tools to enable user inputs before an R code is run on an Opasnet page; for further instructions, see http://en.opasnet.org/w/R-tools. However, ovariables can be used independently for building modular assessment models without any connection to Opasnet.

The example code shows some of the most important functionalities. Each operation is followed by an explanatory comment after # character.

```r
install.packages("OpasnetUtils") # Install the package OpasnetUtils. This is done only once per computer.

library(OpasnetUtils) # Open the package. This is done once per R session.

objects.latest("Op_en4004", code_name="conc_mehg") # Fetch ovariables stored by code conc_mehg at Opasnet page Mercury concentrations in fish in Finland (with identifier 4004)

conc_mehg <- EvalOutput(conc_mehg) # Evaluate the output of ovariable conc_mehg (methyl mercury concentrations in fish) that was just fetched.

dat <- opbase.data("Op_en4004", subset="Kerty database") # Download data from Kerty database on the same page and put that to data.frame dat

a <- Ovariable("a", data=data.frame(Fish=c("Herring","Salmon"), Result=c(1,3))) # Define ovariable for scaling salmon results with factor 3.

mehg_scaled <- conc_mehg * a # Multiply methyl mercury concentrations by the scaling factor.
```

An ovariable is well defined when there is enough data, code or links to evaluate the output. Ovariables often have upstream dependencies whose output affect the output of the ovariable at hand. Therefore, ovariables are usually stored in a well defined but unevaluated format (i.e. without output). This makes it possible to use the same ovariable in different contexts, and the output varies depending on the upstream dependencies. On the other hand, it is possible to store all evaluated ovariables of a whole assessment model. This makes it possible to archive all details of a certain model version for future scrutiny.

Ovariables have an efficient index handling, which makes it possible to do arithmetic operations such as sums and products in a very simple way with ovariables. The basic idea is that if the outputs of two ovariables have two columns by the same name, they are automatically merged (or joined, using the SQL vocabulary) so that rows are merged iff they have the same location values in those two columns. The same principle applies to all pairs of columns by the same name. After the merge, the arithmetic operation is performed, row by row, to the Result columns of each ovariable. This results in an intuitive handling of outputs using a short and straightforward code.
Recursion is another important property of ovariables. When an ovariable is evaluated, a code checks whether it has upstream dependencies. If it does, those ovariables are fetched and evaluated first, and recursively the dependencies of those ovariables are fetched also, until all dependencies have been evaluated. Case-specific adjustments can be done to this recursion by fetching some upstream ovariables before the first ovariable is evaluated; if an upstream ovariable exists already in the global environment, the existing object is used and the respective stored object is not fetched (dependencies are only fetched if they do not already exist; this is to avoid unnecessary computation).

**Decisions and other upstream commands**

The general idea of ovariables is such that their code should not be modified to match a specific model but rather define the knowledge crystal in question as extensively as possible under it's scope. In other words, it should answer its question in a reusable way so that the question and answer would be useful in many different situations. (Of course, this should be kept in mind already when the question is defined.) To match the scope of specific models, ovariables can be modified without changing the ovariable code by supplying commands upstream. A typical decision command is to make a new decision index with two scenarios, "business as usual" and "policy" and use the original ovariable result for business as usual and adjust the result for the policy e.g. by adding or multiplying it by a constant reflecting the impact of the policy on the ovariable. Such adjustments can be done on the assessment level without a need to change the ovariable definition in any way.

Evaluating a latent ovariable triggers first the evaluation of its unevaluated parent ovariables (listed in dependencies) since their results are needed to evaluate the child. This chain of evaluation calls forms a recursion tree in which each upstream variable is evaluated exactly once (cyclical dependencies are not allowed). Decision commands about upstream variables are checked and applied upon their evaluation and then propagated downstream to the first variable being evaluated. For example, decisions in decision analysis can be supplied this way:

1. pick an endpoint ovariable
2. make decision variables for any upstream ovariables (this means that you create new scenarios with particular deviations from the actual or business-as-usual answer of that ovariable)
3. evaluate endpoint ovariable
4. optimize between options defined in decisions.

Other commands include: collapse of marginal columns by sums, means or sampling to reduce data size; and passing input from model level without redefining a whole ovariable.

**Opasnet Base**

Opasnet Base is a storage database for all kinds of data needed in open assessments. It may contain parameter values for models, which are typically shown as small tables on knowledge crystal pages, from which they are automatically stored to the database. It may also contain large dataset such as research datasets or population datasets of thousands or even millions of rows, and they are uploaded to the database using an importer interface. Each table has its own structure and may or may not share
column names with other tables; however, if a table is directly used as data slot for an ovariable, it must have a Result column.

Technically, Opasnet Base is a noSQL database using MongoDB software. Metadata of the tables is stored in a MySQL database. This structure offers the speed, searchability, and structural flexibility that a large amount of non-standard data requires. The database also offers version control, as old versions of a data table are kept in the database when new data is uploaded.

The database also contains data about model runs that have been performed at Opasnet, if objects were stored during that model run. This makes it possible to fetch objects produced by a particular code on a particular knowledge crystal page. Typically the newest version is fetched, but information about the old versions are kept as well. The objects stored are not located in MongoDB but on server files that can be accessed with a key. It is also possible to save objects in a non-public way so that the key is not stored in the database and is only given to the person who ran the code. Due to disc storage reasons, Opasnet does not guarantee that stored objects will be kept permanently; therefore, it is a good practice to store final assessment runs with all objects to another location for permanent archival.

There are several ways to access database content.

- If the data is on an Opasnet page, simply go to that page, e.g. http://en.opasnet.org/w/Mercury_concentrations_in_fish_in_Finland#Data
- Use a link to the Opasnet Base interface, e.g. http://en.opasnet.org/w/Special:Opasnet_Base?id=op_en4004.mercury_in_baltic_herring
- Use a function in R: dat <- opbase.data("Op_en4004", subset="Mercury in Baltic herring")
- Use a function in R for stored objects: objects.latest("Op_en4004", code_name="conc_mehg")

For further instructions, see http://en.opasnet.org/w/Opasnet_Base_UI for user interface and http://en.opasnet.org/w/Table2Base for the wiki interface of small tables.
Appendix S5: Tools to help in shared understanding

There are lots of software and platforms to support decision making. Some of them have been listed here. The focus is on open source software solutions when available. Many examples come from Finland, as we have practical experience about them. The list aims to cover different functionalities and show examples rather than give an exhaustive list of all possibilities; such lists may be found from Wikipedia, e.g. https://en.wikipedia.org/wiki/Comparison_of_project_management_software. All links were accessed 1 Feb 2020.

| Item | Functionality or process phase | Tool or software |
|------|--------------------------------|-----------------|
| Decision process | Information-based decision support | There is no single tool covering the whole decision process. Development work is needed. An interesting pilot software is being developed by the city of Helsinki for comprehensively managing and evaluating their ambitious Climate Watch and its impacts. |
| Initiative | | Several websites for launching, editing, and signing citizen initiatives at municipality or national level: Kansalaisaloite (Citizen Initiative), Nuortenideat (Ideas of the Young), Kuntalaisaloite (Municipality Initiatives). Similar tools could be used also for initiatives launched by Members of Parliament or the Government. |
| Content management | | Diary systems, file and content management systems. Lots of individual solutions, mostly proprietary. VAHVA project by the Finnish Government will provide knowledge and tools for content management. |
| Research data and analyses | | AVAA, IDA, Fairdata and other data management tools help in managing research data from an original study to archival. Avoin data (open data in Finland), platform for publishing open data. Findicator: indicators from all sectors of the society. Datahub for open data sharing. Tools for separate analysis tasks are numerous, e.g. QGIS for geographical data. Several research fields have their own research and article databases, such as ArXiv.org (articles about physics, mathematics and other fields), Several biological databases. |
| Public discussion, argumentation, statements | | Otakantaa, Facebook, Twitter, blogs, and other social media forums for discussion. Websites for fact checking: Factbar, Fullfact, Need to know project for fact checking. Agoravoting is an open voting system. Lausuntopalvelu collects statements from the public and organisations related to planned legislation and Government programs in Finland. Swarm AI for collective intelligence |
| News | | News feeds (open source) CommaFeed, Tiny Tiny RSS. Semantic, automated information searches, e.g. Leiki. |
| Item | Functionality or process phase | Tool or software |
|------|--------------------------------|------------------|
|      | Description and assessment of decision situations and relevant causal connections | Opasnet for performing Open assessments and impact assessments. Knowledge crystals as integral parts of models and assessments. Simantics System Dynamics in semantic models. Jupyter notebooks for collaborative model development. Wikidata, Wikipedia as storages of structured data and information. |
|      | Laws and regulations | Semantic Finlex contains the whole Finnish legislation and e.g. the decisions by the Supreme Court in a semantic structure. |
| Preparation of documents, co-creation, real-time co-editing | Several co-editing tools, e.g. Hackpad, MS Office365, Google Docs, Etherpad, Dropbox Paper, MediaWiki and Git. These tools enable the opening of the planning and writing phase of a decision. E.g. the climate strategy of Helsinki was co-created online with Google Docs and Sheets in 2018. |
| Development and spreading good practices | InnoVillage helps to develop practices faster, when everyone's guidance is available online and can be commented. |
| Methods | Organising systems for information and discussions | Decentralised social networking protocol Activitypub Tools: Full Fact automated fact checking Compendium. Vocabularies and semantic tools: Resource Description Framework (RDF), Finto (Finnish Thesaurus and Ontology Service), AIF-RDF Ontology using Conceptual Graphics User Interface COGUI. These act as a basis for organising, condensing and spreading knowledge. |
| Information design, visualisations | Interactive and static visualisations from complex data. Shiny, Diagrammer, Gapminder, Lucify Plotly Cytoscape |
| Work | Work processes in decision making, research etc: follow-up, documentation | Ahjo decision repository and Openahjo interface document and retrieve decisions that have been done in the city of Helsinki. Git enables reporting of both research and decision processes. There are several new platforms for improving science, such as Open Science Framework for facilitating open collaboration in research. Omidyar Network is a philanthropic investment firm supporting e.g. governance and citizen engagement. |
|      | Co-creation, experiments, crowdsourcing | Kokeilun paikka promotes experiments when applicable information is needed but not available. Sociocracy 3.0 provides learning material and principles for open collaboration in organisations of any size. |
| Item       | Functionality or process phase | Tool or software                                                                 |
|------------|--------------------------------|----------------------------------------------------------------------------------|
|            | Project management             | There are lots of project management software, mainly targeted for enterprise use but somewhat applicable in decision making or research. Some examples: [OpenProject](https://openproject.org), [Project Management Body of Knowledge](https://www.pmbok.com), [Comparison of project management software](https://www.capterra.com), [Fingertip](http://Fingertip). |
| Stakeholders | Expert services                | [ResearchGate](https://www.researchgate.net) [Solved](https://www.solved.com) and other expert networks. |