MareFrame

# Decision Support Framework

## Co-creating Ecosystem-based Fisheries Management Solutions

Guidelines for using:

Scenario visualization tools

MultiCriteria Analysis tool

Bayesian Belief Net tool

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# Guideline for using the scenario visualization tools

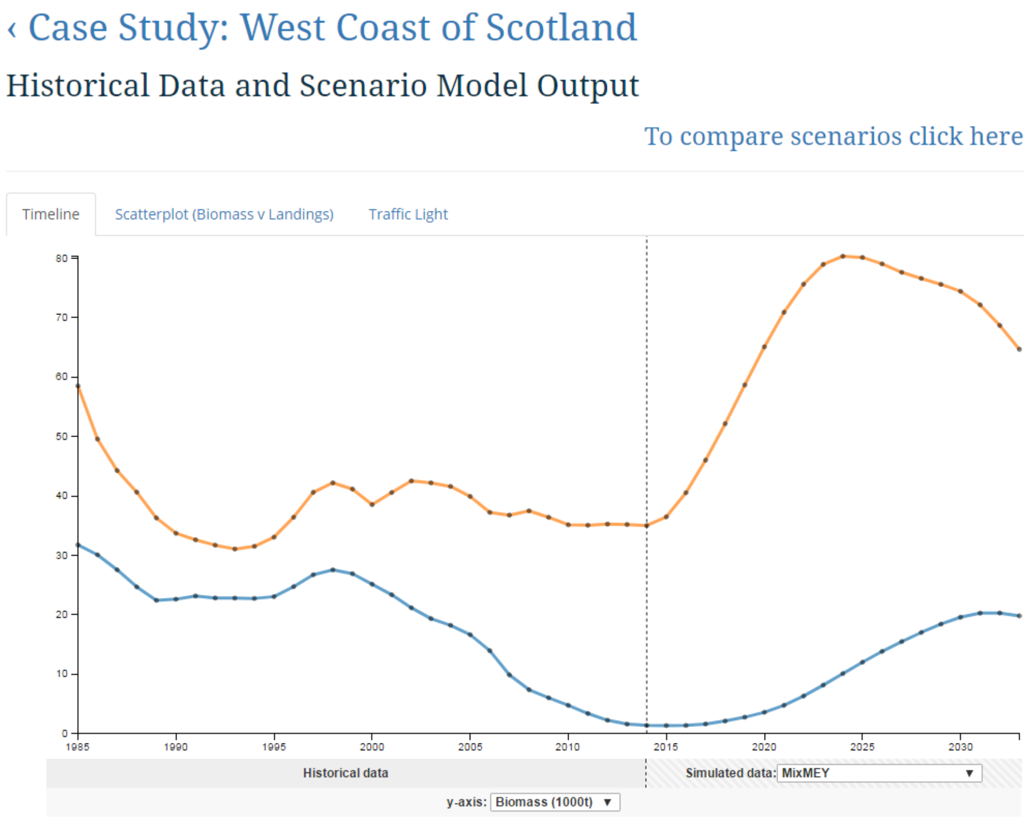


FIGURE 1: SCENARIO MODEL OUTPUT WITH MAIN APPLICATIONS HIGHLIGHTED WITH READ CIRCLES. SEE TEXT FOR AN INTRODUCTION OF THESE APPLICATIONS.

The scenario visualization tool is currently available in the following web browsers:

TABLE 1 WEB BROWSER COMPATIBILITY AS OF DECEMBER 2017

| | Iceland | West Coast of Scotland | North Sea | Baltic Sea | Gulf of Cadiz | Strait of Sicily | Black Sea |
|---|---|---|---|---|---|---|---|
| Firefox | ✓ | ✓ | – | ✓ | – | ✓ | ✓ |
| Chrome | ✓ | ✓ | – | ✓ | – | ✓ | ✓ |
| Internet Explorer | ✓ | ✓ | – | ✓ | – | ✓ | ✓ |

✓ = applied and available, ✗ = applied in case study but unavailable in web browser, – = not applied in case study.

### *Timeline*

The Timeline function (Figure 1) shows selected scenarios and variables through both historical and projected time series. The user can choose to show the projected progression for either biomass, profit, catch or value for different species under the different available management scenarios. The user can select one or more species by ticking the boxes below the main panel, or use the "Select all" or "Deselect All" buttons. The timeline functionality allows for multiple species, but only one scenario or variable to be shown at a time.

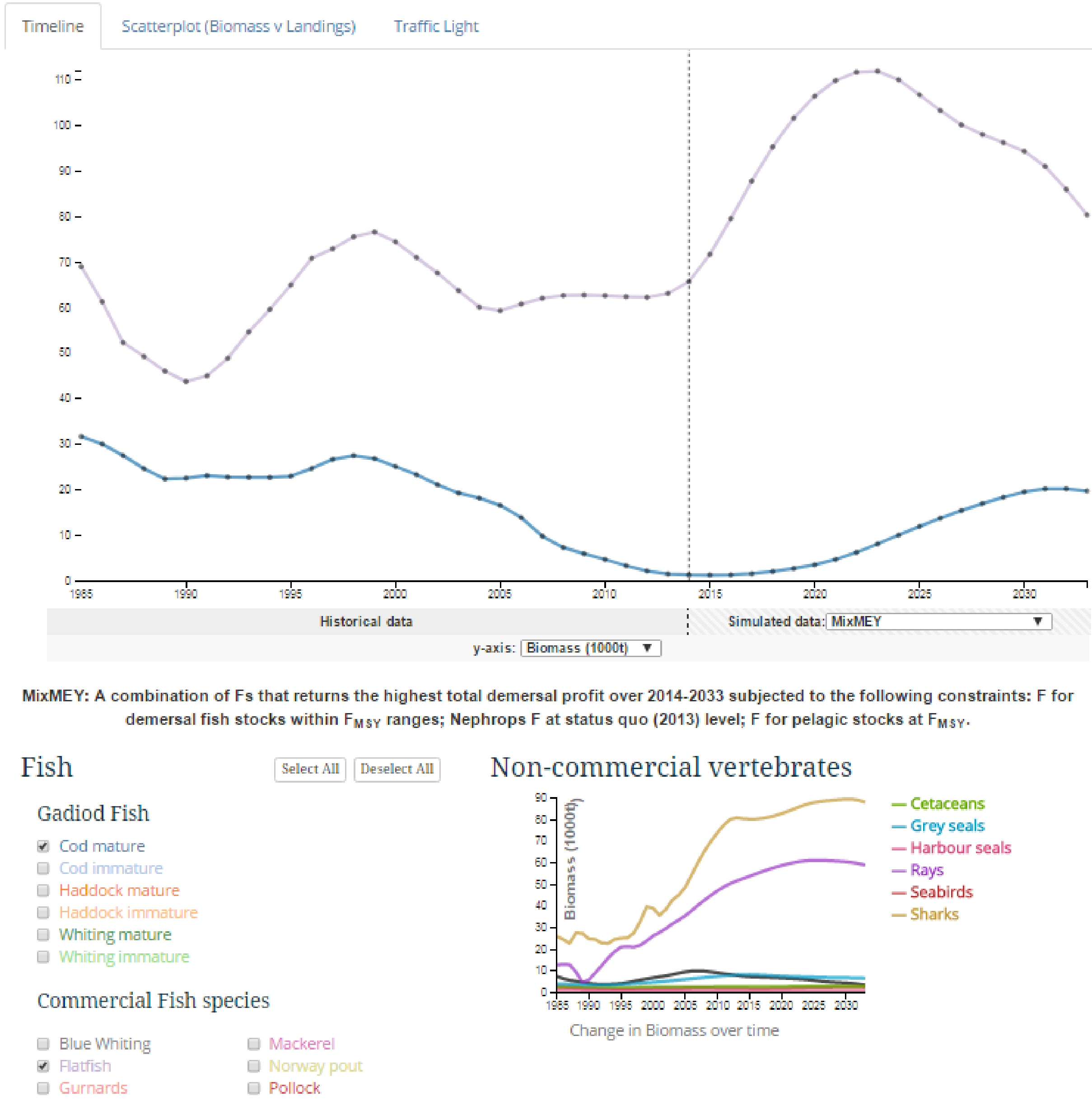


FIGURE 2: TIMELINE FUNCTION SHOWING BIOMASS VALUES FOR THE SELECTED SPECIES IN A GIVEN SCENARIO

### *Timeline Scenarios*

The Timeline scenario function (Figure 3) allows the user to compare different scenarios. The user can choose between all of the available scenarios for a given case study by ticking the boxes below the graph. The user can further choose between showing the historical and projected values for either biomass, catch or value. Contrary to the timeline function, only one species can be shown at a given time.

The individual scenarios are colour coded and can be identified by hovering the cursor over the scenario of interest. Confidence intervals (a 95% confidence level was chosen in this example) can be displayed by ticking the box marked "Show confidence intervals" below the graph. The method for estimating confidence intervals vary by the modelling approach. They can be described as the modeller’s subjective evaluation of uncertainty in the hindcast and forecasts. The confidence intervals are shown as a colour shading of the graph area.

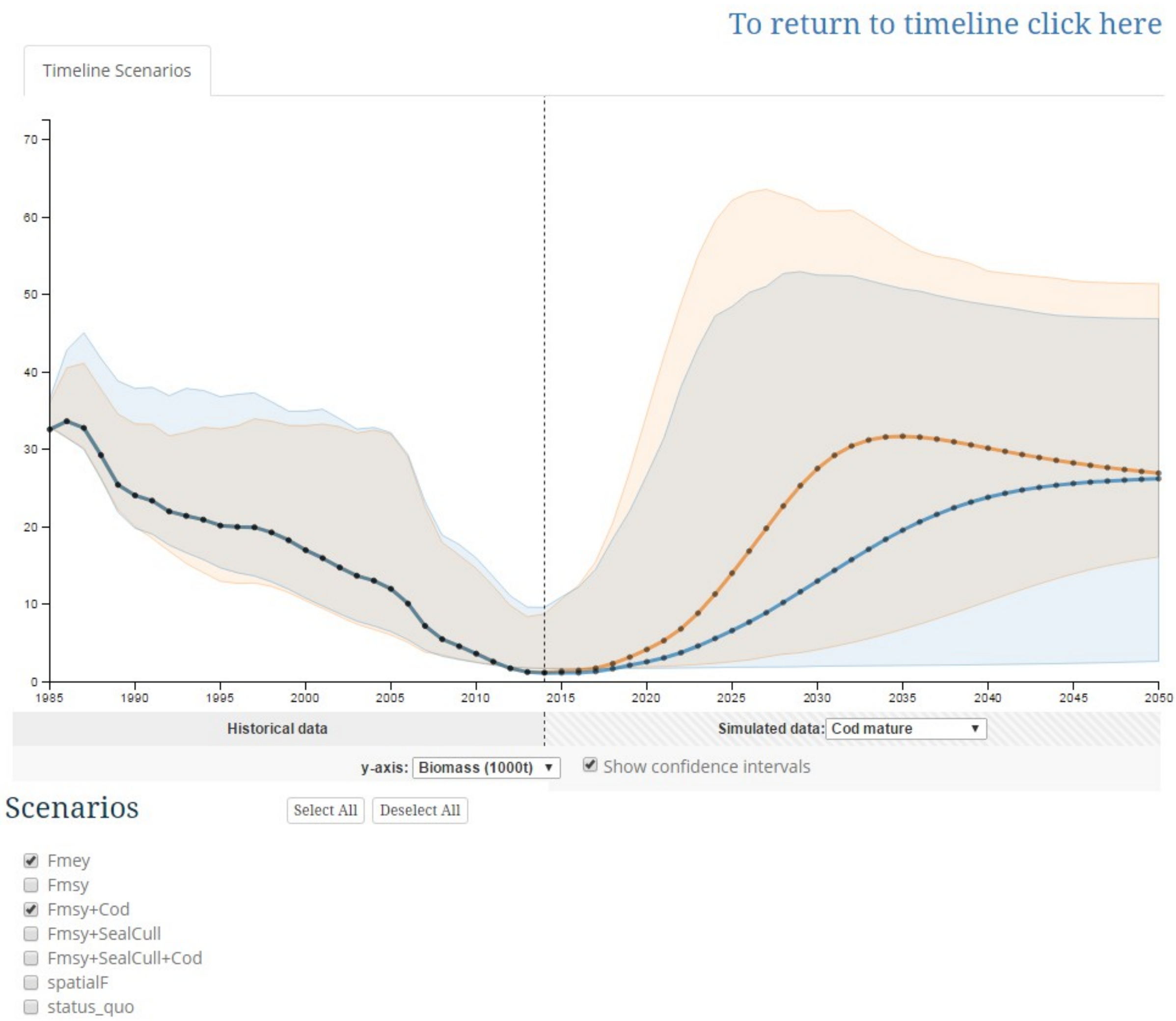

FIGURE 3: TIMELINE COMPARISON SHOWING THE PROJECTED CATCH VALUES FOR THE SELECTED SCENARIOS FOR A GIVEN SPECIES

## *Scatterplot*

The Scatterplot application provides dynamic plots of biomass, landings and value for one or more selected species through a historical and projected time series for a selected scenario (Figure 4).
The user selects a scenario via a scroll down menu and one or more species in a selection panel below. The scatterplot displays landings as a function of biomass for the selected species. The position of a given year in this graph is displayed by a coloured circle, where the size of the circle is proportional to the value of the landings of the species in this year (specific data point information for any point on the graph is available through a mouse over function). The user can either move through the historical and projected trajectory using a slider below the graph area or view the changes in biomass/landings and value displayed through time as an animation (available by clicking on a "press play" button to the left of the time slider).

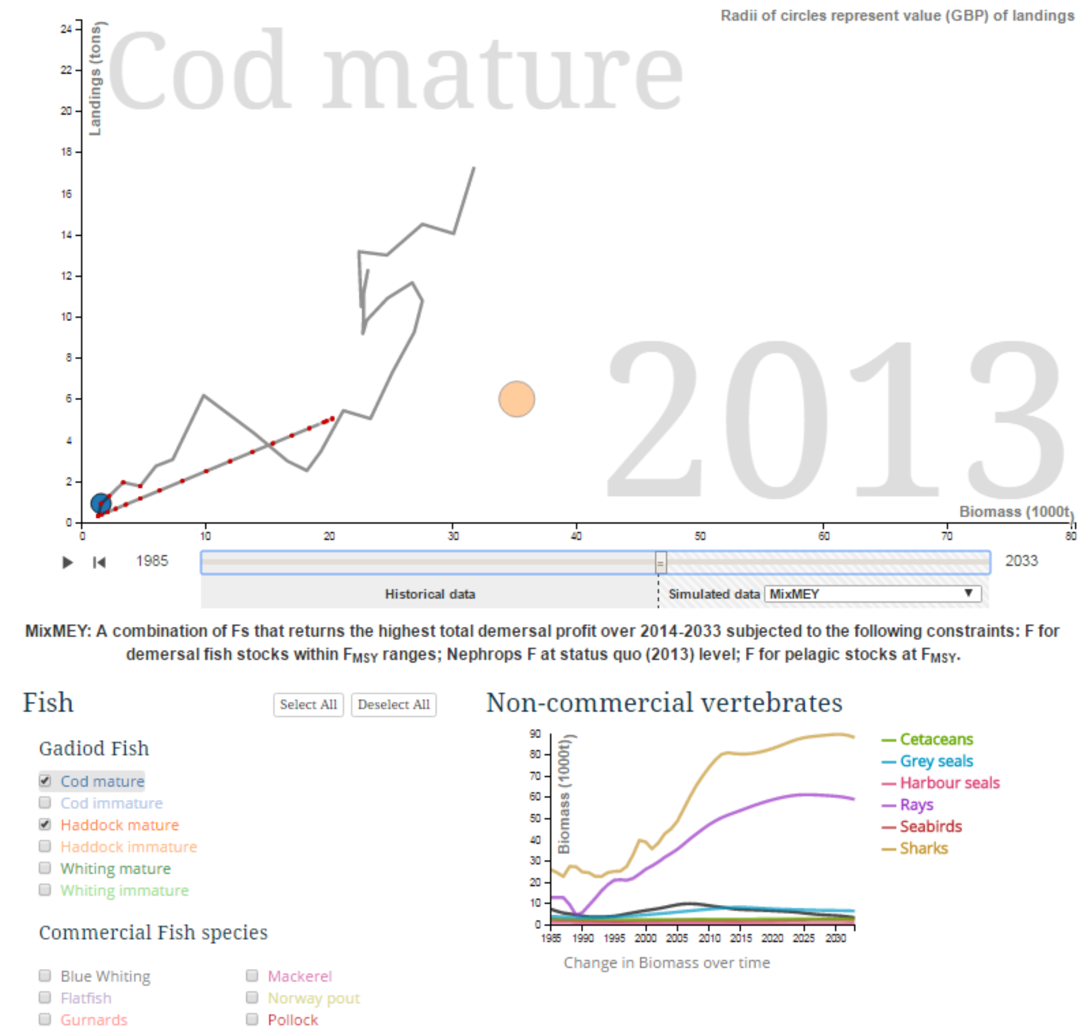


**Figure 4: Scatterplot showing projected values for the selected species in a given scenario**

## *Traffic Light*

The Traffic Light application (Figure 5) provides the user with a tabulated overview of the state of variables (column 1) through the historical and projected time span with regard to defined thresholds (column 2 and 3) for the modelled scenarios, represented by "traffic light colours". Two thresholds are defined for each group: a value for switching from red to yellow, and a value for switching from yellow to green[1]. The cells in the column under each scenario changes colour depending on the position of variables with regards to the thresholds. Using a slider, the user can scroll through the years and thereby quickly "screen" the scenarios with regard to the thresholds.

Year: 2033

1985 — 2033

Historical data — Simulated data

| Species | Red-Yellow | Yellow-Green | MixMEY | Spatial_F | Gadiod recovery | Gadiod recovery with seal cull | MSY | Status Quo |
|---|---|---|---|---|---|---|---|---|
| Grey seals | 3.75 | 4.783 | 6.548 | 5.907 | 6.186 | 4.566 | 6.232 | 8.949 |
| Harbour seals | 0.765 | 0.939 | 0.690 | 0.731 | 0.835 | 0.831 | 0.590 | 0.456 |
| Cetaceans | 2.533 | 2.614 | 2.833 | 2.750 | 2.764 | 2.780 | 2.815 | 2.883 |
| Seabirds | 1.728 | 2.036 | 2.456 | 2.367 | 2.415 | 2.416 | 2.591 | 1.513 |
| Cod mature | 14 | 22 | 19.786 | 39.125 | 30.748 | 31.642 | 24.159 | 0.002 |
| Cod immature | 5.201 | 13.551 | 15.132 | 26.419 | 23.508 | 23.770 | 17.293 | 0.002 |

**Figure 5: Traffic light function showing projected values for different species under different scenarios for a given year**

1 These thresholds are set by the modeller and cannot be changed by the user (however, the modeller can of course cooperate with stakeholders about defining relevant thresholds).

## Guideline for using the MultiCriteria Analysis tool

A complete MCA application comprises four components: the decision tree, the composite analysis graph, the consequence table, and the sensitivity analysis (Figure 13). Users can define priorities, and compare and evaluate the relative performance of the alternatives across a set of criteria, calculated as a weighted sum of scores. Advanced users can define new decision trees and upload or manually insert required data in the consequence tables, making the MCA tool readily applicable to new case studies.

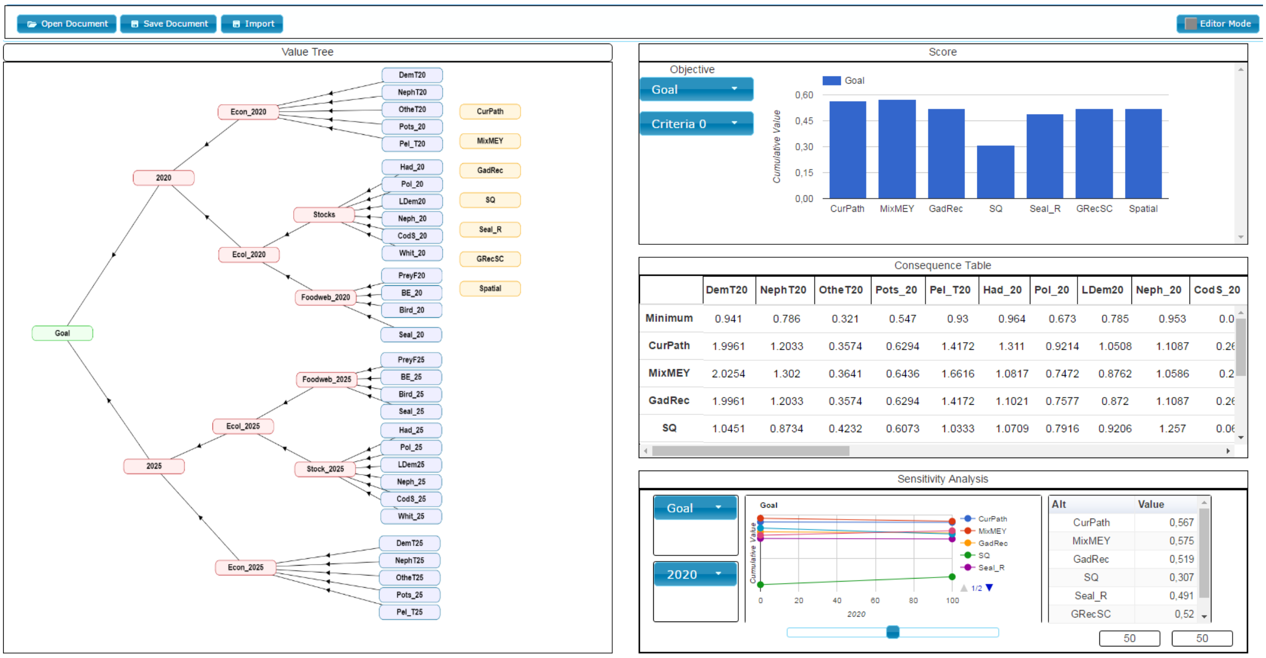


FIGURE 6: INTERFACE OF THE MULTI-CRITERIA ANALYSIS TOOL: DECISION TREE (YELLOW), COMPOSITE ANALYSIS (BLUE), CONSEQUENCE TABLE (GREEN) AND SENSITIVITY ANALYSIS (RED)

### *Decision tree*

The decision tree is constructed in collaboration with stakeholders to reflect the main aspects of the evaluation, arranged into a hierarchical structure. From the left to right, the decision tree includes four types of elements. The type of each element and potential descriptive information is revealed by clicking on them:

- Goal: This is the placeholder for the formal but abstract goal that each alternative should aim to achieve (e.g. "sustainable and prosperous fisheries")
- Objectives: these are higher and lower order objectives that reflect main types of concerns as arranged into a logical and hierarchical order. In the example of Figure 6, the decision tree includes two higher-level objectives, respectively relating to the short-term concerns ("2020") and long-term concerns ("2025"). Each of these branches are subsequently divided into two lower level sub-objectives, respectively relating to economic concerns ("Econ_2020") and ecological concerns ("Ecol_2020), which in turn is subdivided into "stocks" and "foodweb".
- Attributes: the indicators that each of the objectives on the lowest level are evaluated against. For instance, Econ_2020 is evaluated against the forecasted economic performance (total revenue) of five fleet segments (DemT20, NethT20, etc.) for each alternative.
- Alternative: the management alternatives to be evaluated. If the user knows that an

alternative is clearly inferior or irrelevant in some way, it can be excluded from the evaluation by double-clicking on the alternative, and checking the button marked "Exclude alternative". This simplifies the presentation of outcomes in the composite analysis. The alternative can be brought back later if needed by unchecking the exclusion button.

The user can define value functions in an interface that appears when double-clicking on an attribute (Figure 14). The value function is shaped by adding points (double click) to a desired place in the graph area.

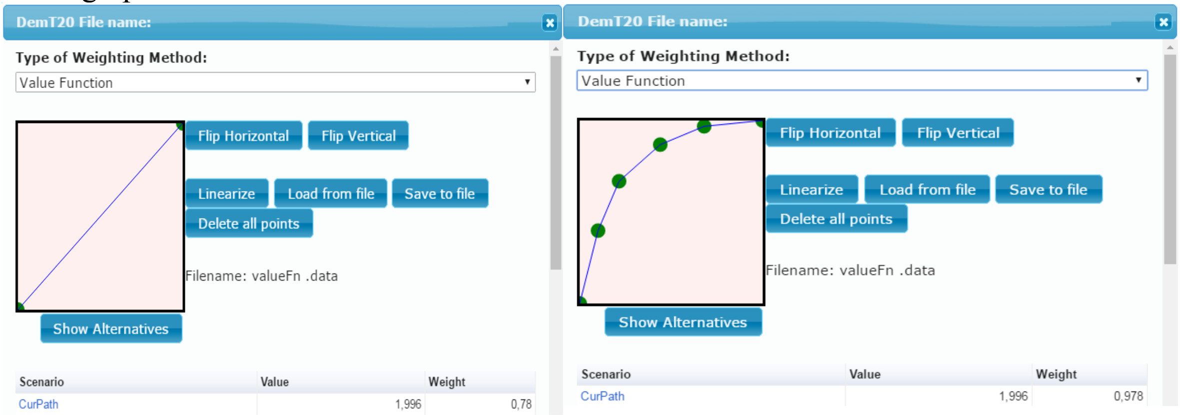


FIGURE 7: INTERFACE FOR DEFINING UTILITY FUNCTIONS – PRE-SET LINEAR FUNCTION (LEFT) AND USER-DEFINED UTILITY FUNCTION (RIGHT)

The default value function is linear, and increases (vertical axis) from 0 to 1, where 1 signifies a maximum utility score. The horizontal axis represents the range of the indicator in question within defined minimum and maximum limits in the original scale of the attribute (euros, tonnes, full time equivalent jobs ets.

The user can invert the value function ("flip vertical") for indicators for which an increase in the indicator value involves a decreased utility (indicator of cost, pollution or other harm). The user may also define any shape of the value function, provided that it starts at 0 and ends at 1 (or the opposite).

For haddock SSB, for instance, the x-axis reflects SSB and the y-axis reflects utility on a scale from 0-1. If we imagine that the $SSB_{MSY}$ for haddock is around the middle of the diagram, the users might want to define a utility function as illustrated above, reflecting that increases in SSB above $SSB_{MSY}$ are less important than any increase until that point.

The user can define the relative priority of different concerns by assigning weights to different objectives. This is done in an interface that becomes available when clicking on a node in the decision tree (Figure 7). The decision weights can be defined either by moving a slider or by typing a number.

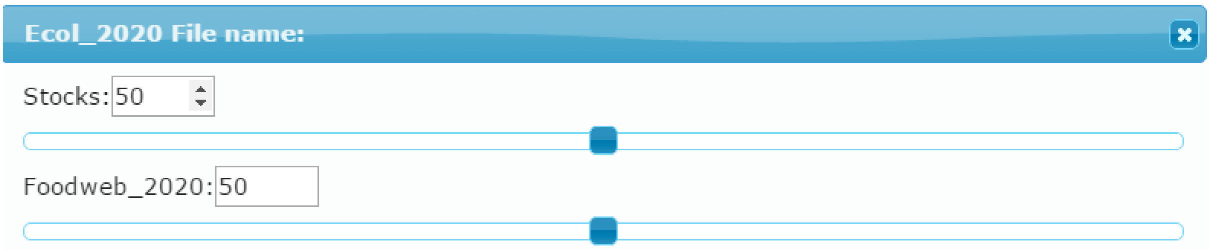


FIGURE 8: INTERFACE FOR DEFINING DECISION WEIGHTS IN THE MAREFRAME MULTI-CRITERIA ANALYSIS TOOL

### *Composite analysis*

Once decision weights and utility functions are defined, the composite analysis allows the user to assess the overall performance of each alternative with a selected level of detail (Figure 9).

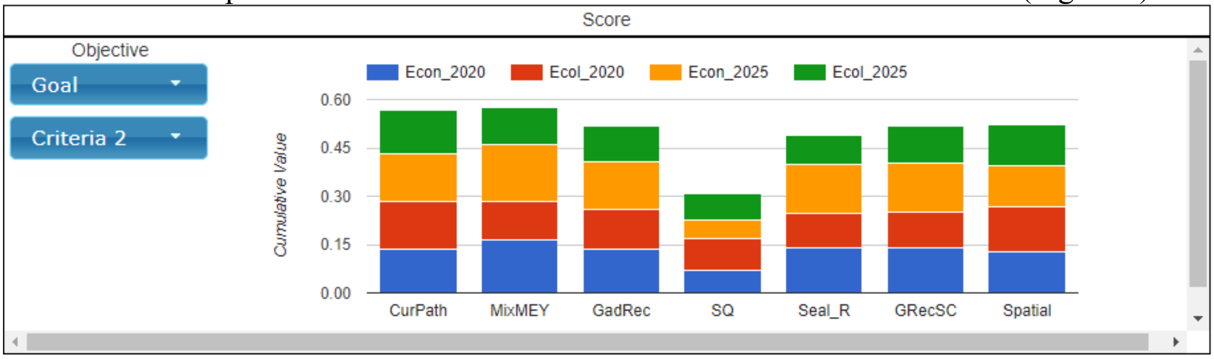


FIGURE 9: THE COMPOSITE ANALYSIS INTERFACE IN THE MAREFRAME MULTI-CRITERIA ANALYSIS TOOL

In the example shown, the management alternative (scenario) "MixMEY" performs best overall, closely followed by "CurPath". The user has here chosen to display the overall performance of the alternatives ("Goal") with an intermediate level of detail ("Criteria2"). The composite analysis interface allows the user to inspect the contributions of each indicator to the overall performance in different levels of details. For instance, as the indicator "Econ_2015" provides a large contribution to the overall result, the user could inspect why this is so in more detail by selecting that "Econ_2025" is displayed in relation to indicators on the lowest level, i.e. "Criteria 3" (Figure 10).

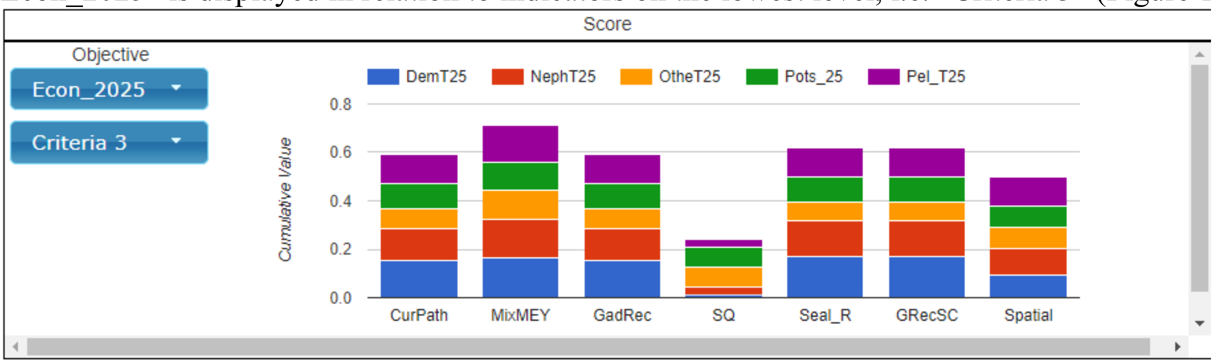


FIGURE 10: THE COMPOSITE ANALYSIS INTERFACE IN THE MAREFRAME MULTI-CRITERIA ANALYSIS TOOL. THE FIGURE SHOWS AN EXAMPLE OF AN INTERFACE IN WHICH THE USER CAN ANALYSE HOW THE DIFFERENT SCENARIOS PERFORM WITH REGARD TO OBJECTIVES ON DIFFERENT LEVELS OF ANALYSIS. THE FIGURE SHOWS THE RELATIVE PERFORMANCE OF SCENARIOS WITH REGARD TO A SUB-OBJECTIVE (ECON_2025).

### *Consequence table*

The consequence table (Figure 11) displays the expected performance for the different alternatives on the criteria. The consequence table allows the user to inspect the forecast that is used in the analysis.

In the illustrated example, the estimates shown are rendered relative to a reference period (average values for the period 2011-2013). For instance, the estimated outcome for DemT20 for the "Current Path" alternative is 1.9961, predicting that the revenue of demersal trawls will double by 2020 compared to the reference period if this alternative is pursued.

Consequence Table

| | DemT20 | NephT20 | OtheT20 | Pots_20 | Pel_T20 | Had_20 | Pol_20 | LDem20 | Neph_20 | CodS_20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Minimum rating | 0.941 | 0.786 | 0.321 | 0.547 | 0.93 | 0.964 | 0.673 | 0.785 | 0.953 | 0.058 |
| Baseline | 1.618 | 1.109 | 0.394 | 0.628 | 1.379 | 1.418 | 0.844 | 0.97 | 1.168 | 0.184 |
| CurPath | 1.9961 | 1.2033 | 0.3574 | 0.6294 | 1.4172 | 1.311 | 0.9214 | 1.0508 | 1.1087 | 0.2605 |
| MixMEY | 2.0254 | 1.302 | 0.3641 | 0.6436 | 1.6616 | 1.0817 | 0.7472 | 0.8762 | 1.0586 | 0.264 |

FIGURE 11: THE CONSEQUENCE TABLE IN THE MAREFRAME MULTI-CRITERIA ANALYSIS TOOL

The minimum and maxim limits are set to define the boundaries for the indicator range. In the example, the lower and upper limits were respectively set to 0.90*the lowest indicator value across the alternatives and 1.10 * the highest indicator value across the alternatives.
The user can revise the entries in the consequence table, but the changes will only apply to the interface of the user in question and will be reverted to original values after the work session unless the changes are saved as a local file (see section 4.2.2.3 below).

### *Sensitivity analysis*

The sensitivity analysis interface (Figure12) allows the user to explore the robustness of the evaluation with regard to changes in decision weights or in the forecasts. The sensitivity analysis of the MCA also allows for an exploration of sensitivity of evaluation outcomes with regard to uncertainty in the estimation of indicator values in the consequence table (e.g. uncertainty in the SSB level). The user can change the weighting of indicators by moving the slider left or right, between values of 0 and 100. For exploring sensitivity of the scores (value functions), the scale will range between the minimum and maximum values given in the consequences table.
In the example shown, the MixMEY strategy outperforms all other alternatives regardless of the weight given to short-term concerns (2020), although the "CurPath" alternative performs just about as well if all decision weight is given to short-term concerns. In turn, the relative ranking of "Spatial" (pink line), "GadRec" (orange line), and GRecSC (pale blue line) is sensitive to the short term vs. long-term tradeoff;  GRecSC will perform best among these alternatives for a decision weight lower than 68 (relative to a decision weight of 100 for 2025 concerns) whereas "Spatial" will perform better for a higher prioritisation of short-term concerns.

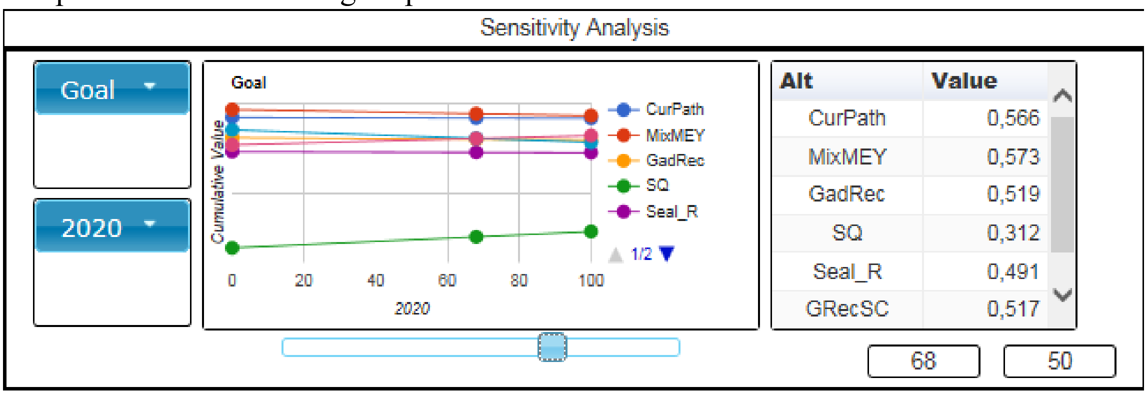


FIGURE 12: THE SENSITIVITY ANALYSIS INTERFACE IN THE MAREFRAME MULTI-CRITERIA ANALYSIS TOOL

### Input for the MCA and how to create and save a MCA

The scenario visualisation tools can utilize any quantitative data in the form of point estimates that provides information on the variables in question. The data can be uploaded as a single file by the web-administrator or be entered manually. The user can revise the entries and save the changes as a local file, but the data entries for the MCA tool on the web can only be permanently changed by the web administrator. Data can be uploaded to the consequence table in Excel-format. When adding new data to an existing MCA structure, the order of the indicators must be in the same order as the ones in the consequence table.

### *How to upload new data for an existing MCA model*

In the editor mode, the user can revise individual data entries in the consequence matrix manually. If the consequence matrix is large (due to a large number of attributes or alternatives or both), it is convenient to upload a new data set from a file. The MCA program defines the required file structure once the value tree is defined. The input file to be uploaded needs to be a csv file and have the format shown in Error: Reference source not found below.
Note that instances of the small letter "x" in the column to the right are required for the uploading to succeed).

TABLE 2: FORMAT OF THE CSV-FILE WITH DATA INPUTS FOR THE CONSEQUENCE TABLE THAT CAN BE UPLOADED FOR THE MAREFRAME MCA PROGRAM.

| | AttributeA | AttributeB | AttributeX | | |
|---|---|---|---|---|---|
| **Minimum limit** | Min A | Min B | Min X | | |
| **Alternative1** | Data A1 | Data B1 | Data X1 | Description of Alternative1 | x |
| **Alternative2** | Data A2 | Data B2 | Data X2 | Description of Alternative 2 | x |
| **AlternativeX** | Data A3 | Data B3 | Data X3 | Description of Alternative X | x |
| **Units** | Unit A | Unit B | Unit X | | |
| **Maximum limit** | Max A | Max B | Max X | | |
| **Attribute Descriptions** | Description of alternative A | Description of alternative B | Description of alternative X | | |

### *How to create a new MCA*

A new MCA can be constructed from scratch in the following location on the MareFrame web site:

- Case studies -> "test case" -> link to MCA[2]

This opens an empty MCA page, in which the user can construct a new model.
Alternatively, the user can open an existing case study, activate the "editor mode", delete all elements of the existing case, and then build the new MCA, but this involves more work than the previous approach.
The best way to construct the new MCA is as follows:

1) Complete the consequence matrix with descriptions as in the format shown in Error: Reference source not found

2) Upload the csv file to the MareFrame MCA page. This imports the attributes with names and

2 http://mareframe.mapix.com/dev/MCA2/DST.html?model=testcase

descriptions and data values into the MCA.

3) Create, name and connect objectives to complete the value tree. This is done in "editor mode" as follows.

   a. Add new element.

   b. Double-click to modify the element, double-click on the default name given to the element (e.g. "Objective1") and change the name to the required name.

   c. Use the mouse to drag the element to the desired location in the value tree space (conventionally with higher order objectives to the left and lower order objectives to the right, followed by attributes and alternatives further to the right (see existing case studies using MCA for examples)

   d. Connect elements with arrows using the "connect tool". The arrows must go from attributes to lower order objectives and then to the higher level objective(s). The alternatives should not be connected to other elements with arrows.

4) The new MCA will now include data and correct names for each element and can be saved locally as a new MCA file (see below).

### *Saving a new or modified MCA*

Users can save a new or modified MCA as follows:

1) Click "save document"

2) Click on "Download" in "Filename xxx.xdsl" located just below the value tree window (Figure 13)

3) The file will be sent to the user's default download folder and will be given a default name (e.g. "model(1).xdsl."). The files and can renamed provided that the name ends with the required file specification, i.e. ".xdsl". The user can store and share files, e.g. through email.

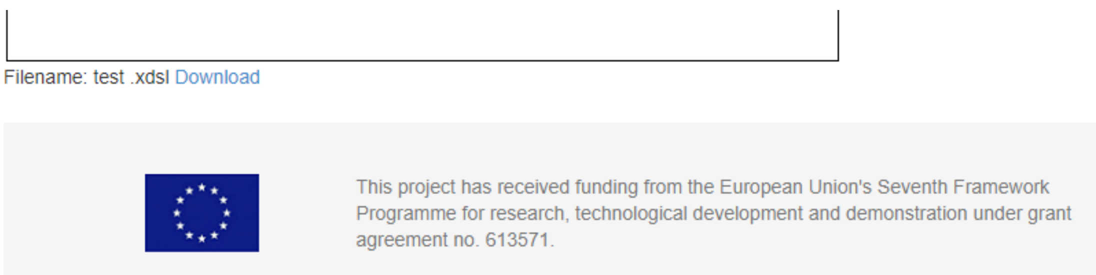


FIGURE 13: EXCERPT SHOWING THE LOCATION OF THE FUNCTION TO DOWNLOAD/SAVE A MCA FILE LOCALLY

Note that steps provided here are general. Certain aspects of the download procedure may differ depending on the web browser being used.

## Programs for the MultiCriteria Analysis tool

The MCA tool is developed as a web application. The great advantage of web-applications are there is no installation process. All the user needs is a browser. Going to the application urls[3] will load everything, and after there is no dependency on a web connection, every calculation is performed in the browser

The MCA web-application is written in typescript, which translates the code to JavaScript.

JavaScript is the most used programming language for web applications. 3rd party libraries used are jQuery, easeljs and Google Charts.

The jQuery framework[4] is used for general HTML document traversal and event handling, like buttons or sliders.

Easeljs is used for the value tree elements and connections and for value function design.

Google Charts[5] is used for MCA tables and graphs.

The CreateJS framework for the MCA model interface[6].

The source code for MCA is available at: https://github.com/Tokni/Mareframe-BBN-MCA-VS15/tree/css

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3 http://mareframe.mapix.com/dev/MCA2/DST.html

4 https://jquery.com/

5 https://developers.google.com/chart/

6 http://www.createjs.com/

# Guideline for using the Bayesian Belief Net tool

The BBN structure includes decision nodes and nodes representing external drivers, chance nodes that represent the main dynamics of the system in question, and utility nodes that represent perceived utilities associated with the states of system indicators. The strength of linkages between chance nodes are defined in terms of conditional probabilities. Advanced users can define new BBNs and upload or manually insert required data in conditional probability tables, making the tool readily applicable to new case studies.

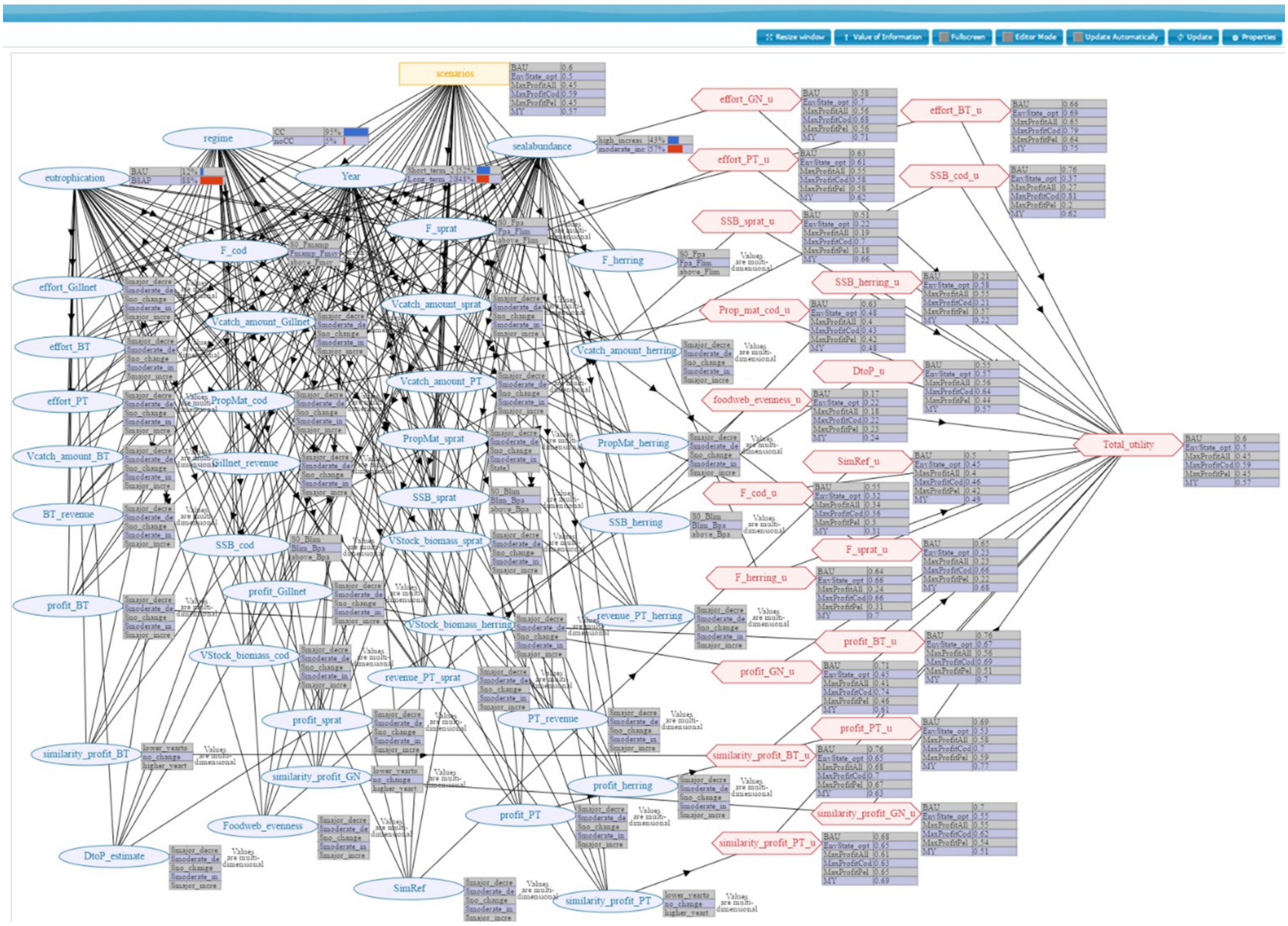



Figure 14: Interface of the MareFrame Bayesian Belief Net tool as it is applied to the Baltic case study.

For the purposes of this description, this BBN is divided into three areas (Figure 15) decisions aspects and uncertainty about external drivers (blue), representation of system dynamics (orange) and utility aspects of outcomes (green)[7].

7 Technically, the inclusion of decision nodes and utility nodes renders the BBN into a Bayesian Decision Network (Pollino & Henderson, 2010). For convenience, we will nevertheless stick to the term BBN throughout this text.

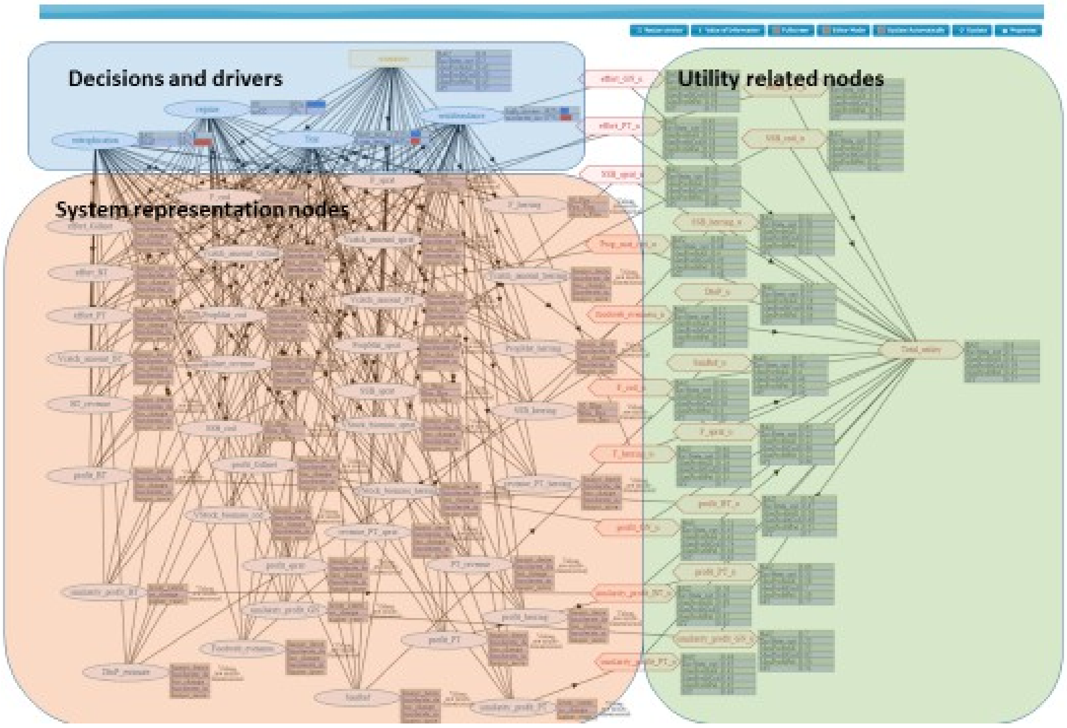



FIGURE 15: INTERFACE OF THE MAREFRAME BAYESIAN BELIEF NET (BBN) TOOL AS IT IS APPLIED TO THE BALTIC CASE STUDY. THE BBN INCLUDES NOTES THAT RESPECTIVELY REPRESENT DECISION ASPECTS AND DRIVERS (BLUE), SYSTEM DYNAMICS (ORANGE) AND ASPECTS OF UTILITY (GREEN).

### *System Representation*

The main interactions of the fisheries and environmental system in question are represented by an influence diagram, in which several "chance nodes" are connected to each other with unidirectional arrows, i.e. arcs (Figure 16).

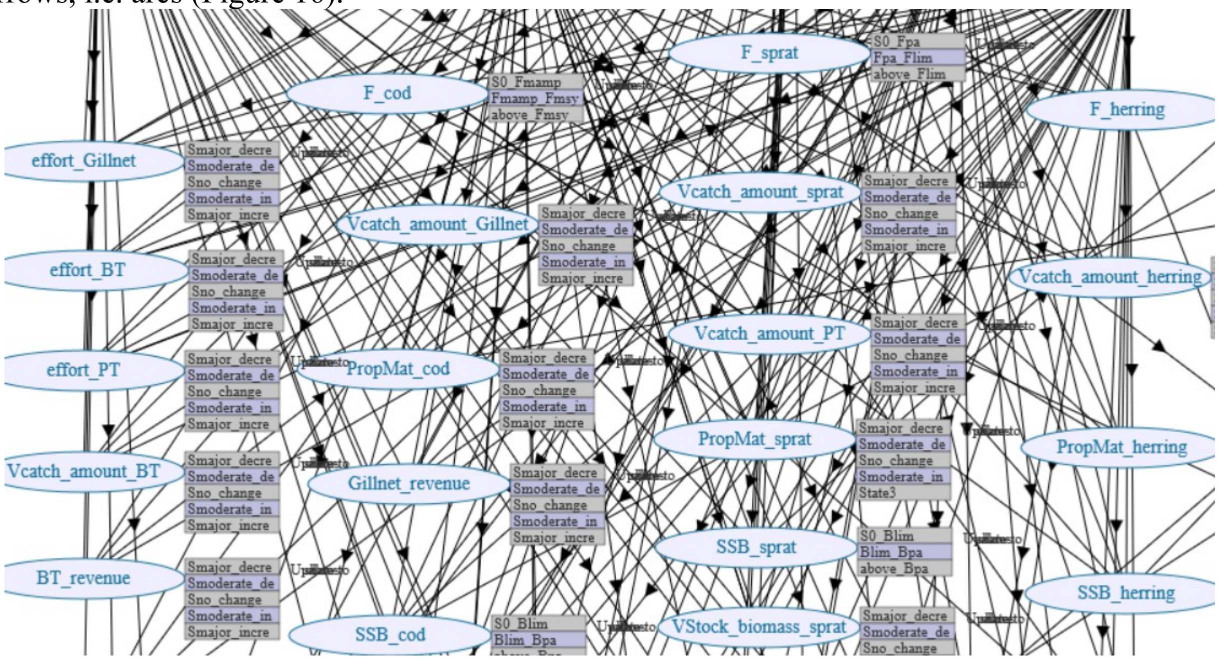



FIGURE 16: EXCERPT OF INFLUENCE DIAGRAM TO REPRESENT MAIN INTERACTIONS OF THE FISHERIES AND ENVIRONMENTAL SYSTEM OF THE BALTIC CASE STUDY.

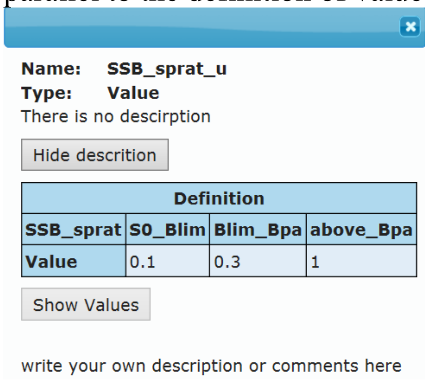
The strength of the influence of one node on another is expressed with a conditional probability table, which appears when double clicking on a chance node. An excerpt of the conditional probability table for the variable "F_cod" (which represents the fisheries mortality for cod) is shown in Figure17. The probability of F_cod being above or below certain thresholds values depends on a range of nodes, including the management alternative (scenario), whether we are considering a short or long-term perspective (“year”), presence or absence of climate change (“regime”), as well as “eutrophication” and “seal abundance”.

| | | | | | |
|---|---|---|---|---|---|
| **scenarios** | **BAU** | **BAU** | **BAU** | **BAU** | **BAU** |
| **Year** | **Short_term_2020** | **Short_term_2020** | **Short_term_2020** | **Short_term_2020** | **Short_term_2020** |
| **regime** | **CC** | **CC** | **CC** | **CC** | **noCC** |
| **eutrophication** | **BAU** | **BAU** | **BSAP** | **BSAP** | **BAU** |
| **sealabundance** | **high_increase** | **moderate_increase** | **high_increase** | **moderate_increase** | **high_increase** |
| **S0_Fmamp** | 0.112 | 0.071 | 0.091 | 0.1 | 0.149 |
| **Fmamp_Fmsy** | 0.442 | 0.536 | 0.66 | 0.397 | 0.511 |
| **above_Fmsy** | 0.446 | 0.393 | 0.249 | 0.502 | 0.34 |

FIGURE 17: EXCERPT OF CONDITIONAL PROBABILITY TABLE FOR F_COD FOR THE BALTIC CASE STUDY.

### *Utility Nodes*

The utility nodes allows the user to define details of preferences in relation to different states of a variable. The definition of preferences support a structured evaluation of alternatives in a similar way as for MCA, i.e. by calculating a weighted sum of utility contributions from the estimated outcomes of variables of each of the management alternatives/scenarios (see description of the MareFrame MCA tool). Preferences are defined in a utility node, which is associated to the chance nodes that are considered of direct relevance for the evaluation. The main difference between MCA and BBN is that the former relies on the expected outcome (point estimate) while the letter uses probability distribution of the parameters (i.e. chance nodes) in the model.
The user specifies the utility associated with each of the states of the variable in question, such as shown for the SSB of sprat in Figure 25. In this example, SSB for sprat is defined to be at a maximum for any SSB value at Bpa or higher, whereas lower utilities are ascribed respectively for SSB values between Blim and Bpa and below Blim. The definition of utility nodes in BBN is parallel to the definition of value functions in MCA.


**Name:** **SSB_sprat_u**
**Type:** **Value**
There is no descirption

Hide descrition

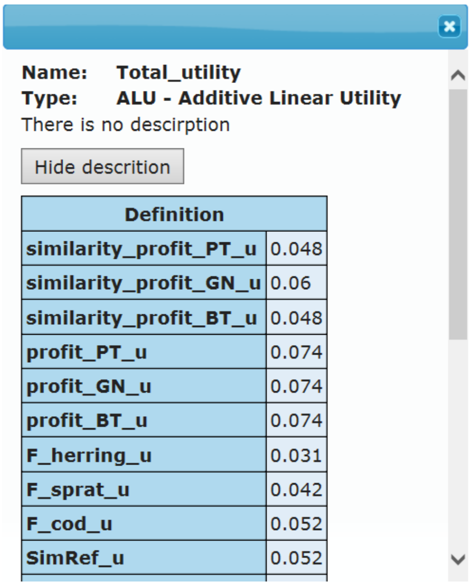
| **Definition** | | | |
|---|---|---|---|
| **SSB_sprat** | **S0_Blim** | **Blim_Bpa** | **above_Bpa** |
| **Value** | 0.1 | 0.3 | 1 |

Show Values

write your own description or comments here

FIGURE 18: UTILITY TABLE FOR SPRAT SSB FOR THE BALTIC CASE STUDY.

The priority of the objective represented by the utility nodes is defined in an integrative utility node (Figure 18). In this node, the user defines the relative weights (which sum up to 1) attributed to each utility nodes. In the example in Figure 19, the utility of the profit for the three fleets: pair trawls (profit_PT_u), gillnetters (profit_PT_u) and bottom trawls (profit_BT_u) are set equal to each other, each with a weight of 0.074.



Name: Total_utility
Type: ALU - Additive Linear Utility
There is no descrption
Hide descrition

| Definition | |
|---|---|
| similarity_profit_PT_u | 0.048 |
| similarity_profit_GN_u | 0.06 |
| similarity_profit_BT_u | 0.048 |
| profit_PT_u | 0.074 |
| profit_GN_u | 0.074 |
| profit_BT_u | 0.074 |
| F_herring_u | 0.031 |
| F_sprat_u | 0.042 |
| F_cod_u | 0.052 |
| SimRef_u | 0.052 |

FIGURE 19: TABLE FOR DEFINING DECISION WEIGHTS IN THE BALTIC CASE STUDY. THESE QUANTITIES REPRESENT SUBJECTIVE VALUE STATEMENTS BY STAKEHOLDERS.

### *Decision nodes*

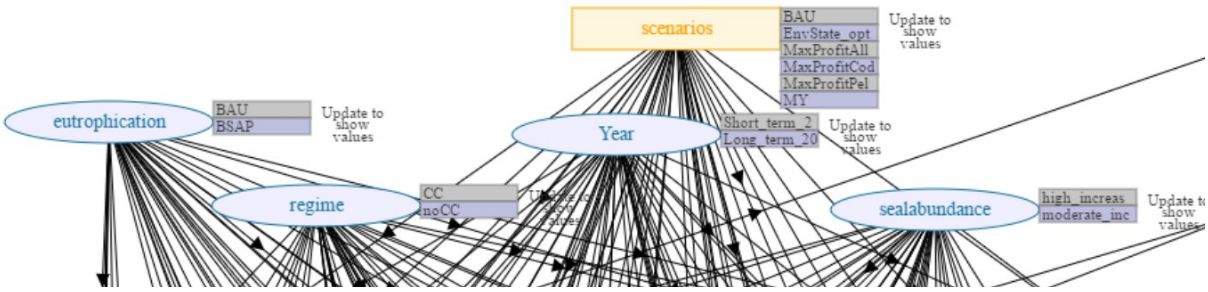



FIGURE 20: CLOSE UP ON NODES WITH A DECISION ASPECT FOR THE BBN OF THE BALTIC CASE STUDY BEFORE THE MODEL HAS BEEN UPDATED.

The BBN allows the user to explore likely effects of various decisions on indicator states, and to evaluate the desirability of management alternatives. Various decisions can be explored by the user either by i) selecting one of the pre-defined scenarios contained within the pale yellow box “scenarios”, or ii) by making changes in the set of starting assumptions (chance nodes), which are conditioned on driving factors like *eutrophication*, *regime*, *year* and *seal abundance* (Figure 20)

### *Pre-defined scenarios*

The decision node of BBN (the yellow rectangle in Figure 21 titled “scenarios”) includes a set of management alternatives (“scenarios”) to be evaluated. The user can select a scenario and then click “Update Automatically” to calculate likely outcomes throughout the BBN. For instance, outcomes of the alternative named “MaxProfitCod” is shown in Figure 22.

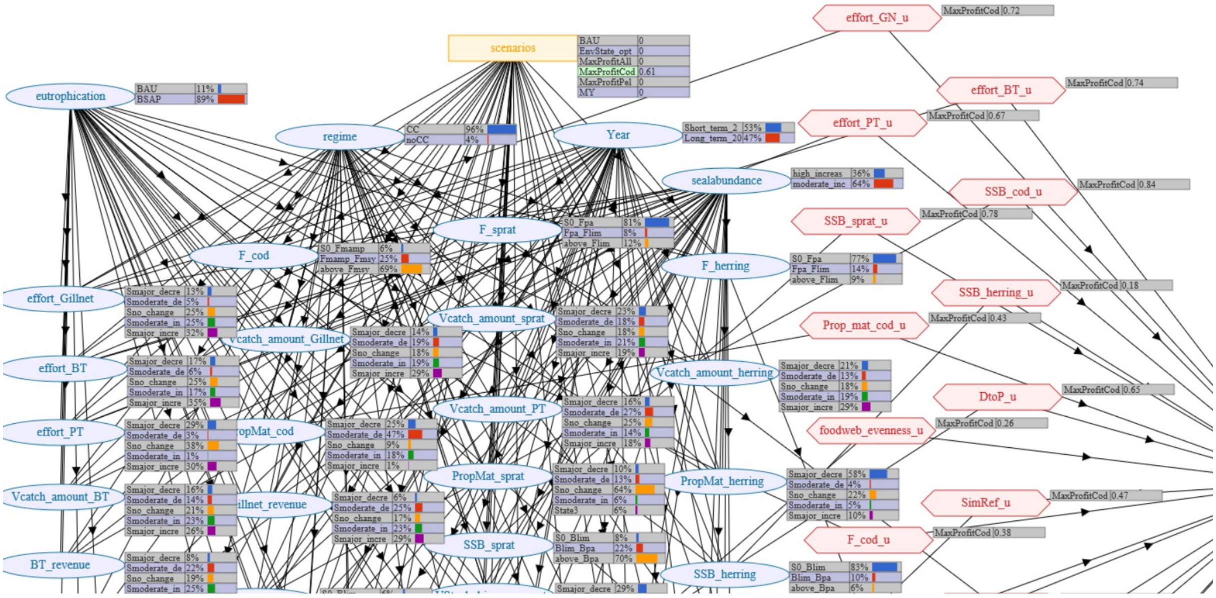



FIGURE 21: EXCERPT OF THE BBN OF THE BALTIC CASE STUDY AFTER THE MODEL HAS BEEN "UPDATED" TO ESTIMATE OUTCOMES OF THE MANAGEMENT ALTERNATIVE "MAXPROFITCOD".

The outcomes of the scenarios are displayed in terms of probabilities of achieving indicator values below or above defined thresholds, such as shown for the SSB for herring in Figure9.

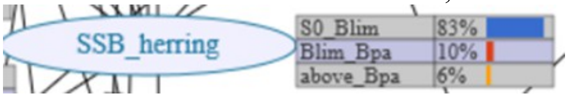



FIGURE 22: EXCERPT OF THE BBN OF THE BALTIC CASE STUDY AFTER THE MODEL HAS BEEN "UPDATED" TO ESTIMATE OUTCOMES OF THE MANAGEMENT ALTERNATIVE "MAXPROFITCOD": CLOSE UP ON THE OUTCOMES FOR SSB FOR HERRING.

### *Prior beliefs about the forcing factors*

In addition to explore anticipated outcomes of a single management scenario, the user can (once utility nodes are defined) evaluate the relative performance of the management scenarios under different assumptions about external drivers. This is done by updating the model while no single pre-defined scenario is selected. In the given case, the performance and evaluation of the management scenarios is conditioned on set of forcing factors, which include "eutrophication", "regime", "year" and "seal abundance" (Figure 23). In this example, the BBN indicates that the Business as Usual alternative ("BAU") performs best overall, although it only performs marginally better than MaxProfitCod.

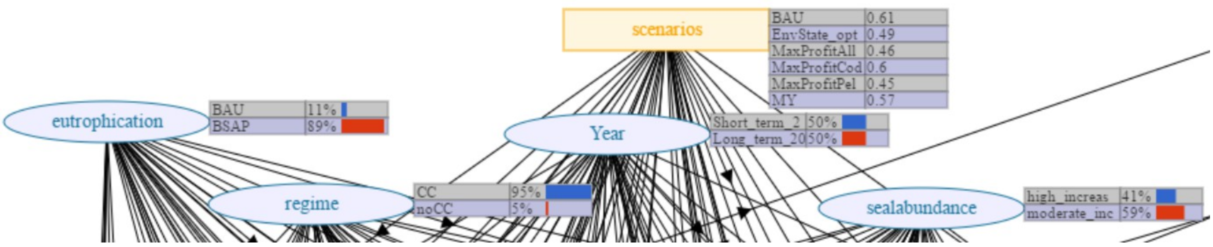



FIGURE 23: CLOSE UP ON NODES THAT REPRESENT POSSIBLE STATES AND UNCERTAINTY ABOUT DRIVERS THAT CONDITION THE PERFORMANCE OF MANAGEMENT SCENARIOS FOR THE BBN OF THE BALTIC CASE STUDY.

Having selected the editor mode, the user can change the input of probability tables for the different states of variables of the nodes that contain assumptions about external drivers. For instance, the user might know that new information significantly increases the probability of a high increase in seal biomass, and that the risk of Eutrophication has increased because it, and because of some political conflict, it suddenly appears unlikely that the Baltic Sea Action Plan will be implemented. The user accordingly revises the probabilities for a high seal increase from 41 % to 75% and the probability of BSAP from 89% to 10%. The user can the update the model to see how the changes affect the evaluation of management alternatives and the outcomes of the chance nodes (Figure24).

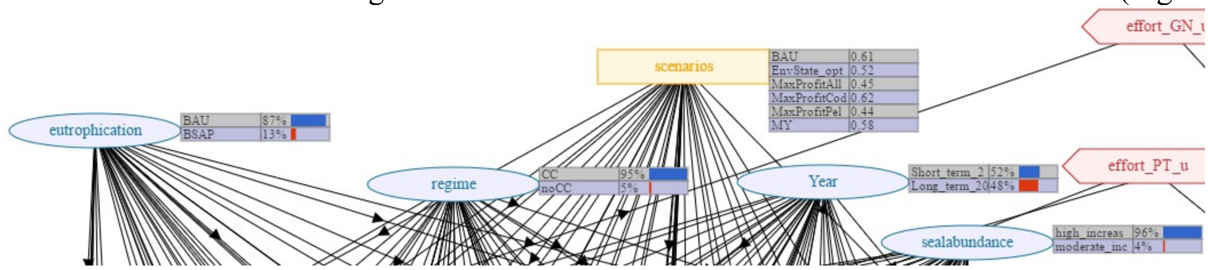



FIGURE 24: CLOSE UP ON NODES THAT REPRESENT STARTING ASSUMPTIONS THAT CONDITION THE PERFORMANCE OF MANAGEMENT SCENARIOS FOR THE BBN OF THE BALTIC CASE STUDY. THE STARTING PROBABILITIES FOR EUTROPHICATION AND SEAL ABUNDANCE (BASED ON EXPERT KNOWLEDGE) HAVE BEEN REVISED COMPARED TO THE PREVIOUS FIGURE.

As seen in Figure 30, the changes influence the evaluation as the MaxProfitCod alternative now is estimated to be the preferred alternative overall, although it only performs marginally better than "BAU". The figure also shows that some of the probabilities tables for eutrophication and seal abundance deviate slightly from the starting values after the model has been updated. This is due to imprecisions in the algorithms used to calculate the outcomes of the BBN model. The precision can be improved by increasing the number of iterations (Properties -> select # iterations), but this will also increase the estimation time (e.g. 10-20 seconds for the default level of 500 iterations).

## Input for the BBN and how to create and save a BBN

### *How to create a new Bayesian Belief Network*

A new BBN can be constructed from scratch in the following location on the MareFrame web site:

Case studies -> "test case" -> link to BBN[8]

This opens an empty BBN page, in which the user can construct a new model.

(Alternatively, the user can open existing case study, activate the "editor mode", and open a new model).

The complexity of a Bayesian net depends not only on the amount of nodes but also depends heavily on the number of arcs between the nodes. The number of entries in the conditional probability table is the number of arcs multiplied with multiplied with the number of possible states in the node and in each parent node. The best way to construct a new BBN, provided that it is relatively simple (for building more complex BBNs, see below), is as follows:

5) Create the random nodes as new elements to describe the key process and interest variables of the decision problem. Name the nodes of the network. This is done in the "editor mode": as follows. A) Add new chance. B) double-click to modify the node, double-click on the default name given to the element (e.g. "Chance1") and change the name to the required name. C) Add the necessary discrete states in the node by pressing "Add Data Row". D) Assign probability to each state. E) Press "Submit changes" button. F) Use the mouse to drag the element to the desired location in network

6) Describe the causal relationships between the nodes by connecting them with directed arcs using the "Connect tool". Drag an arc from the cause to the consequence node. It is advisable to set the states of the parent nodes (cause) before connecting them with the child

8 http://mareframe.mapix.com/dev/BBN2/DST.html?bbn=true

nodes (consequence) as it can be helpful in understanding the resulting conditional probability table. Insert the probabilities by clicking a cell in the table and by typing the probability there. Use values 0-1 and note that probabilities must sum up to 1 in every column. The software does not allow loops to be created among the nodes.

7) Create decision node by pressing “New Decision”. Double click to edit name and provide definitions. In this stage, add new decision alternatives by pressing “Add data row”.

8) Create utility nodes by pressing “New Utility” button. Use “Connect tool” to link utility node the chance node(s) which will influence the perceived utility. Provide the perceived utility as a function of the state of parent random node. Utility node(s) can be linked directly with a decision node. Press “submit changes” when done.

### *Saving a new or modified BBN*

Users can save a new or modified BBN as follows:

4) Click “save document”

5) Click on “Download” link “ located in the top-left area of the network.

6) The file will be sent to the user’s default download folder and will be given a default name (e.g. “model(1).xdsl.”). The files and can renamed provided that the name ends with the required file specification, i.e. “ .xdsl”. The user can store and share (e.g. using email) as for any other normal file type.

### *How to upload new input for an existing BBN model*

The BBN tool can utilize any quantitative estimates that provide information on the variables in question. Preferably, the data should include uncertainty information, as this will be needed to complete the probability tables (however, if only point estimates are available, uncertainty distributions can be generated by various approximation approaches).

The data be entered manually. The user can revise entries in “editor mode” and save the changes as a local file, but the data entries for the BBN model on the web can only be permanently changed by the administrator.

The user can build more complex models using the freely available GeNIe software[9], which will enable uploading of structured data files to complete large consequence tables. Using GeNIe requires registration and installation of the software. However, importing observations from, for instance ecosystem models, into the Bayesian network and learning the parameter values to receive posterior knowledge is possible only by using a complementary software such as GeNIe. Use the GeNIe tutorials to learn how this is done. The relevant tutorials under the GeNIe help will be a)

9 https://dslpitt.org/genie/

Accessing Data and b) Learning Structure. Save the GeNIe file in xdsl-format and import the file into the MareFrame software with "Open Model" button in the Editor mode.

## Programs for the BBN tool

The BBN tool is developed as a web application. The great advantage of web-applications are there is no installation process. All the user needs is browser. Going to the application urls[10] will load everything, and after there is no dependency on a web connection, every calculation is performed in the browser

The BBN web-application is written in typescript, which translates the code to JavaScript.

JavaScript is the most used programming language for web applications. 3rd party libraries used are jQuery, easeljs and Google Charts.

The jQuery framework[11] is used for general HTML document traversal and event handling, like buttons or sliders.

Easeljs is used for the value tree elements and connections and for value function design.

Google Charts[12] is used for tables and graphs.

The CreateJS framework is used for the model interface[13].

The source code for the MareFrame BBN is availabe at: https://github.com/Tokni/Mareframe-BBN-MCA-VS15

10 http://mareframe.mapix.com/dev/BBN2/DST.html?bbn=true

11 https://jquery.com/

12 https://developers.google.com/chart/

13 http://www.createjs.com/