User Manual

Helmholtz MCDA Tool (HELDA)

HELDA

HELMHOLTZ MCDA TOOL

Authors:

Tim Müller, KIT-ITES tim.mueller@kit.edu

Laura Mesa Estrada, KIT-ITAS, laura.mesa-estrada@kit.edu

Martina Haase, KIT-ITAS, martina.haase@kit.edu

Karlsruhe Institute of Technology

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This user manual is continuously being updated and not yet complete.

Outline

MCDA (Multi Criteria Decision Analysis) is a methodology to support decision making with the benefit of, simply put, being capable to compare apples and oranges. For the goal to choose one alternative out of a set of several ones, users can interactively define firstly the criteria to be considered and secondly their impact respectively weight when considered. This interactive process is often used when decision makers try to find a stable agreement that can be accepted by all members of the group. Frequently, having a structured discussion on the decision to be made is the greatest benefit of the whole MCDA process. The MCDA tool HELDA, covered by this guide, is a further development of MCDA Tool KIT which was originally created for nuclear emergency management by the Institute of Thermal Energy Technology and Safety (ITES).

HELDA is the result of the ongoing collaboration of Institute of Thermal Energy Technology and Safety (ITES) and the Institute for Technology Assessment and Systems Analysis (ITAS) to provide a MCDA software to meet the demands for sustainability assessment while still being applicable to decision making problems in general.

Note

At the time of writing this document the MCDA tool HELDA provides a great amount of functionality and is used in many scientific projects as showcase for the potential use of the MCDA methodology. It is operationally used in the field of sustainability analysis and generally very reliable. Nevertheless, it is a non-commercial application. It is a scientific tool and being continuously improved. Therefore, recently added functionality may not be fully tested and it is recommended to always create backups of important analyses when upgrading to a more recent version. Upgrades can be found on the HELDA download-page. Finally, any feedback is always appreciated to further improve the usability of HELDA.

Content

Introduction

The MCDA software HELDA is available for download from the website of the Helmholtz Working Group on MCDA.

https://www.mcda-helmholtz.de/

The site has become the hub of MCDA activities within the Helmholtz group. Special questions or requests regarding the software should be directed to KIT, namely Tim Müller (*Tim.Mueller@kit.edu*). We are still considering a public community collaboration project at KIT or even using a platform similar to SourceForge or GitHub.

Requirements

HELDA is completely written in Java and requires a Java Runtime installation (JR) when used. Therefore, the software is independent from mayor operating systems like MS Windows, Linux, MacOS and can be used on any computer that supports Java 17 or higher. The application itself neither requires high computation power nor a large amount of memory, with probably the one exception of very large ensemble evaluations in the range of millions. If no JR is installed on the target PC yet, several compatible implementations are available on the internet. At time of writing while many implementations of JR are available we use the Zulu JDK implementation for development and runtime. The installation of a JR is usually straightforward. For convenience, we provide downloads bundled with a Zulu JDK for Windows, Linux and MacOS. For Linux, the executable bit must be explicitly set on the binaries in the bin folder of the bundled JR (e.g. **chmod +x jdk/bin/***) after unpacking the HELDA bundle.

Installation and start

The installation of HELDA is very easy: download and unzip the software in a directory of your choice. Switch into the newly created directory named **HELDA-vX.Y-build(ABCD)**, where **X** and **Y** are the actual version numbers and **ABCD** is the actual build number, which is helpful to keep previous versions of HELDA and not losing track. On most systems, a double-click on **HELDA.jar** will start the application, but it is recommended to use the start scripts according to the operation system, which is **start.bat** for MS Windows systems, **start.sh** for Linux systems and a **start.command** for MacOS. The scripts can be customized if the use of a specific Java version is desired. In rare circumstances, e.g. to get additional information in case of a reproducible error, you may have to run it manually in a command line window. Open such a terminal according to your operating system, change to the installation folder and execute the following commands:

cd \path\to\installation
./start.bat

Starting the MCDA application presents the wizard window. It allows you to load an existing analysis or to create a new one from scratch, supported by a guided process. The wizard provides an easy starting point for new users. Therefore, it simplifies and hides details from the user during the creation process. Once the general definition of the MCDA analysis is complete, the main application is launched, which provides the full functionality of the application.

Points of interest

The application is prepared to be multi-lingual. Up to now, English and German are provided. Semi-automatically generated translations of the report are available for Slovak, Spanish, French and Italian. New languages, even special wording, can be easily integrated by users themselves. Help and proposals for translations are welcome. All subcomponents follow the same concept and style. Icons and colors usually have the same meaning. The icons and colors can also easily be customized. Many components of the user interface already provide brief contextual help, which is activated by hovering the mouse over it. More detailed help is available by clicking the help buttons, which are available in several contexts. Most components also provide context menus, which are activated by clicking onto a graphical component using the second (or right) mouse button. A global undo/redo is provided, yet not all operations can automatically be undone. The analyses, as well as parts of it like the weights, can be stored and restored from a file. The format is XML, thus allowing it to be edited manually with text editors if necessary.

License

In-app help

In general, the MCDA application consistently provides context sensitive help. When in doubt hover the mouse over a graphical element like a button or a label. In many cases a helpful tooltip will appear. Also using the second mouse button on a graphical component often opens a context menu with additional functionality.

Furthermore, an explicit context help is available displayed in a separate panel. This panel can be toggled by menu or any button with the lifesaver icon.

Basics of MCDA

Multiple Criteria Decision Analysis (MCDA) is a subdiscipline from OR that supports decision-making processes through the comparison of potential solutions or alternatives using relevant, often conflicting, criteria. The process of MCDA generally consists of the following steps: problem definition, selection of criteria (and indicators), definition of alternatives, preference modelling (criteria weighting and aggregation), comparison and evaluation of alternatives, sensitivity/robustness analysis and problem resolution(Greco et al., 2016).

MCDA methods can be distinguished into Multi-Objective Decision Making (MODM), Multi-Attribute Decision Making (MADM), and combinations of MODM and MADM (Kumar et al., 2017). HELDA specializes in methods from MADM which simplest form boils down to a value matrix as shown in Figure 1. For a given problem to be solved, i.e., to choose one solution from a set of solutions, the columns of the matrix represent the set of available solutions to the problem, and the rows represent the attributes and their weights (or importance value) that are considered to rank the alternatives.

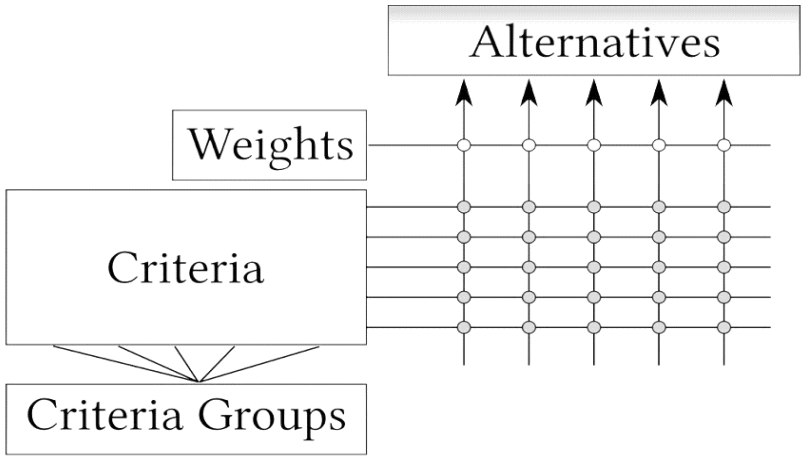

Figure 1: Basic Concepts of MCDA

MADM methods can be categorized into i) elementary methods (e.g. weighted sum method), ii) single synthesizing criterion (e.g. TOPSIS, AHP), iii) outranking methods (e.g. PROMETHEE, ELECTRE). HELDA includes the following MADM methods:

- Weighted Sum
- Weighted Product
- Weighted Rank
- TOPSIS
- VIKOR
- PROMETHEE I and II
- ELECTRE III
- User-defined Expression

and the following weighting methods:

- AHP
- SWING
- SMART
- Deck of Cards Method
- Direct absolute and relative weighting
- Equalizing and Harmonizing

In the further context of this document, MCDA refers to MADM, the problem is referred to as the goal, the solutions are referred to as the alternatives, and the attributes are referred to as the criteria.

The more criteria are used, the more complex it is to understand and organize the value matrix. In real-life applications, many criteria belong to certain groups with a more general name (e.g., different cost types all belong to the general group "*cost*"). Therefore, HELDA provides means to organize the criteria in groups assigning a hierarchy, resulting in a treelike view that helps clarify the overall structure. In HELDA, this process is referred to as *grouping*. Grouping of criteria serves to enhance the understanding of the structure. The grouped structure is treated internally as a plain matrix when evaluating the problem.

Getting started

The following chapters explain HELDA by applying a simple use case “Buy a car”.

A video for the following actions is available from the website or the help menu.

Starting HELDA presents a window with different entry points to select from, as can be seen from Figure 2. It provides a list of recently processed problems and four buttons with different functions:

- Wizard: create a new MCDA in a guided process from scratch,
- Load: load an already existing MCDA from a file,
- Import: import a MCDA from various external file formats like MS Excel, CSV, …
- Process: load an already existing MCDA from a file and immediately process it in the background without displaying the user interface,
- Exit: close the application.

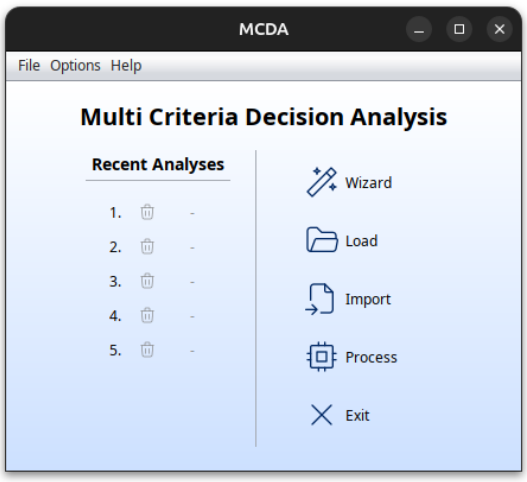

Figure 2: The greeting window of HELDA

Creating a new MCDA

Clicking on the **Wizard** button will provide a guided process to create a new MCDA. In the unlikely event of a crash of the previous session, the wizard will have created a backup during the process. In that case, one must initially choose if the previous content should be restored. Selecting **Yes** will restore the previous content, while selecting **No** will start from scratch normally.

Either way, the wizard will continue and present a form to enter the basic information about your new project. The first thing to do is to enter the label and description of your goal like in Figure 3.

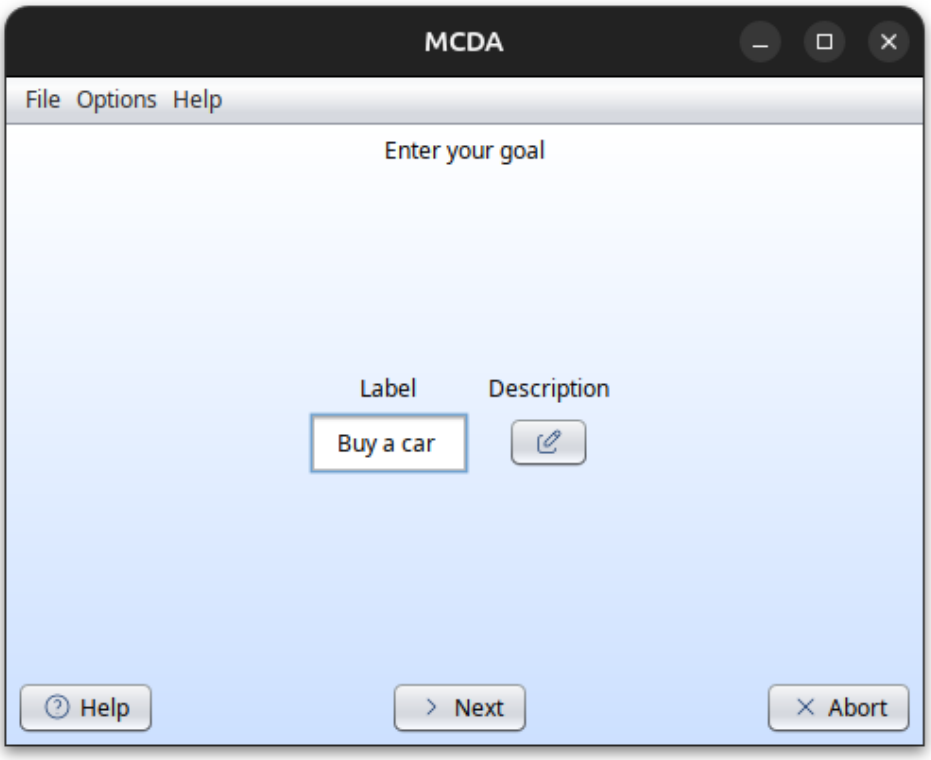

Figure 3: The definition of the goal

Click the **Next** button to continue. The following form allows you to enter the set of alternatives as seen in Figure 4. Each alternative has a label (preferably distinctive), which can be typed into the text field, and a textual description.

The description can be entered by clicking on the **Description** button. Initially, two alternatives are defined by default. Alternatives can be added by clicking on any Add button in the rows and removed accordingly by clicking on the Remove button in the corresponding row. At least two alternatives must be defined. Once the input is complete, the Next button must be clicked to move on to the definition of criteria.

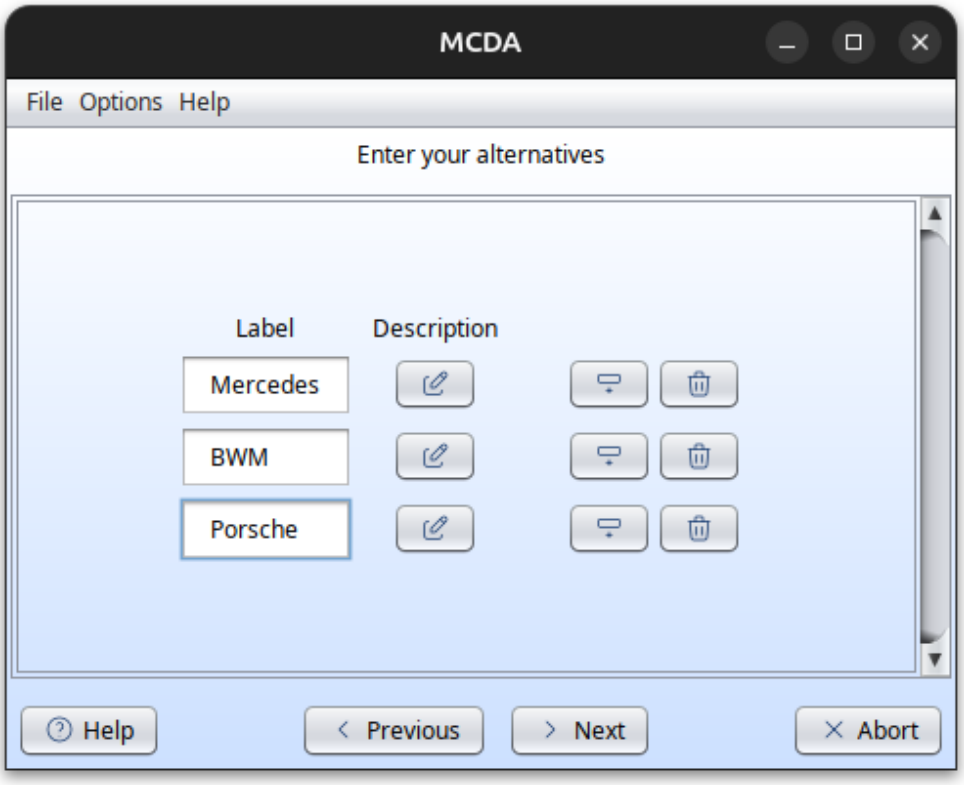

Figure 4: The form to define alternatives

The procedure to define criteria is basically identical to the way of defining alternatives as displayed in Figure 5. The only additional input to be defined is the weight, respectively the importance factor, of each criterion.

Values between 1.0 and 10.0 are allowed as input, with 1.0 meaning least important and 10.0 meaning most important. Bear in mind that the importance factor is relative, i.e., if two criteria are defined with importance factors 1.0 and 2.0, the second criterion is twice as important as the first one. Importance factors of 5.0 and 10.0 would have the same meaning and would lead to the same result in the end.

Once the criteria are defined, the Next button allows you to move on to the first of a series of value input forms.

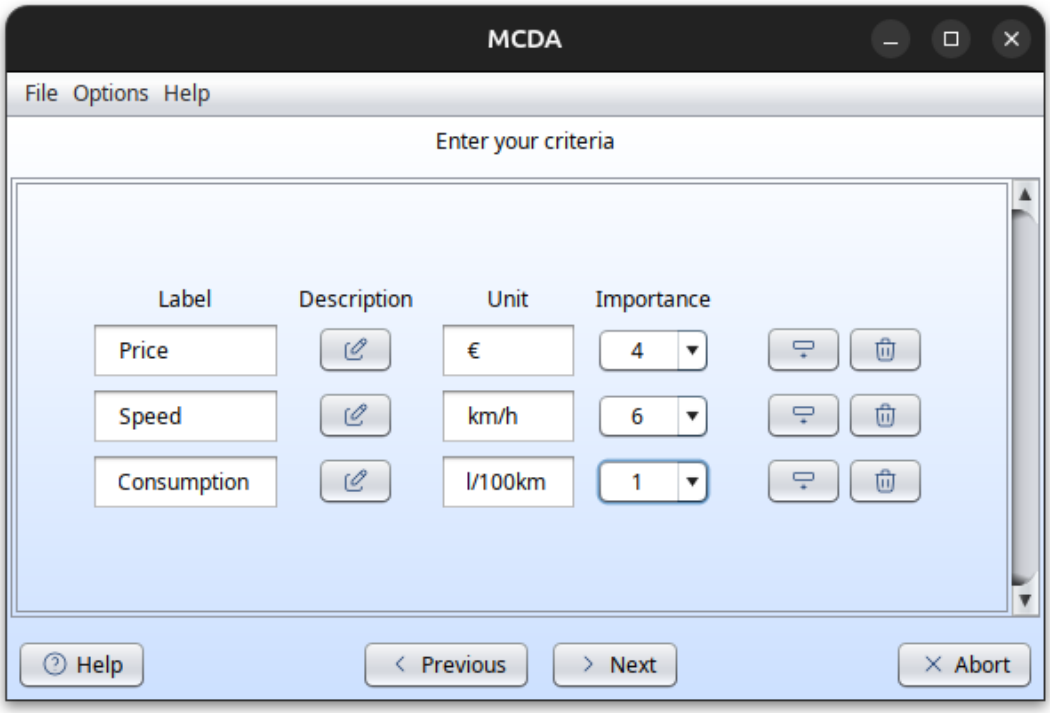

Figure 5: The form to define criteria and their importance

For each criterion, an input form is presented where the values for each alternative must be entered as in Figure 6. As input, any numerical value is allowed. Since the values will be normalized internally, it is mandatory to establish a ranking for them.

This is simply done by marking the “best” value, which is usually either the maximum or minimum of the criterion, though it is not necessarily so. It can also be one of the values between the maximum and minimum.

If multiple alternatives share the same best value, any of these can be marked. Once the best value is marked, clicking the **Next** button will lead you to the input form for the next criterion. The Next button on the last criterion input form will lead to the summary.

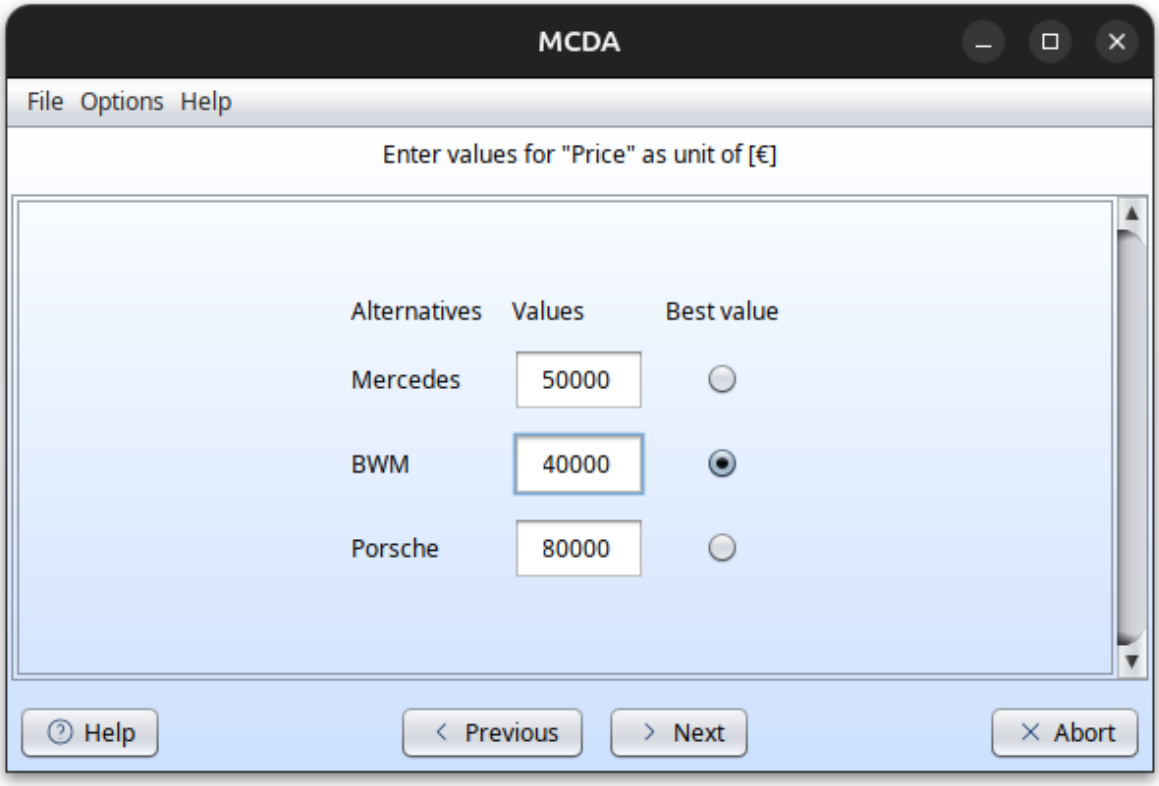

Figure 6: The form to define the values and their ranking for normalization.

After completing the input of the criteria values, a summary is presented, allowing you to briefly check for any obvious mistakes as displayed in Figure 7.

This summary provides an overview of all entered data, ensuring that everything is accurate before proceeding further. Clicking on the Finish button closes the wizard window and opens the main window of HELDA.

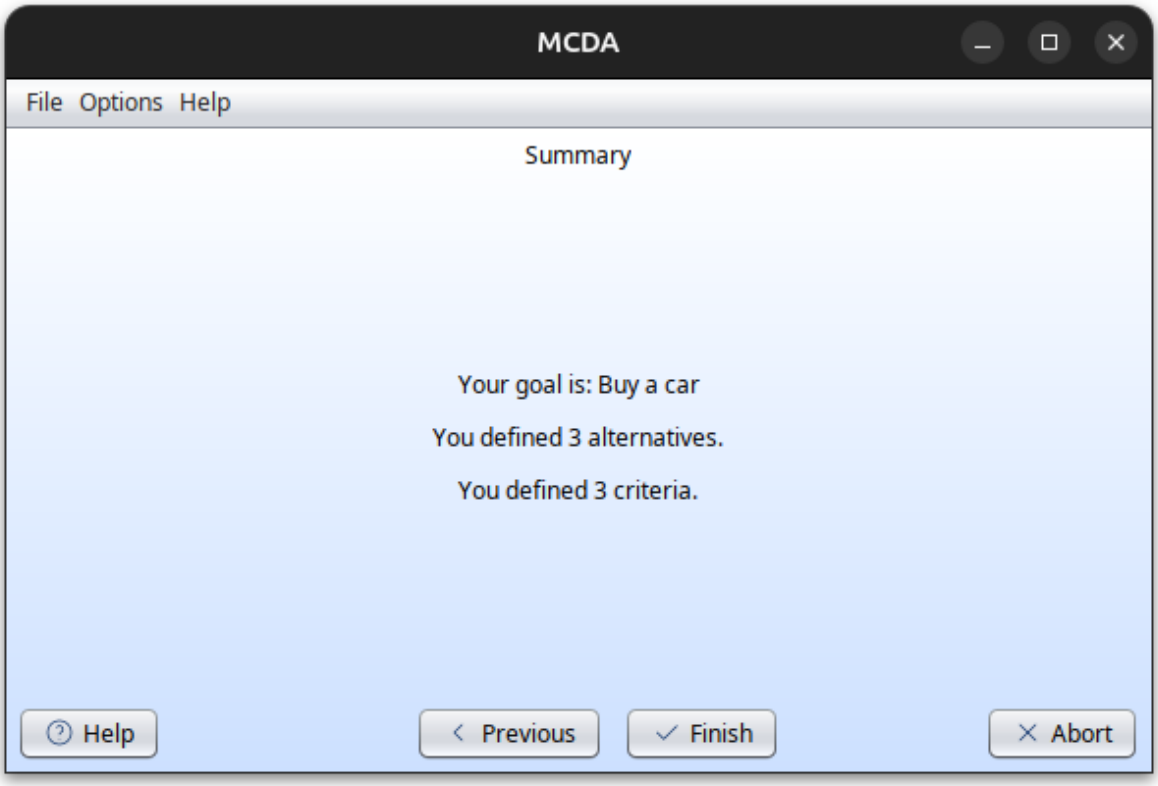

Figure 7: The input summary

Loading an existing MCDA

To load an already existing MCDA, either click on a recent analysis or on the Load button in the initial window Figure 2. Clicking on a recent analysis will directly open the main window, while clicking on the Load button will first open a file chooser. Older HELDA versions had file suffixes of .xml, while more recent ones use .mcda. The filtered suffixes are selectable in the file chooser.

After selecting an appropriate MCDA file, the main window will be displayed. The *examples* directory in the MCDA installation folder contains several example files for reference.

Directly processing a MCDA

HELDA provides a shortcut to directly process an existing MCDA and generate results, such as an HTML report. This feature is particularly useful for evaluating ensembles or to use HELDA as backend for other applications like a web service.

While the automatic ensemble evaluation is not yet implemented, the evaluation within the GUI is available and complete.

Working with HELDA

The MCDA application provides a single main window where all functionalities for editing and analyzing are accessible as in Figure 8.

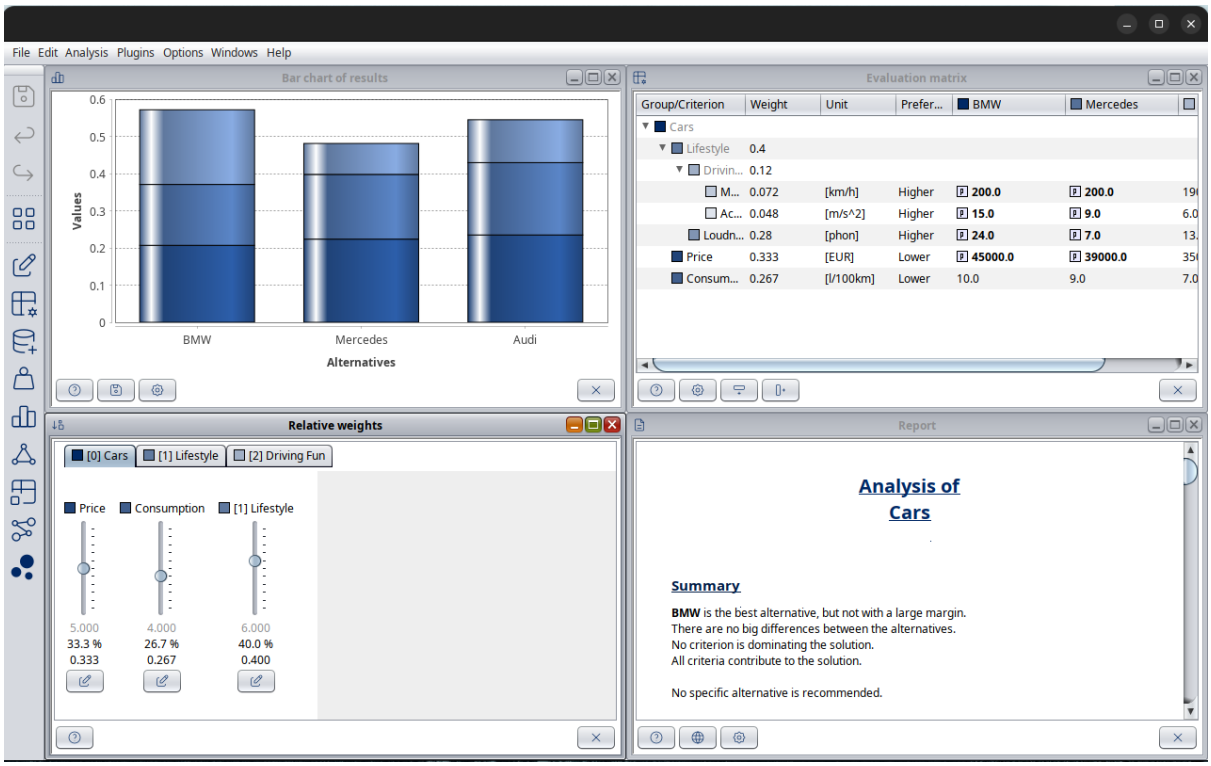

Figure 8: The main window of HELDA

Main Window

The main window consists of three noticeable parts:

- Workspace
- Menu Bar
- Tool Bar

Workspace

The largest part of the main window is covered by the workspace. It contains the internal windows of various tools. The workspace functions like a standard desktop, allowing users to move, minimize, maximize, and close windows. Some menu and tool bar entries provide additional functionality, such as arranging windows as tiles.

Internal windows can be dragged outside the workspace resulting in external windows. Closing such external windows will put them back into the desktop.

Menu Bar

All available functions are accessible through the menu bar. While the tool bar contains only a selection of stable tools, the menu bar provides access to all available tools, even experimental ones. The menu bar is divided into the following groups:

File: This group gathers all input and output functions. Besides creating, loading, and saving projects, it also allows the import and export of parts of the MCDA. For example, you can separately store the definition of weights, enabling easy combination of different setups with the same structure. Additionally, reports can be exported as HTML.

Edit: This group includes undo and redo functionality, as well as tools to edit defining parameters such as meta information, values, and weights. While many editor actions can be undone or redone, not all actions are covered yet. Therefore, it is advisable to keep backups of important projects. The tooltip of the undo or redo menu entry provides a hint about the action that will be performed when activated.

Analysis: This menu provides tools for analyzing the structure and behavior of the MCDA. It includes visualization methods like charts or tree graphs, verbalized reports, and deep analyses regarding stability or correlations. Note that some pie charts are experimental and may not work as intended.

Plugins: This menu is reserved for entries from HELDA extensions. It may be empty if no plugins are installed. Plugins can be created using the plugin framework. Example code as a NetBeans project is provided in the doc/plugins folder for demonstration purposes.

Options: This menu allows customization of preferences such as display language and font size. Other preferences, like window locations or recently used folders, are set implicitly and are hidden from active management.

Windows: Functions from this menu interact with the workspace windows, such as arranging them neatly or bringing a window from the background to the front.

Help: Entries in this menu provide access to the user guide, video tutorial, log file, update check, and application information.

Tool bar

The tool bar provides quick access to a selection of frequently used and stable tools. It is designed for convenience and to shortcut some functionality available in the menu bar.

Internal windows

- Using a function or starting a tool generally opens an internal window within the workspace. All internal windows share the same basic structure, which includes:
- **Decorations**: These include a title and buttons for minimizing, maximizing, and closing the window.
- **Main Panel**: This panel displays the content of the window.
- **Button Toolbar**: The toolbar contains buttons for:
    - **Help**: Provides assistance related to the tool.
    - **Options**: Allows access to additional configuration options (if available).
    - **Close**: Closes the internal window.
    - **Other**: Other buttons may be available providing specific functionality in the context of the according window

A set of internal windows and their arrangement can be saved as a view, allowing quick access to specific combinations of tools. The tools integrated as internal windows are briefly presented in the following sections.

Import and export of data

Several methods are available to import external data defining a MCDA, most noticeable CSV and MS Excel. Besides the plain criteria definition and values, more sophisticated aggregation methods cannot be straightforward imported and require specific file formats.

Import of data from MS Excel

HELDA provides the possibility to import an existing decision matrix with criteria, criteria weights, alternatives, and preference thresholds (if applicable) from MS Excel (File – Import – from Excel). Respective Excel templates for the aggregation methods ELECTRE III, PROMETHEE and Weighted Sum are provided in the folder “examples”. Respective templates for other aggregation methods can be created using the export to Excel function of MS HELDA (see below).

Export of data to MS Excel

HELDA provides the possibility to export an existing use case to MS Excel (File – Export – as Excel).

Edit

Aggregation method

In this window you have the option to select from three types of preference modelling (aggregation) methods: Utility-based, distance to target and outranking methods (see Figure 9).

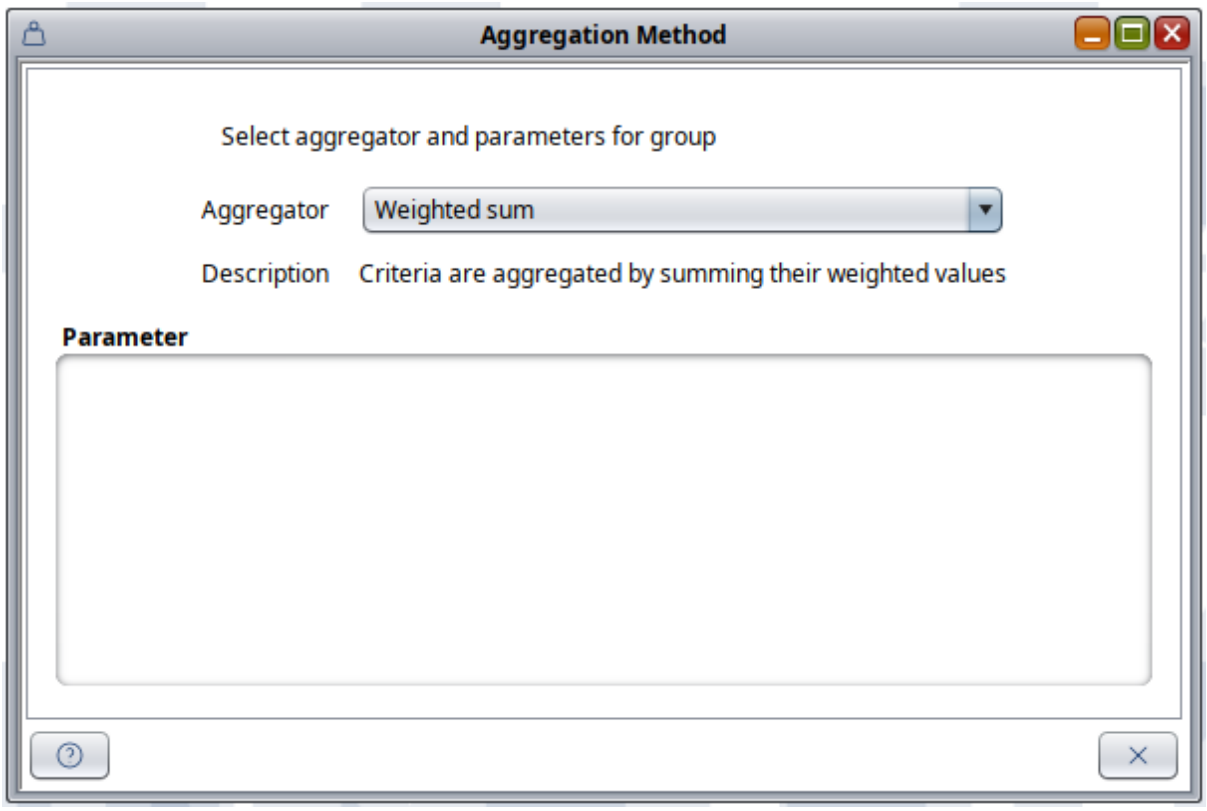

Figure 9: Select aggregation method

Note: The process of method selection depends on different types of information and the respective use case, therefore being aware about the capabilities of the methods before choosing is strongly recommended.

Some methods like ELECTRE III, PROMETHEE, or VIKOR require additional information to be entered as described in the following text.

ELECTRE III

ELECTRE methods comprise two main procedures: aggregation and exploitation.

Please select the type of exploitation procedure:

- Net flow scores or
- Distillation

After selecting the exploitation procedure, please assign discriminating thresholds and veto thresholds to the criteria that applies.

Note: Not necessarily all the criteria are subject to the definition of indifference and preference discriminating thresholds.

$0 < q < p < v$

Preference thresholds (p): The preference threshold, p, between two performances, is the smallest performance difference that when exceeded is judged significant of a strict preference in favor of the action with the best performance. This difference (which is by definition non-negative) can be equal to zero (which corresponds to the case of the true-criterion model).

Indifference thresholds (q): The indifference threshold, q, between two performances, is the largest performance difference that is judged compatible with an indifference situation between wo actions with different performances.

Veto threshold (v): The veto threshold, v, represents a level of performance on a particular criterion beyond which an alternative cannot be considered to outrank another, regardless of the performance on other criteria. It is a way to enforce strict disqualifications based on unacceptable performance in certain key areas.

Source: (Figueira et al., 2016; Roy et al., 2014).

PROMETHEE I/II

Preference functions: A preference function should be associated to each criterion. It defines how pairwise evaluation differences are translated into degrees of preference. It reflects the perception of the criterion scale by the decision-maker. Depending on the type of function, different parameters might be assigned (p, q, s). For p and q see above.

S: This parameter is relevant for Gaussian function. it defines the inflection point of the preference function. It is recommended to determine first q and p and to fix s in between. If s is close to q the preferences will be reinforced for small deviations, while close to p they will be softened.

The criteria are assigned usual function as default, by definition it doesn't require any parameter to be defined. As you select a different function, the cells corresponding to the required parameter will activate.

Be aware of the following relation when entering the data:
$0 < q < p$

Source: (Brans & De Smet, 2016)

VIKOR

Please use the slider to define the trade-off aggregation between simple additive weighting and best value distance.

After entering the required information, click on the ✓ icon at the bottom of the window to finish and save your changes.

Graphs

The Graphs window as seen in Figure 10 offers three distinct graphical representations of the MCDA structure:

1. **Classical Tree View**
2. **Vertical MCDA View**
3. **Horizontal MCDA View**
4. **Floating View**

The preferred display type can be selected through the Options dialog, accessible via the view's Options button.

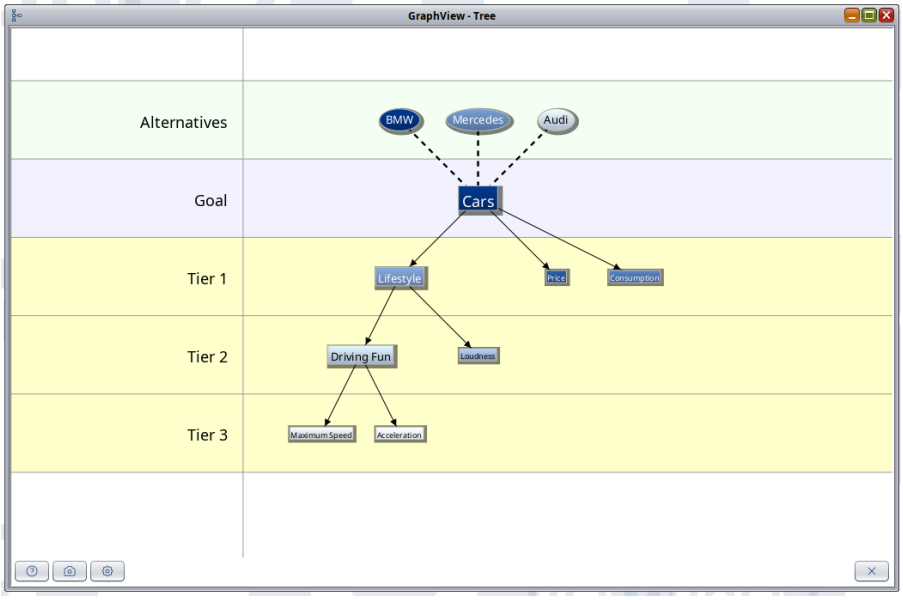

Figure 10: Graph View

This visualization presents the **goal, criteria, alternatives, and groups** simultaneously. In general, **leaf nodes** represent individual criteria, while **inner nodes** signify groups.

Interaction and Navigation

- **Zooming** - Use the *mouse wheel* to zoom in and out.
- **Panning** - Click and drag on the background to move the view.
- **Context Menu** - Right-click on either the background or individual nodes to open a context menu.

The context menu provides similar functionalities to those found in the tree structure of the Values window, allowing for efficient interaction and customization.

Decision problem

The MCDA contains additional information addressed as Decision Problem, such as the label or description of the goal, which is not required for the actual analysis. This data can be changed in the Decision Problem view as shown in Figure 11.

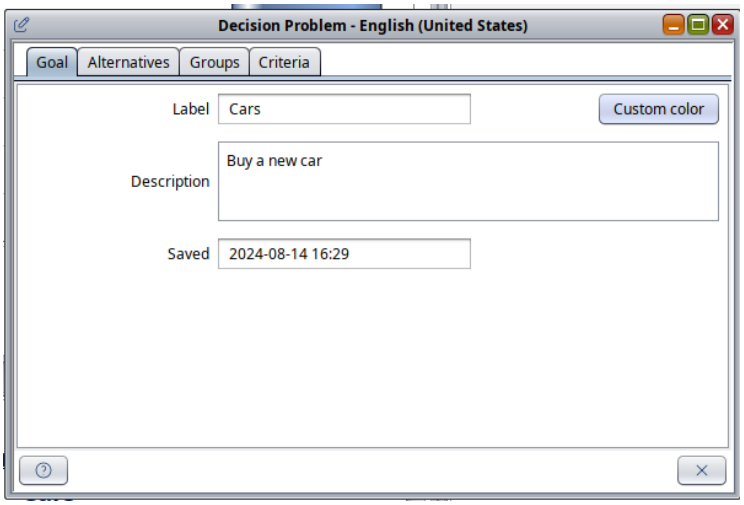

Figure 11: The user interface to handle the Decision Problem.

The window provides four tabs, each following the same structure: for the goal, the alternatives, the groups, and the criteria. The smaller text field holds the label of the entity, while the larger text field holds the description of the entity, which is generally shown as a tooltip in other contexts. The colored rectangle represents the custom color of the entity, which is used, for example, in charts to draw the entity. The custom color can be changed by clicking on the rectangle. For criteria, an additional text field is available for defining the unit of the values. Units are not evaluated but simply displayed to help understand the meaning of values.

Note: Text filled in the fields is specific to the currently selected language, allowing for a localized presentation of the decision problem. For example:

- If the German language is selected, changing the label of the goal will be stored as the German label.
- Switching the language of the application to English afterwards will display the label stored for English.
- If no text is available for the selected language, the default is used. The default is the first text ever entered.

The currently selected language is also displayed in the title of the window for convenience.

Normalization

Before combining criteria values, they must first be **normalized**. While the **Sum method** is the most commonly used approach, a wide range of additional normalization methods is available in the *Normalization* window (see Figure 12). Users should select the normalization method that best suits their specific criterion. As the normalization method has a huge impact on the outcome of the MCDA a comprehensive understanding of the selected normalization method is strongly recommended.

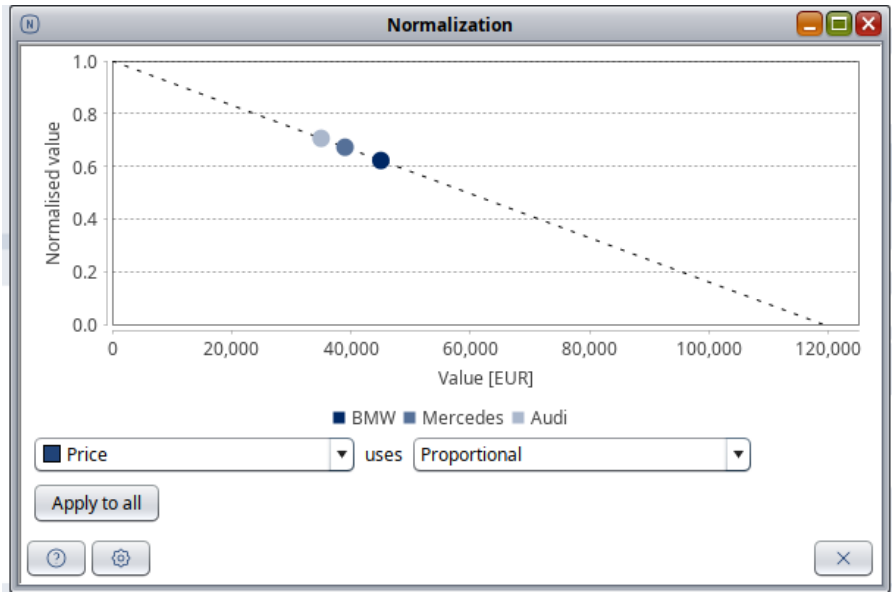

Figure 12: Normalization

For a selected criterion, the chart visualizes how its values are mapped to a normalized range between **0.0 and 1.0**.

- **Zooming** - Drag a rectangle towards the *bottom-left corner* to zoom in on an area of interest. Dragging in any other direction zooms out.
- **Context Menu** - Right-click anywhere on the graph to open additional options.
- **Criterion Selection** - Use the *combo box* beneath the chart to choose the criterion to be adjusted.
- **Method Selection** - The *normalization method* can be chosen from the *combo box* at the bottom of the window.

Some normalization methods require specific parameters, which are displayed in the lower section of the window when applicable.

Evaluation matrix

This tool's window presents the values and normalized results of the MCDA, along with its structural organization as seen in Figure 13. The columns represent the alternatives, while the rows correspond to the criteria. The first column displays the criteria in a hierarchical tree structure, reflecting their grouping. Additionally, the second and third columns show the weights and AHP indicators.

For enhanced visualization, the best and worst values for each criterion can optionally be highlighted in red and blue, respectively. If enabled in the options, value functions such as probability distributions are marked with small colored icons for easy identification.

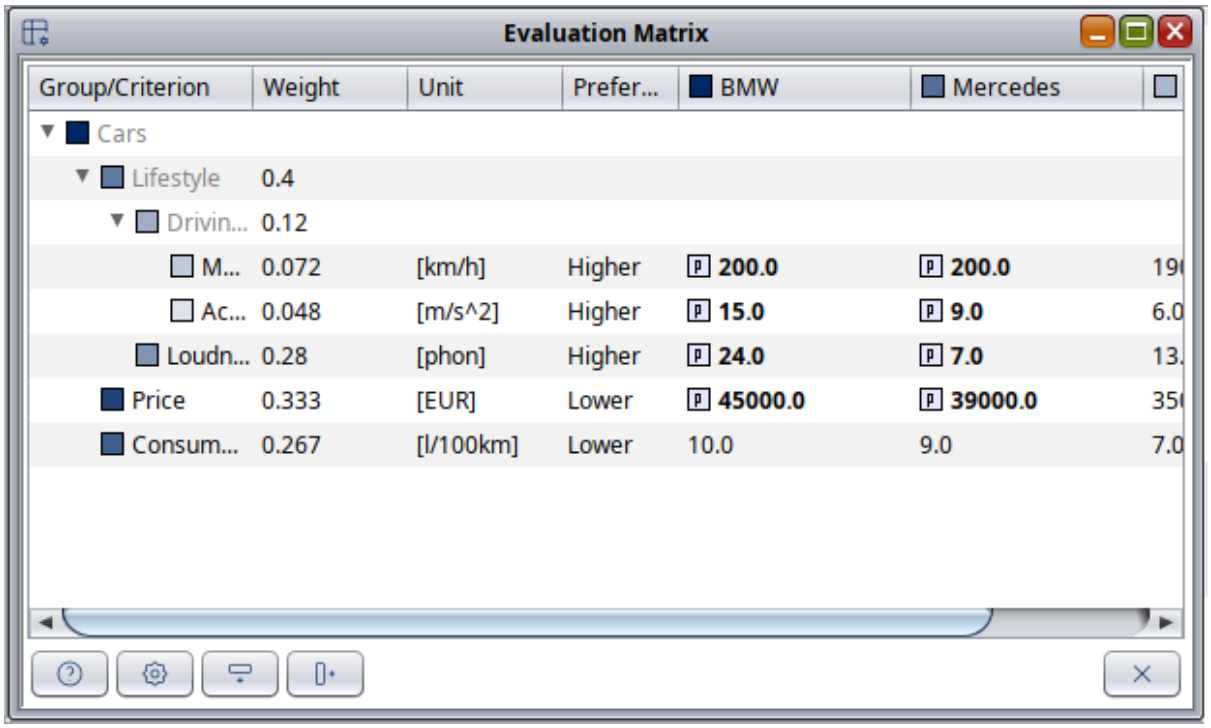

Figure 13: The Evaluation Matrix showing the according alternative values for the criteria. For convenience additional information like the absolute weight factor, preference direction, normalized values, ... can also be displayed.

To edit a value, right-click on the corresponding cell to open a dialog where you can define constant values or apply value functions. However, normalized values, weights, and AHP indicators cannot be modified.

Clicking on a column header sorts the rows in ascending or descending order. Additionally, right-clicking on a column header opens a context menu that allows you to hide or show specific columns as needed.

The tree structure also features a context menu, accessible via right-click. The available menu options vary depending on the selected criterion or group. Among other functions, this menu allows you to add or remove criteria and groups, as well as open the normalization editor for

a specific criterion. For details on AHP usage, refer to the *Analytic Hierarchy Process (AHP)* section on page [has to be done].

Weights

The Weights window is one of the most frequently used features of HELDA, as it focuses on defining the importance of criteria. Several weighting methods are available, including:

- Direct absolute and relative weights
- Equalize and Harmonize
- Smart weighting
- Swing weighting
- Deck of Cards (DCM)
- Analytical Hierarchical Process (AHP)

Direct weights

For each criterion or group, a slider is provided to easily adjust its weight (see Figure 14). Each group is contained within its own panel, which can be accessed by clicking the corresponding tab at the top of the window. The number in brackets next to the tab indicates the tier level of the group.

Within each group, every criterion and sub-group has an individual slider with a value range from **0.0 to 10.0**, representing its relative importance within the group. For instance, a criterion with a weight of **5.0** is considered **twice as important** as one with a weight of **2.5**. A weight of **0.0** means the criterion is not considered at all.

Below the sliders, numerical values provide further insights:

- **Top value** - Absolute local weight within the group
- **Middle value** - Normalized local weight within the group, displayed as a percentage
- **Bottom value** - Normalized global weight relative to all criteria in the MCDA

For example, a normalized global weight of **0.4** indicates that the corresponding criterion contributes **40%** to the overall MCDA result. Note that groups themselves do not have a normalized global weight; instead, they act as multipliers, propagating their weight to their members.

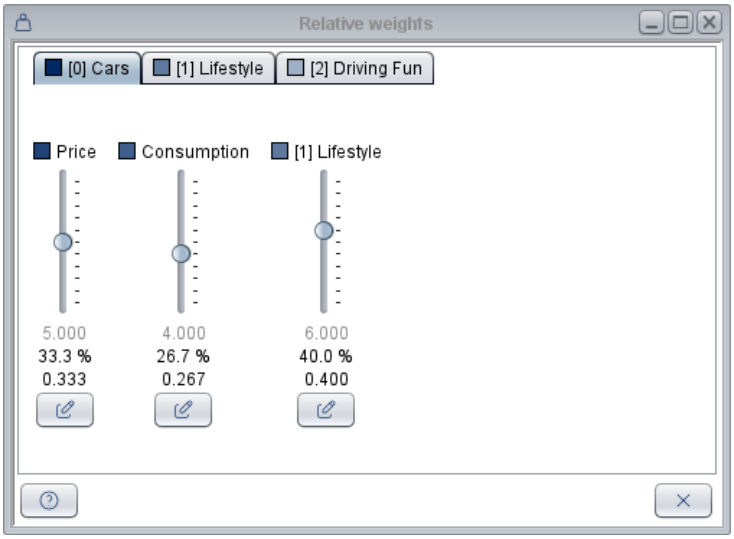

Figure 14: Direct Weights

Equalize and harmonize

These methods distribute the preference weights among the available criteria in an equal respectively harmonized way. Both methods differ only if the decision problem is structured in groups, otherwise the outcome is identical. This is due to the multiplicative way of preference weight proliferation. The following example is used below to illustrate the outcome of the two methods: Consider a decision problem with 3 Criteria: A, B, C. The criteria B and C are combined in a group G located on the same tier as criterion A.

Equalize

This method distributes the preference weights in a way that every criterion in the end contributes by the same amount. In the above-mentioned example all criteria will receive the final weight of 0.33. This is achieved by setting the preference weight for A to 2.5 and for the G to 5, as well as for B and C to 5.

The first equalize button will apply equalize directly (see Figure 15). The second equalize button will apply equalize and in addition add the new weights as a weight set.

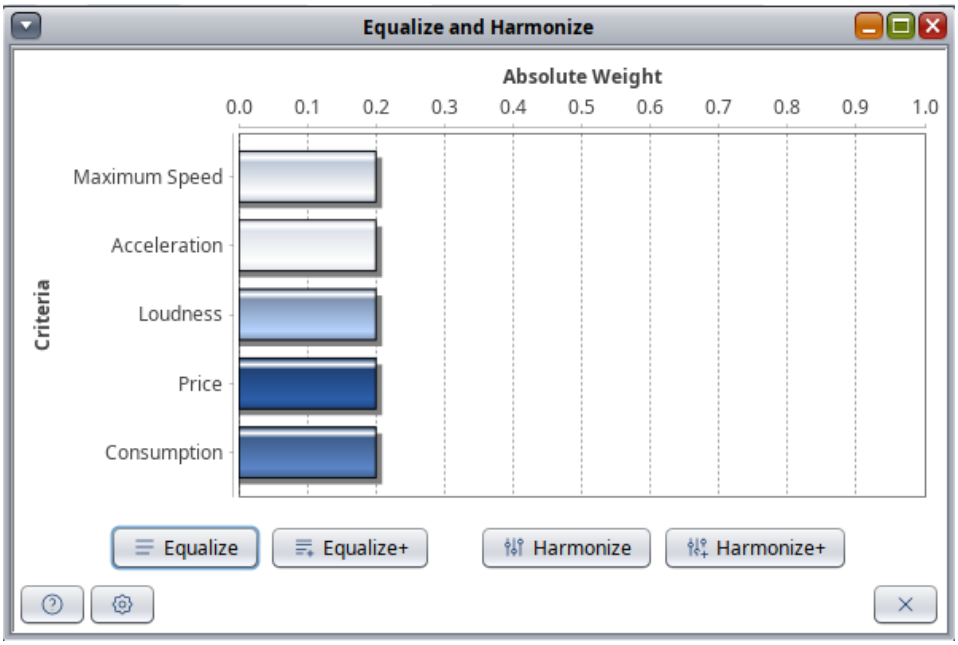

Figure 15: Equalize weights

Harmonize

This method distributes the preference weights in a way that all criteria receive the same amount, but in the end contribute the less to the overall outcome the lower their tier is.

In the upper example, criterion A will receive the final weight of 0.5, while the B and C receive the final weight 0.25. This is achieved by setting the preference weights for A, B, C, and G to 5.

The first harmonize button will apply harmonize directly (see Figure 16). The second harmonize button will apply harmonize and in addition add the new weights as a weight set.

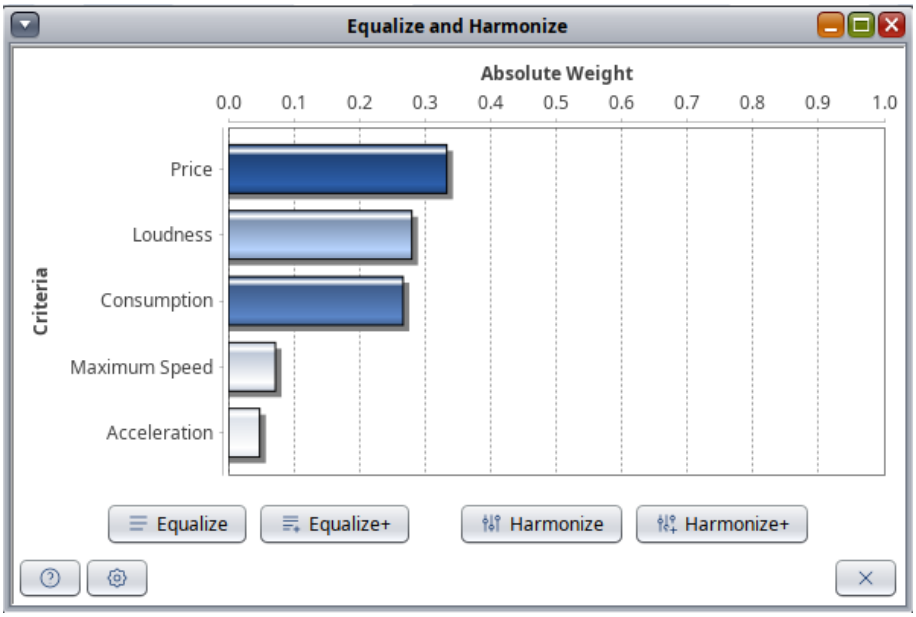

Figure 16: Harmonize weights

Smart weighting

Simple Multi-attribute Rating Technique (SMART) is a simple form of a multi-attribute utility method.

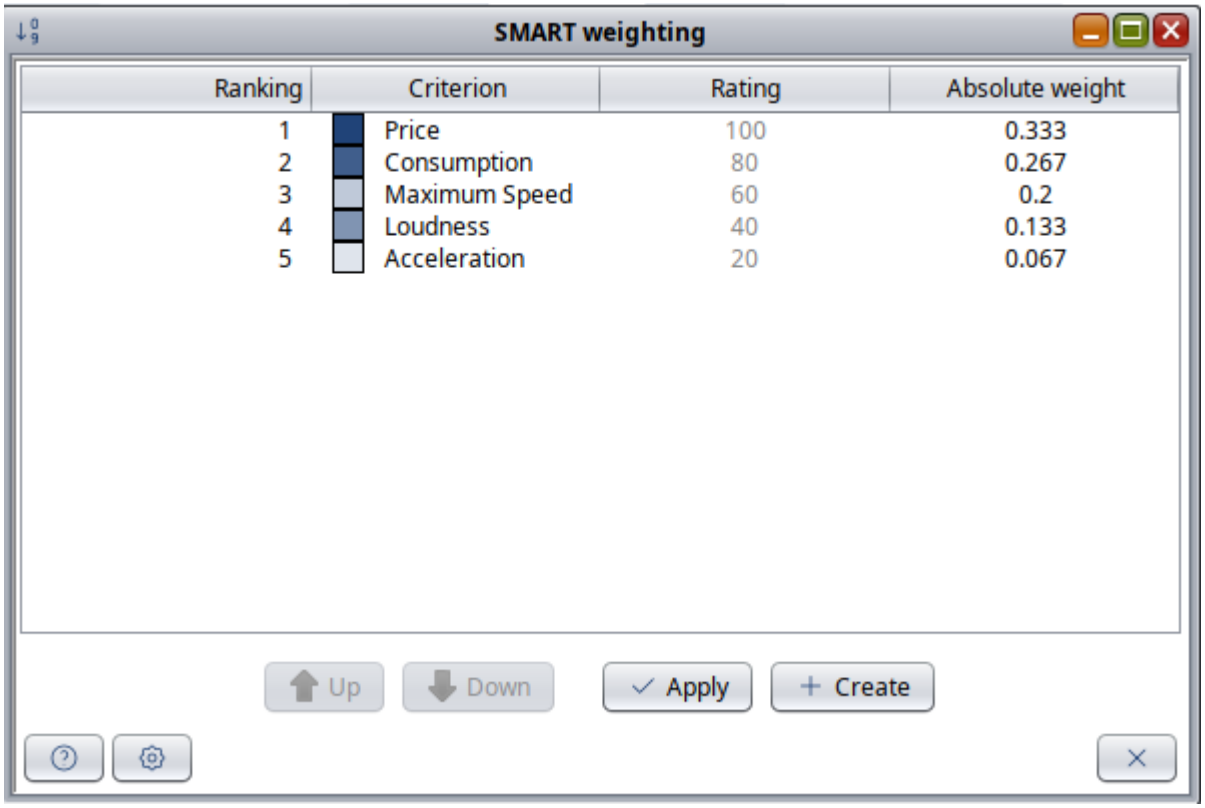

Figure 17: SMART weighting

There are different versions of the SMART method (see Edwards (1977)). For the approach here, the most important criterion receives a rating of 100 and the other criteria are assigned ratings which express the relative importance to the most important criterion. This results in ratings of 0 to 99 for the remaining criteria. The scores of the individual criteria are added up to give a total score and weighting values are derived from the relative proportion of the total score (see Figure 17).

1. Go to options and tick the box custom ratings
2. Assign ratings for all criteria
3. Click on Apply

Swing weighting

Swing weighting is based on the definition of a benchmark reference point for direct comparison of criteria. The benchmark is created by combining the worst criteria values into a new virtual criterion. The matrix displayed shows a row for each criterion with its best value in combination with the worst values of all the other criteria. The criteria rows can then be moved up and down by preference thereby establishing a ranking on the criteria in reference to the assumed worst possible benchmark. The ranking distances are equally spaced from 0 to 100 score points but can be manually defined if desired. The values are then transformed into the absolute criteria weights.

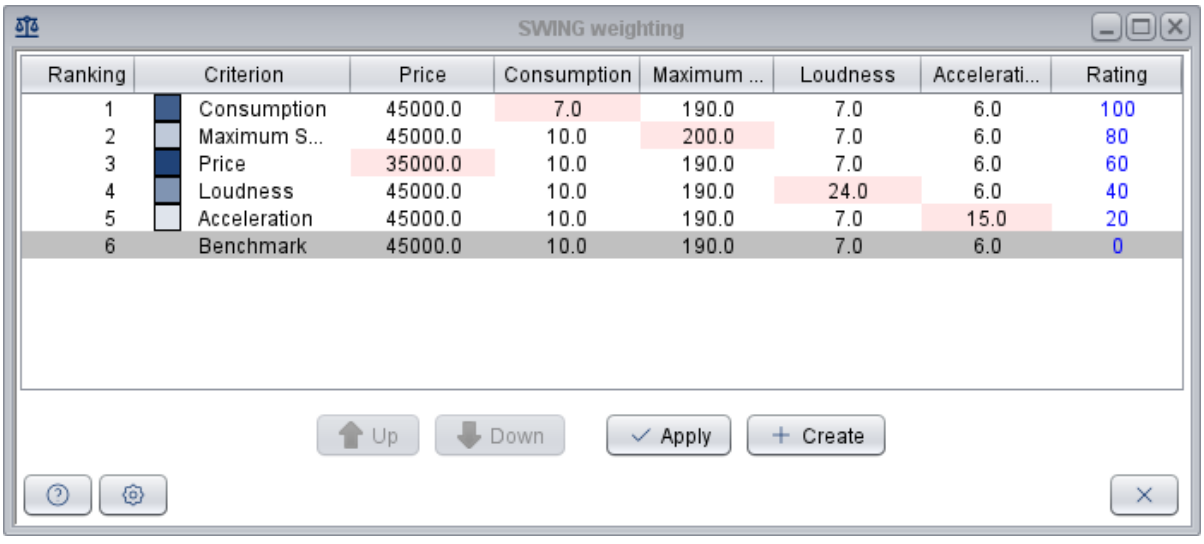

Figure 18: SWING weighting

Deck of Cards

The Deck of Cards Method (DCM) is a recognized approach for eliciting weights for outranking methods proposed by Figueira and Roy (2002).

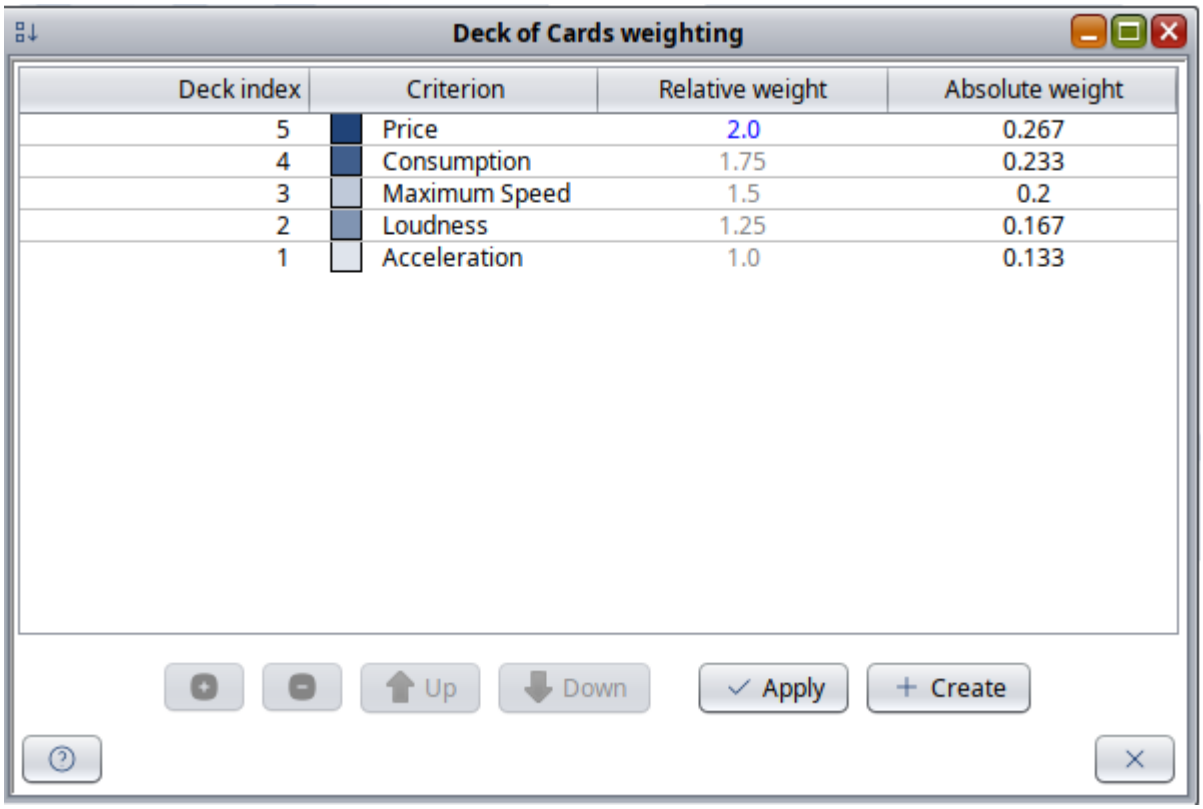

Figure 19: Deck of Cards weighting

Use the up and down arrows to order the criteria from the most important (top) to the least important (bottom). Use the plus (+) button to add white cards between criteria to express the strength of preference between consecutive levels. Define the ratio between the weight of the most important criterion and the weight of the least important one using the top cell (blue number) in the column Relative weight (see Figure 19).

Source: (Figueira & Roy, 2002)

Weight sets

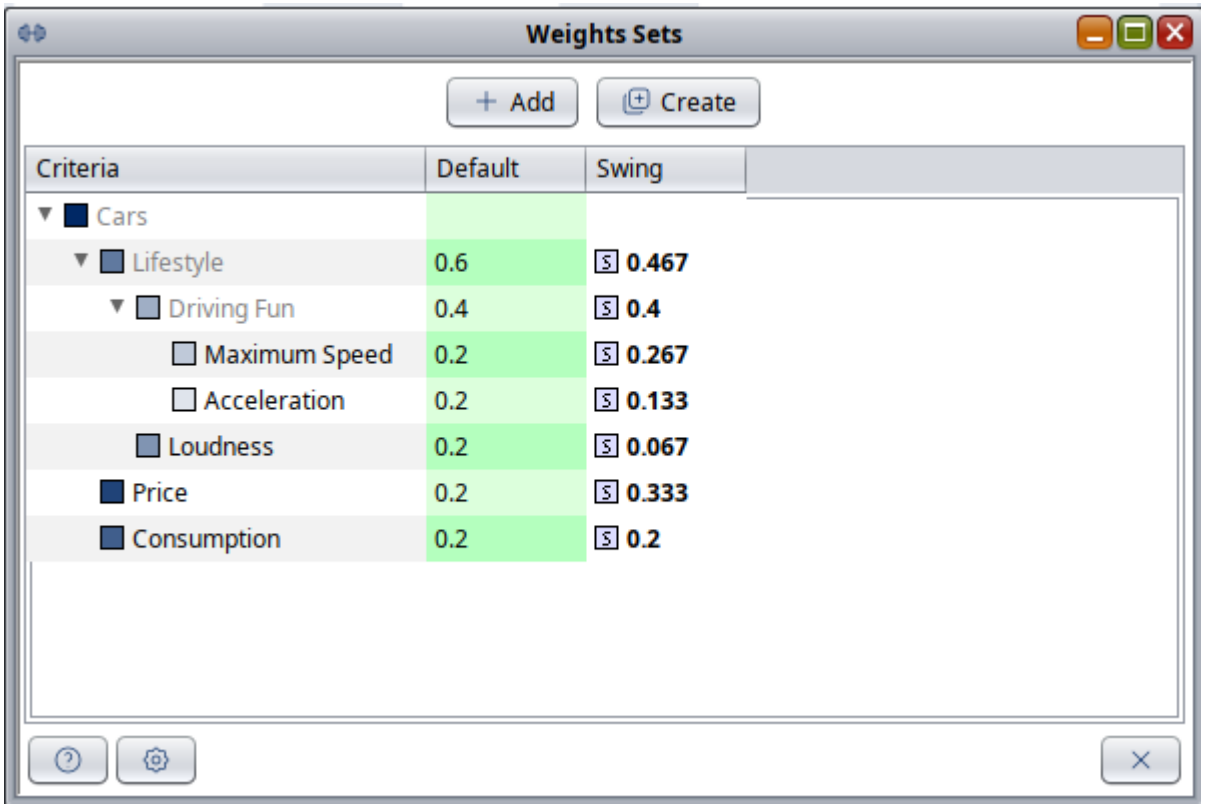

Figure 20: Weights sets

This feature enables users to manage multiple sets of weights for the criteria used in evaluating alternatives. Each weight set represents a different prioritization of the criteria, which can be useful for sensitivity analysis, scenario analysis, and managing different stakeholder perspectives.

You can create a new weight set using Add or Create buttons (see Figure 20). Use Add for completely new weight set. Use Create for new weight sets using the information available existing sets. You can choose to calculate the average value of existing weight sets or create histograms.

Qualitative sets

In contrast to quantitative criteria values qualitative criteria values allow for a linguistic, soft mapping of a human being's assessment of criteria values in terms like bad, good, high, low, etc. The terms are mapped to a numerical scale to be evaluated in the MCDA process. Several predefined quality sets commonly used are available in HELDA. In addition, it is possible to create more sets with personally preferred linguistic expressions.
To use a qualitative set for a criterion it has to be applied in the evaluation matrix by using right mouse context menu and selection of the according set.

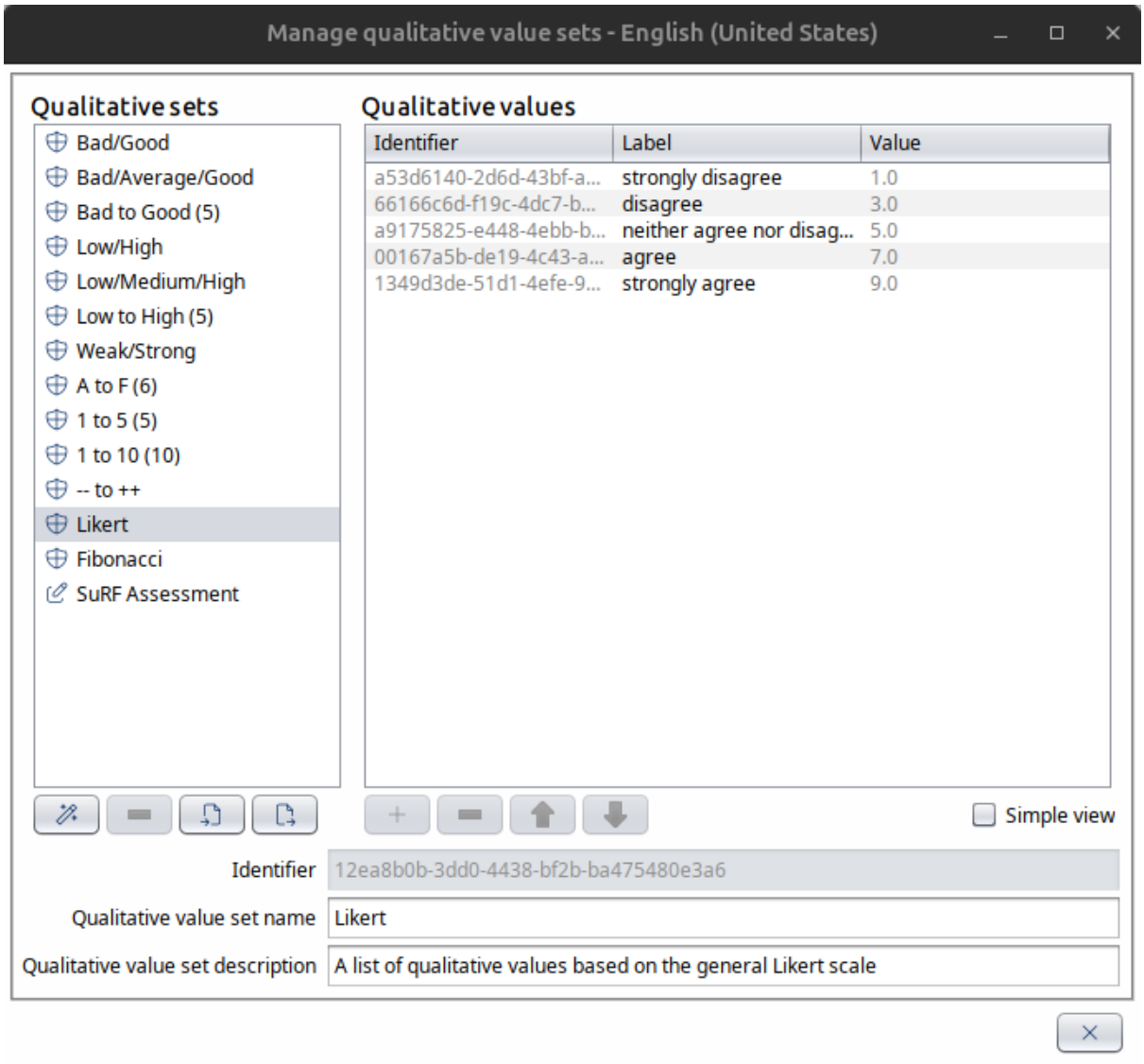

Figure 21: Qualitative sets

Tools

This feature allows users to take a snapshot of the workspace or a specific part of the software interface (see Figure 22). The captured image can then be saved, edited, annotated or shared.

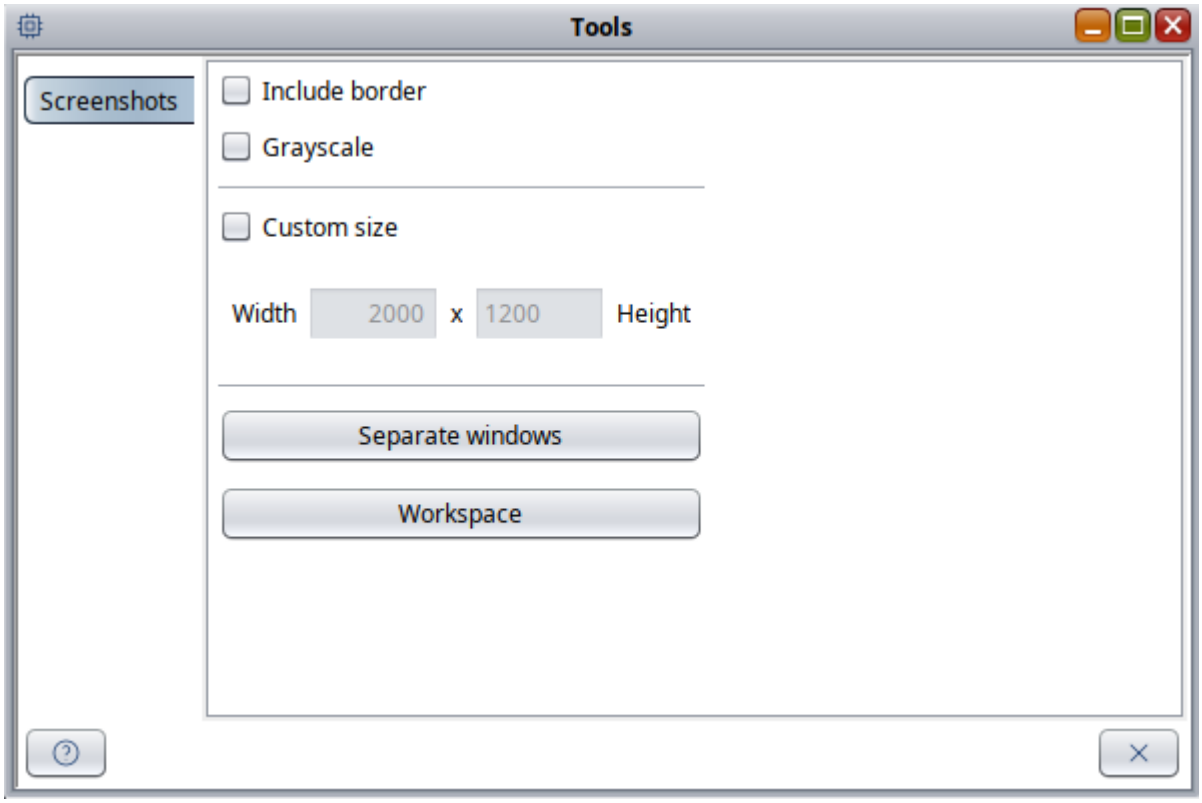

Figure 22: Tools

You can adjust the settings for the image, including window borders and color. It is possible to adjust the image for small and large formats by entering values (pixels) to adjust resolution. If you select Separate window, a window will open in which you should select the window you wish to export and the location. Only active windows are shown in this list.

Analysis

Charts

Bar charts

Bar chart of results

This window visualizes the results of the analysis using a stacked bar chart. Each alternative is represented by a bar, where the total value reflects the overall result. The individual contributions of different criteria are displayed as stacked segments within each bar, illustrating their respective impact on the final outcome (see Figure 23).

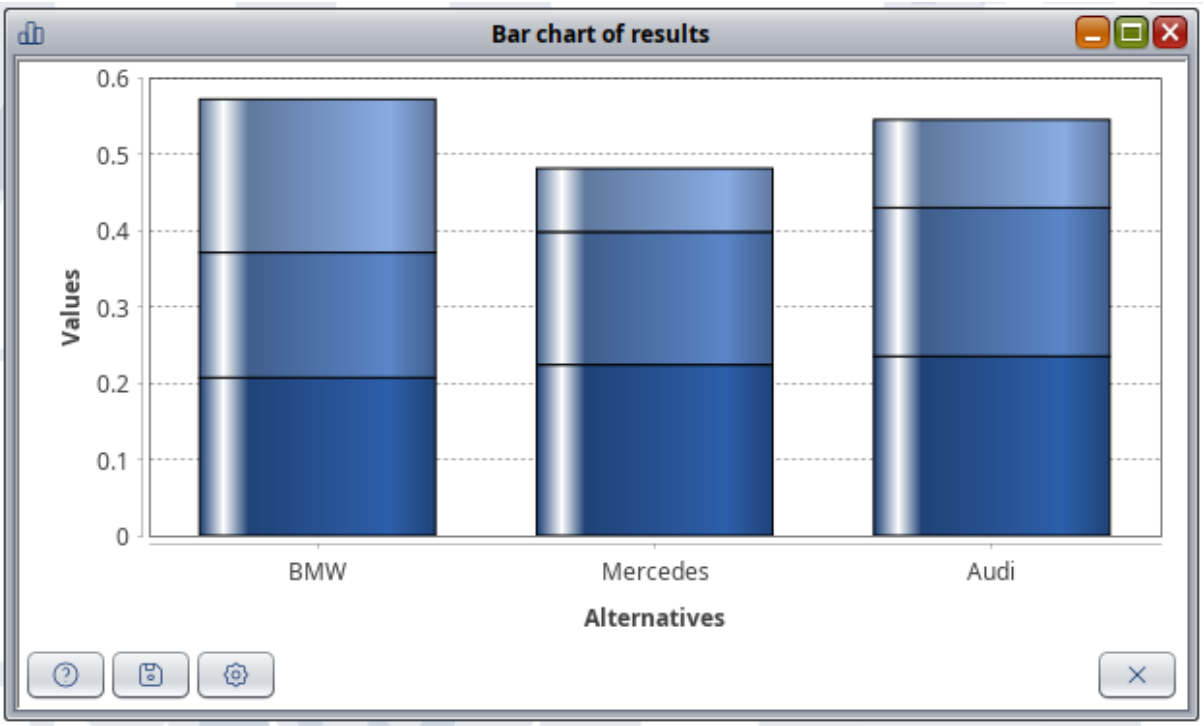

Figure 23: Bar chart of results

To enhance readability, the bars can be sorted, allowing for a clearer comparison of the differences between alternatives. Additionally, a tier threshold can be applied to simplify the chart. This threshold aggregates criteria and groups above a specified tier into a single contribution, reducing visual complexity while preserving meaningful distinctions.

This visualization is only available for aggregation methods that provide comparable rankings, e.g. the ELECTRE distilation method provides also information on incomparable alternatives and cannot be visualized this way.

Bar chart of weights

This chart displays the weights of different criteria. The value for each criterion is displayed as a bar (see Figure 24). The higher the bar the higher the weight.

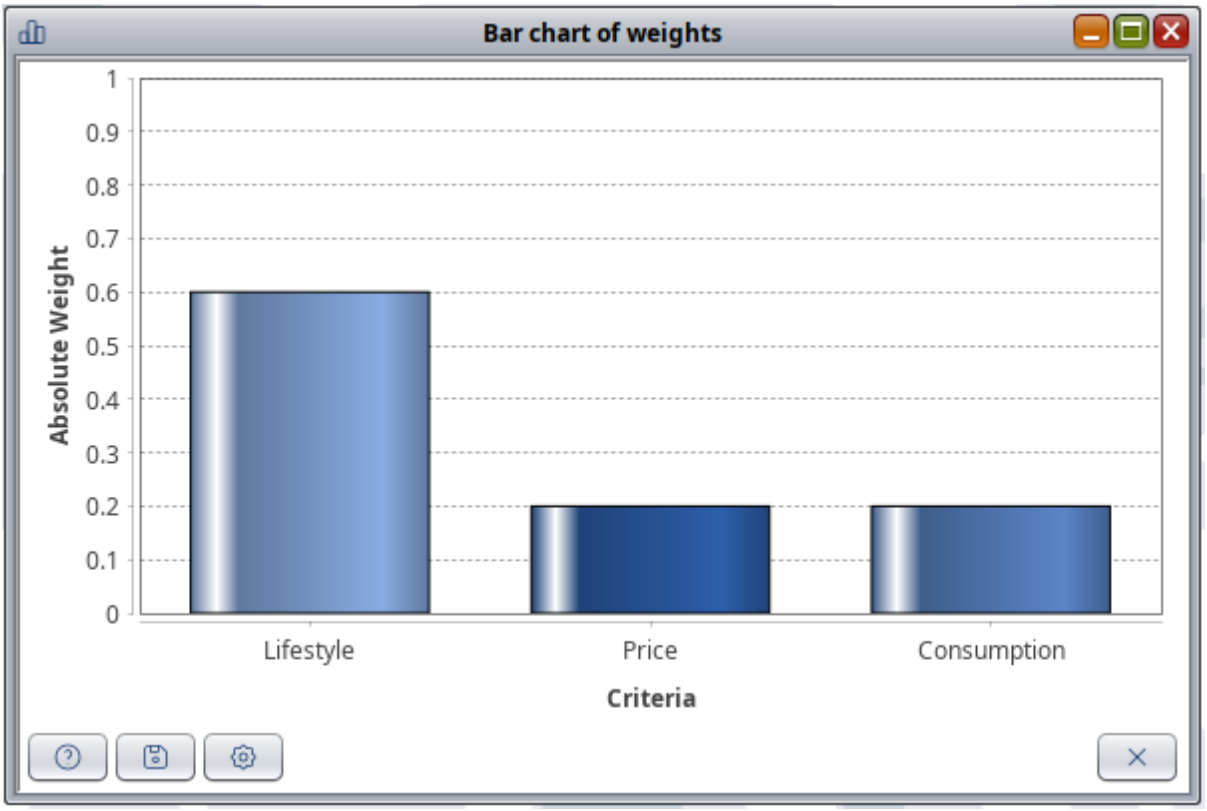

Figure 24: Bar chart of weights

Options

- The drop-down allows to define up to which tier criteria are displayed separately
- Checking the “sort” checkbox will order the bars of the criteria according to their weight
- The “Draw outline” and “Draw 3D” checkboxes enable different layout of bars
- Orientation of bars can be changed using “Horizontal plot” or “Vertical plot”

Cobweb charts

There are two types of cobweb charts: one for displaying the weights of the criteria and another for visualizing the results of the Multi-Criteria Decision Analysis (MCDA)

Cobweb chart of values

This chart displays the input data after weighting and normalization of each alternative for each criterion on a relative scale (see Figure 25). The further from the center, the better the performance of the respective alternative.

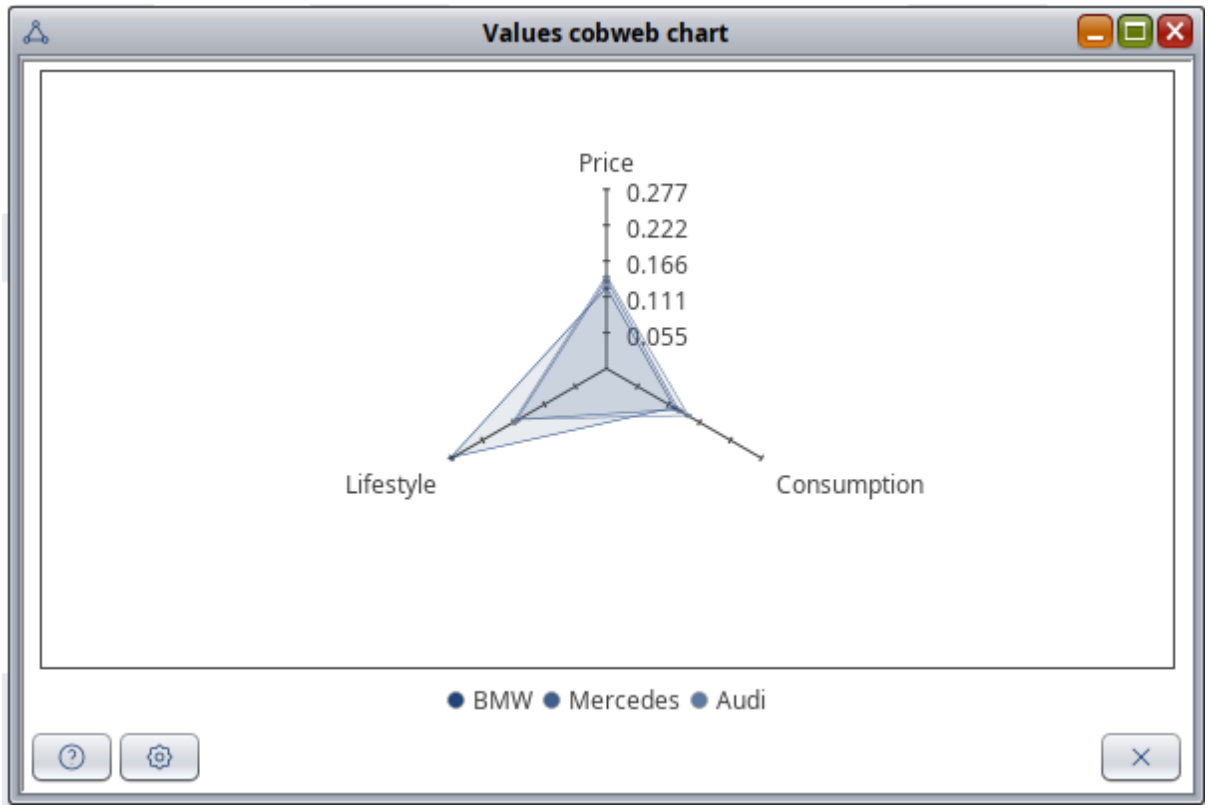

Figure 25: Cobweb chart of values

Options

- The combo box allows to define up to which tier criteria are displayed separately
- Checking respective boxes enables showing filling, labels and values of axis

Similar to the stacked bar charts only methods providing complete comparability can be visualized this way. In addition, also methods providing negative values cannot be displayed.

Cobweb chart of weights

In the given example, three criteria are represented. "Consumption" and "Price" contribute almost equally to the overall result, while "Lifestyle" has only a major impact as seen in Figure 26

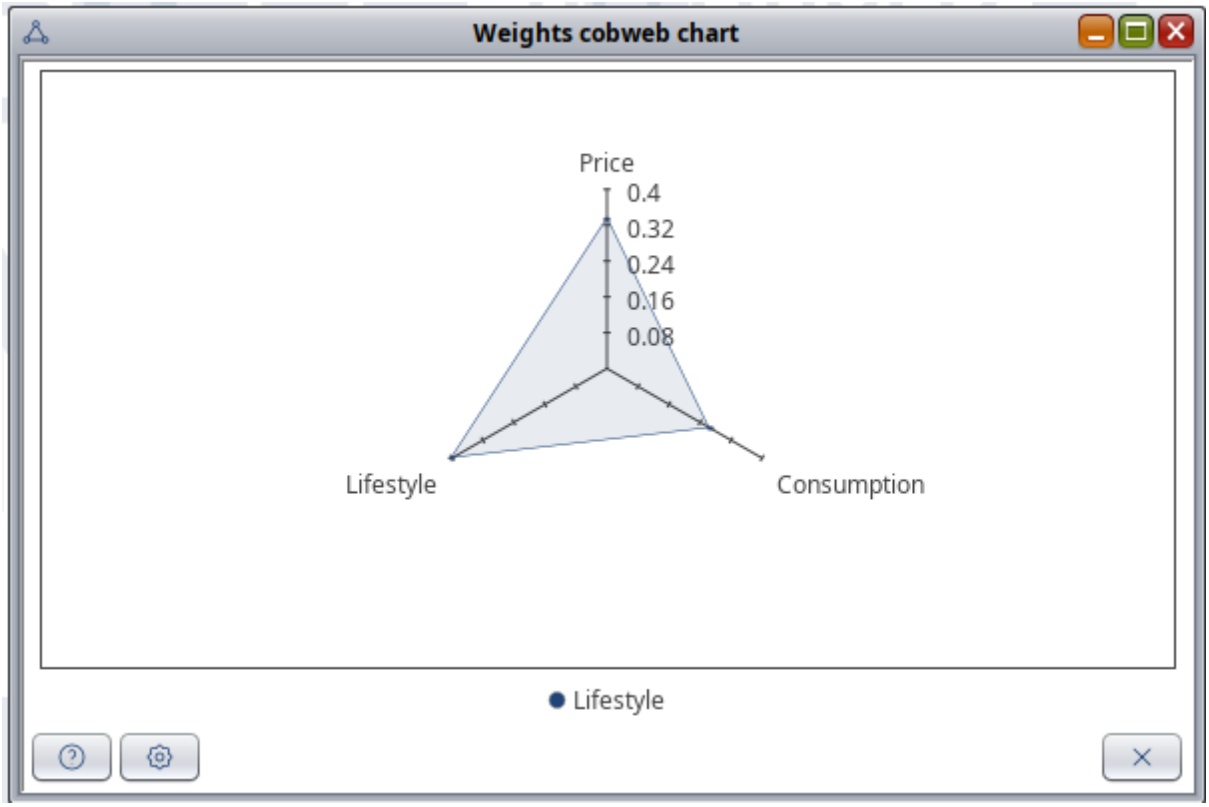

Figure 26: Cobweb chart of weights

Cobweb chart of weight sets

Description will be provided soon

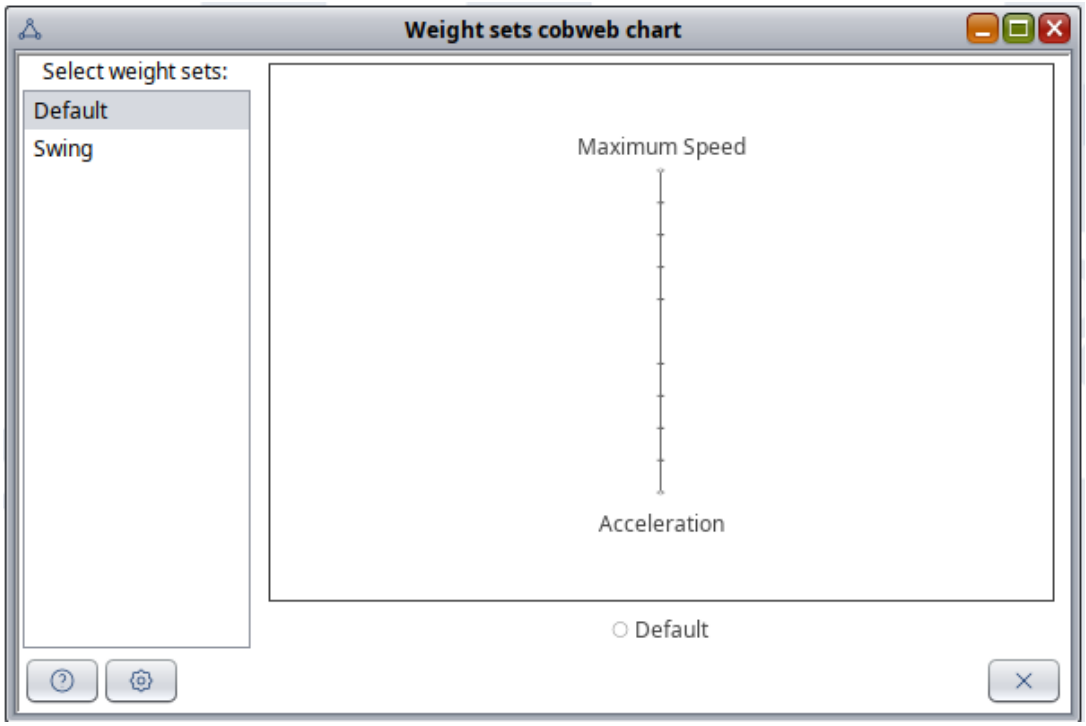

Figure 27: Cobweb chart of weight sets

Pie charts

Pie charts illustrate the proportion of each contributor relative to a combined total. In HELDA, three types of pie charts are implemented: one for the overall result, one for the weights, and one for the values.

Multi-tier pie chart for weights

The multi-tier pie chart visually represents the absolute weight of each criterion using proportional areas within the chart. Additionally, it incorporates groups and tiers, providing a structured and comprehensive visualization as seen in Figure 28.

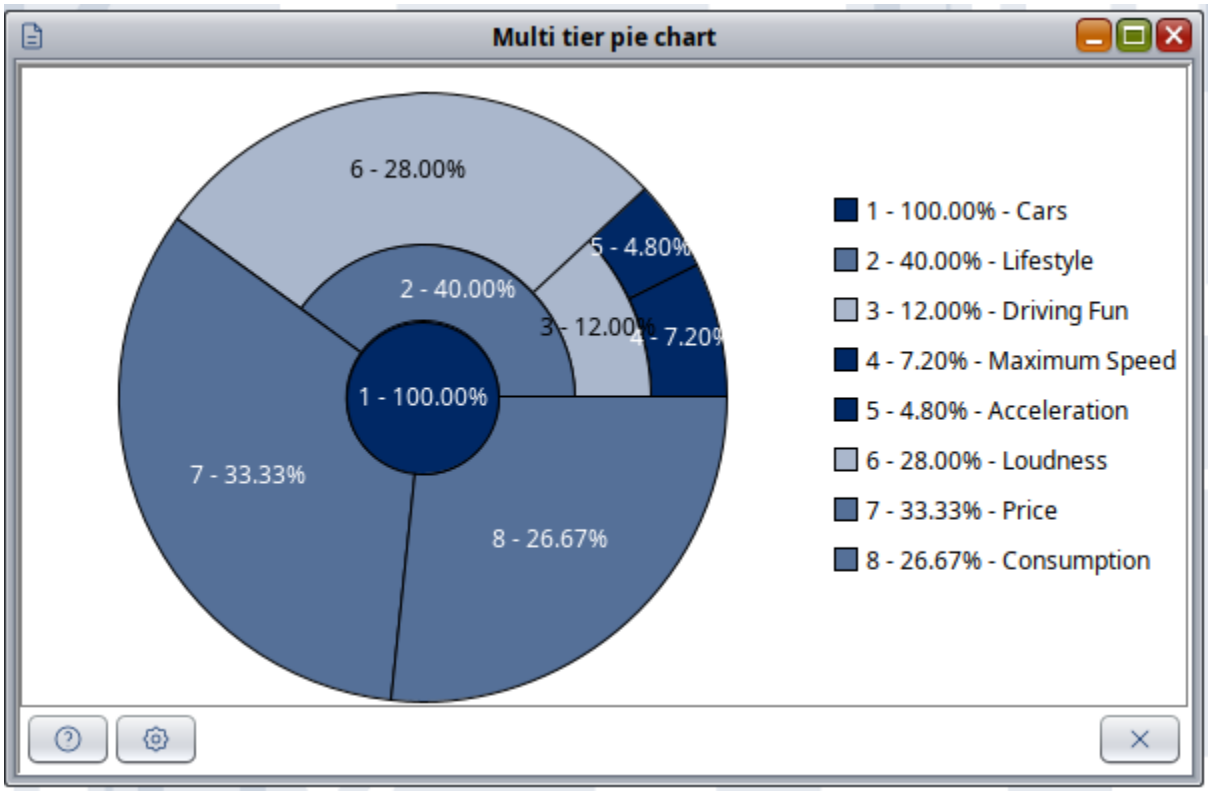

Figure 28: Multi-tier pie chart

Pie charts of results

Similar to cobweb charts the pie charts visualize the alternative ranking values in respect to each other. For pie charts this is in respect to the area of a circle.
As for the other visualization methods of results this method is only possible for aggregation methods providing fully comparable ranking.

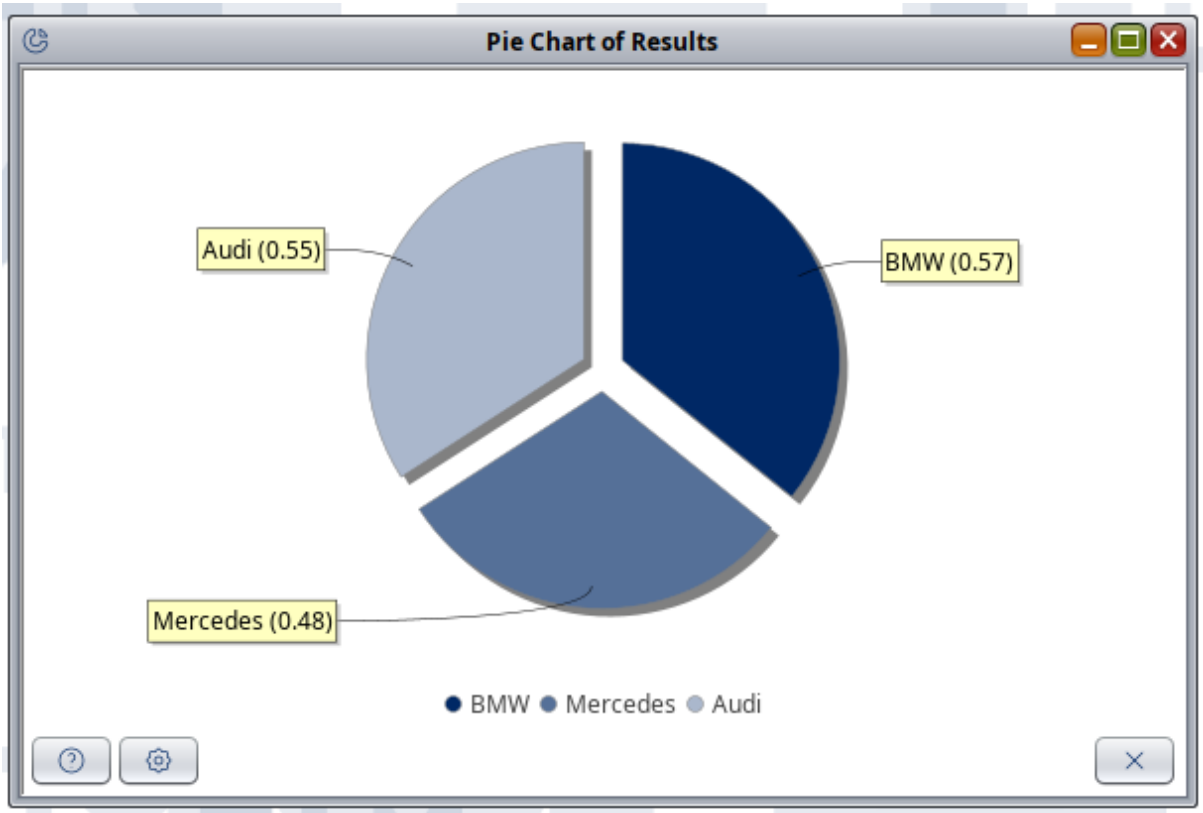

Figure 29: Pie chart of results

Pie charts of values

This chart displays the input data (values) of the MCDA for the considered alternatives and criteria as portions of a pie (see Figure 30).

- The criterion to be displayed can be selected via the drop-down menu
- The options button provides means to display the pie exploded.

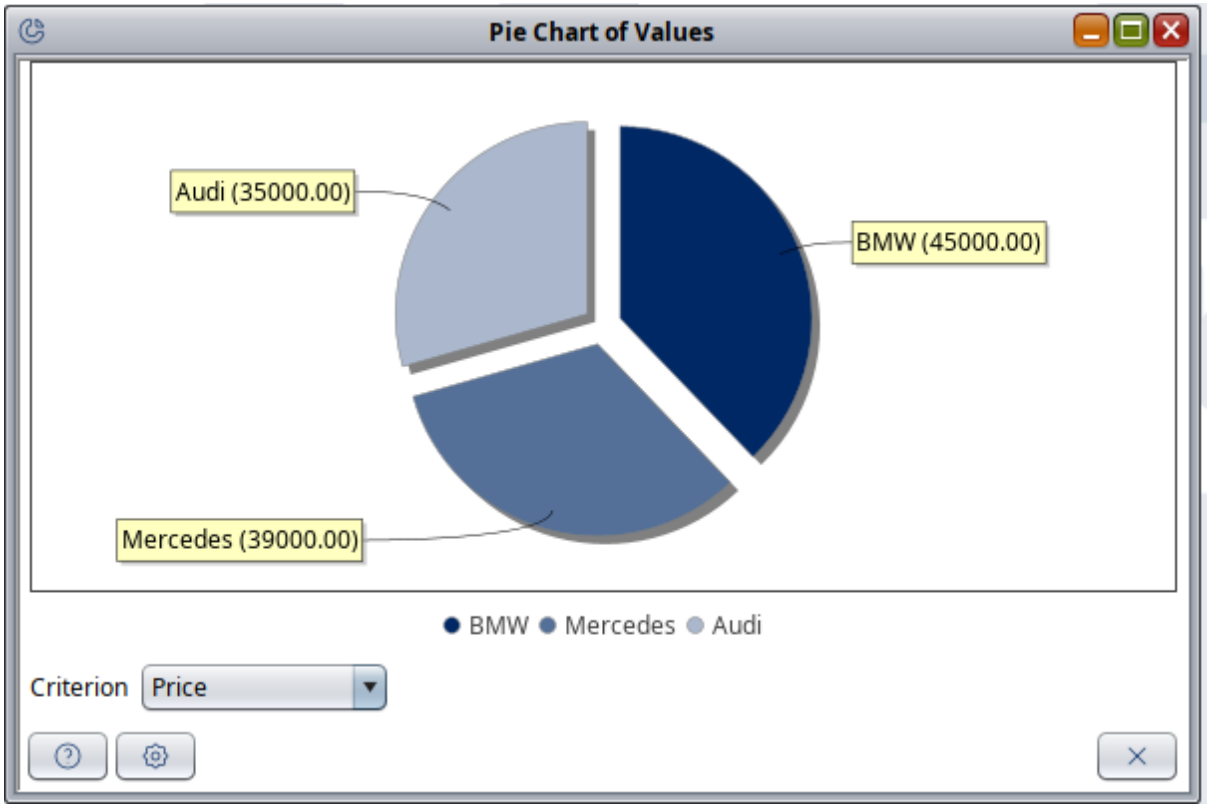

Figure 30: Pie chart of values

Pie charts of weights

This chart displays the relative normalized weights for the different criteria as portions of a pie (see Figure 31. Options: The dropdown menu allows to define up to which tier criteria are displayed. The pie can be display exploded

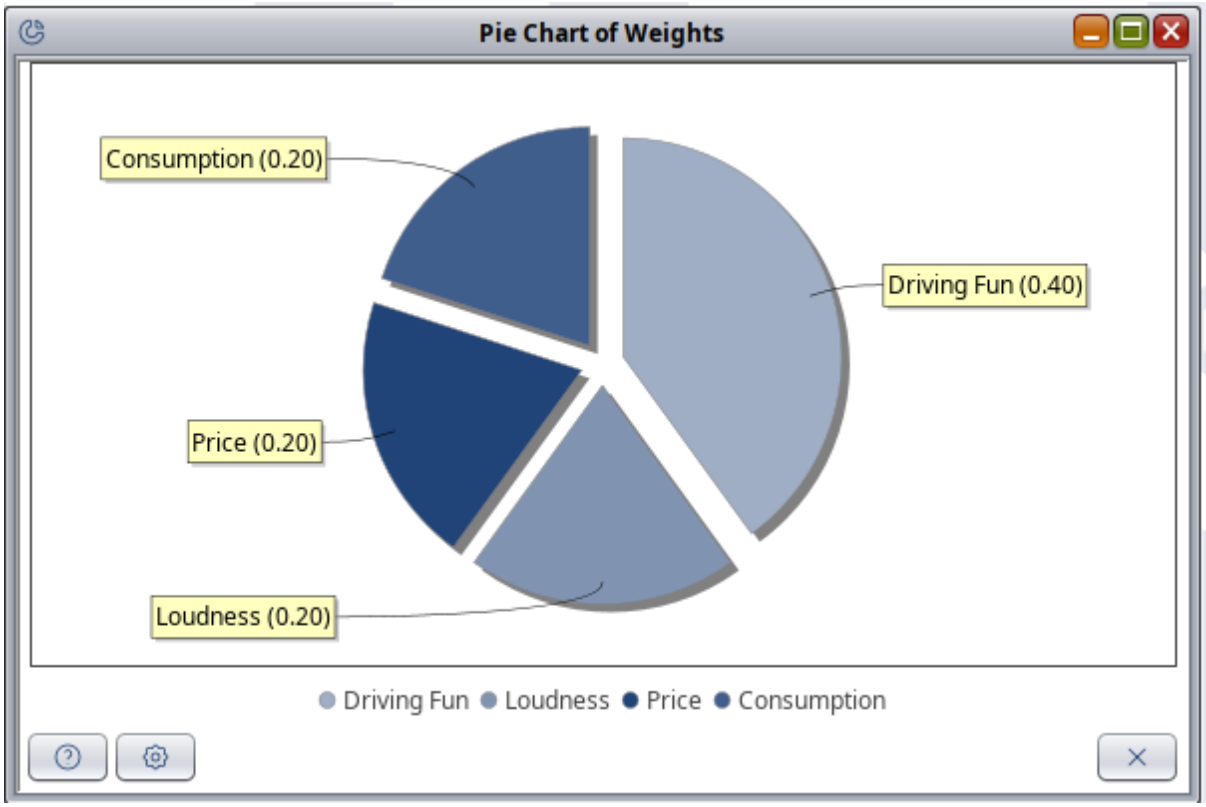

Figure 31: Pie chart of weights

Correlation

This tool enables the analysis of potential correlations between criteria as seen in Figure 32. It presents a matrix displaying ranked correlation values. The color coding from green (low correlation) over yellow to red (high correlation) allow for rapid identification of potential correlations.

Ranked correlation is just one of many methods available for identifying potential relationships between criteria. As such, careful and intelligent interpretation of the results is necessary to draw meaningful conclusions.

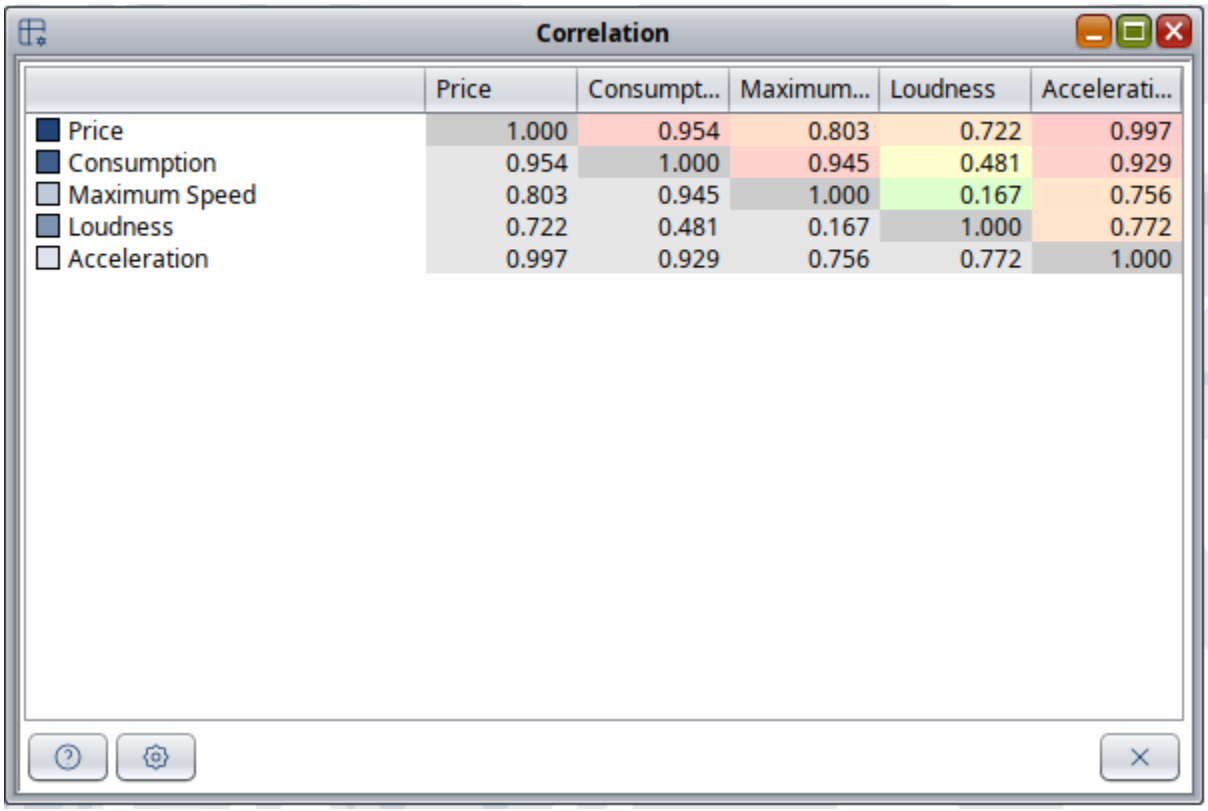

Figure 32: Correlation

Dominance

The Dominance method visualizes the influence of different criteria on each alternative, helping identify the most dominant criterion respectively key driver for each alternative. Dominance is calculated by normalizing each criterion value, multiplying it by the normalized absolute weight, and displaying the results in a chart where each criterion is represented by a line.

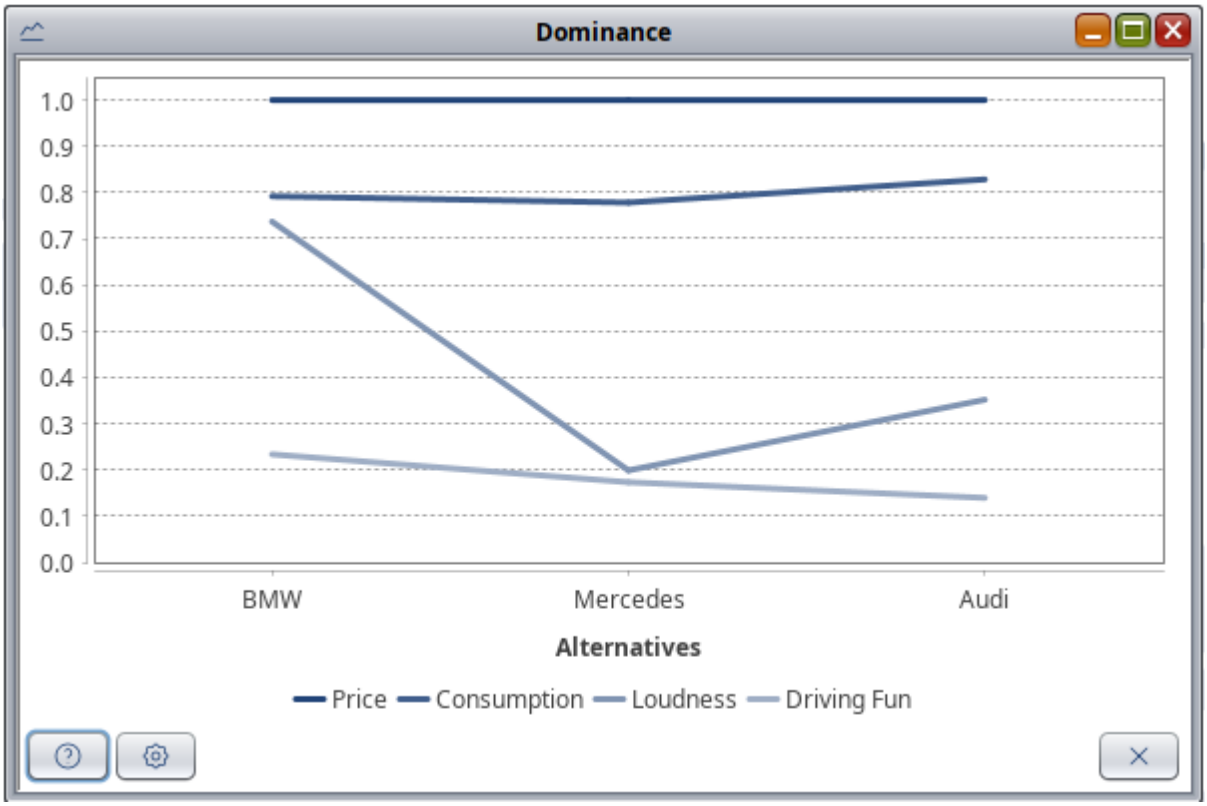

Figure 33: Dominance

The height of the line for each alternative indicates its dominance score, providing a clear way to assess which criteria have the strongest impact (see Figure 36). Users can customize the analysis by adjusting the maximum tier of displayed criteria, with criteria below this tier being aggregated within their respective groups. This allows for a simplified or more detailed visualization depending on the user's needs.

Ensemble

The Ensemble manager (see Figure 37) handles the evaluation of a MCDA when uncertainties are included either for weights or criteria values. These uncertainties are defined as probability distributions. The first tab allows users to define parameters for the ensemble evaluation, while the following tabs provide various possibilities for visualizing the results.

Even with thousands of samples, the evaluation is usually completed within a fraction of a second, though a progress bar is displayed during the process.

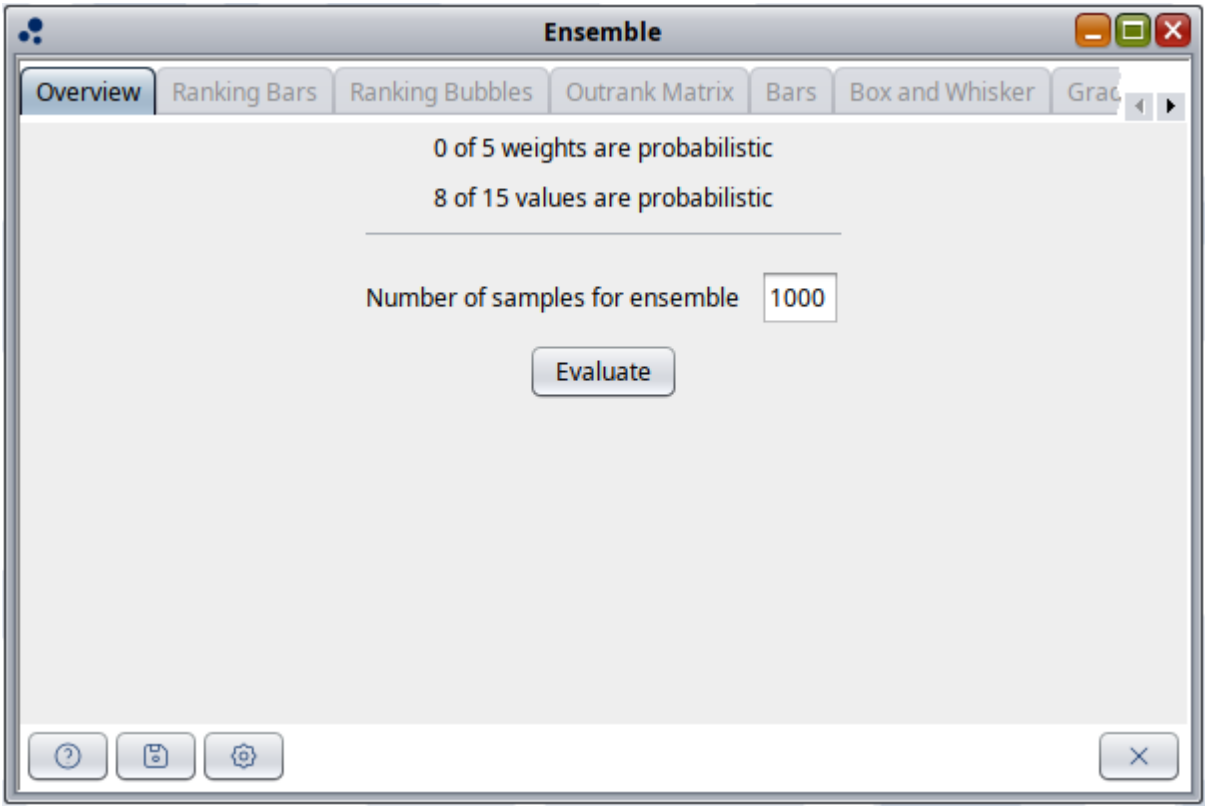

Figure 34: Ensemble

The evaluate button triggers the Monte Carlo simulation. After computation the tabs are enabled and accessible. The Number of Samples field allows users to specify the ensemble size, where higher numbers improve accuracy but also increase computation time. Also, some details are provided on how many probabilistic variables are present in the current MCDA.

Impact

The Impact method visualizes how much each criterion contributes to each alternative relative to the others, helping to understand the magnitude of its influence. The impact for each alternative is calculated by multiplying the normalized criterion value by the absolute weights.

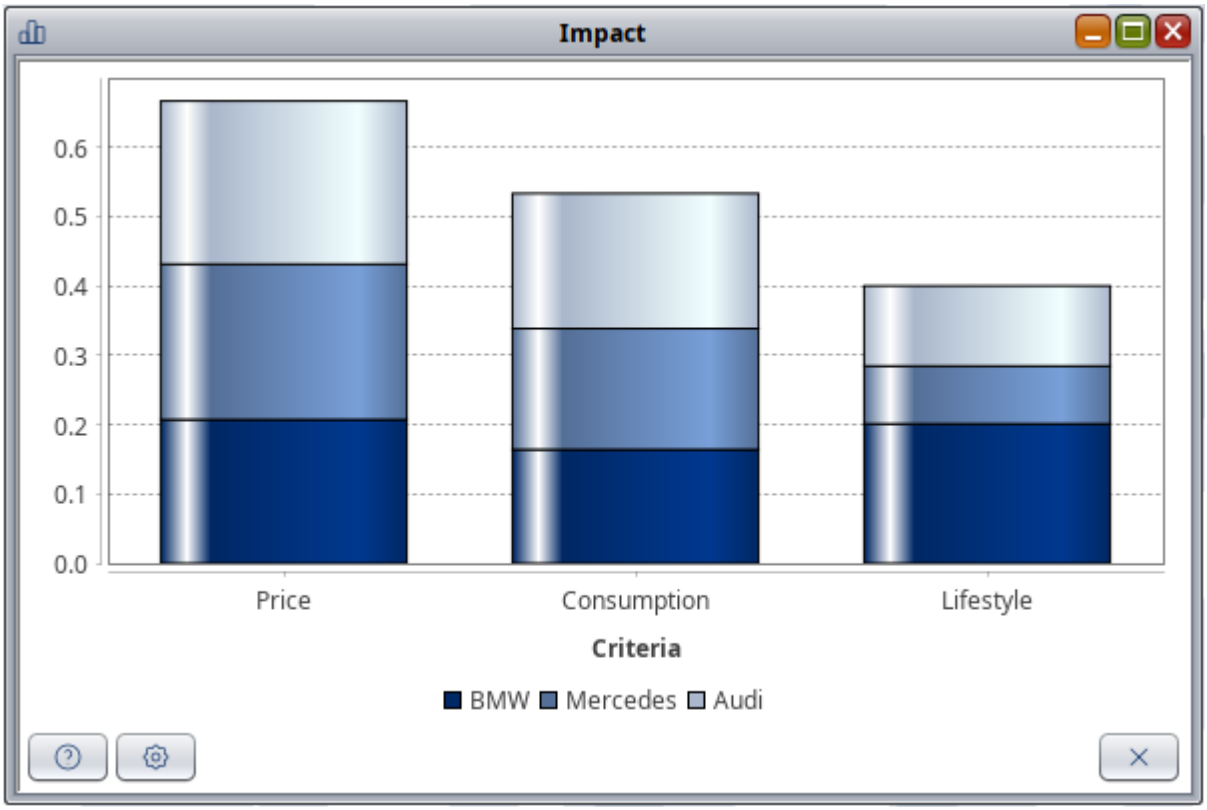

Figure 35: Impact

The results are displayed as a stacked bar chart, making visual comparison straightforward (see Figure 38). The Tier option allows lower-tier criteria to be aggregated into their group when displayed as a bar. The Normalization option scales the tallest bar to a height of 1 for easier comparison. The Outline option enhances visualization by providing sharper contrast for the bars.

Again, this visualization may not be available for every aggregation method.

One on one

Description will be provided soon

Report

The *Report Tool* converts the mathematical results of the analysis into a **comprehensive, human-readable document** as seen inFigure 33.

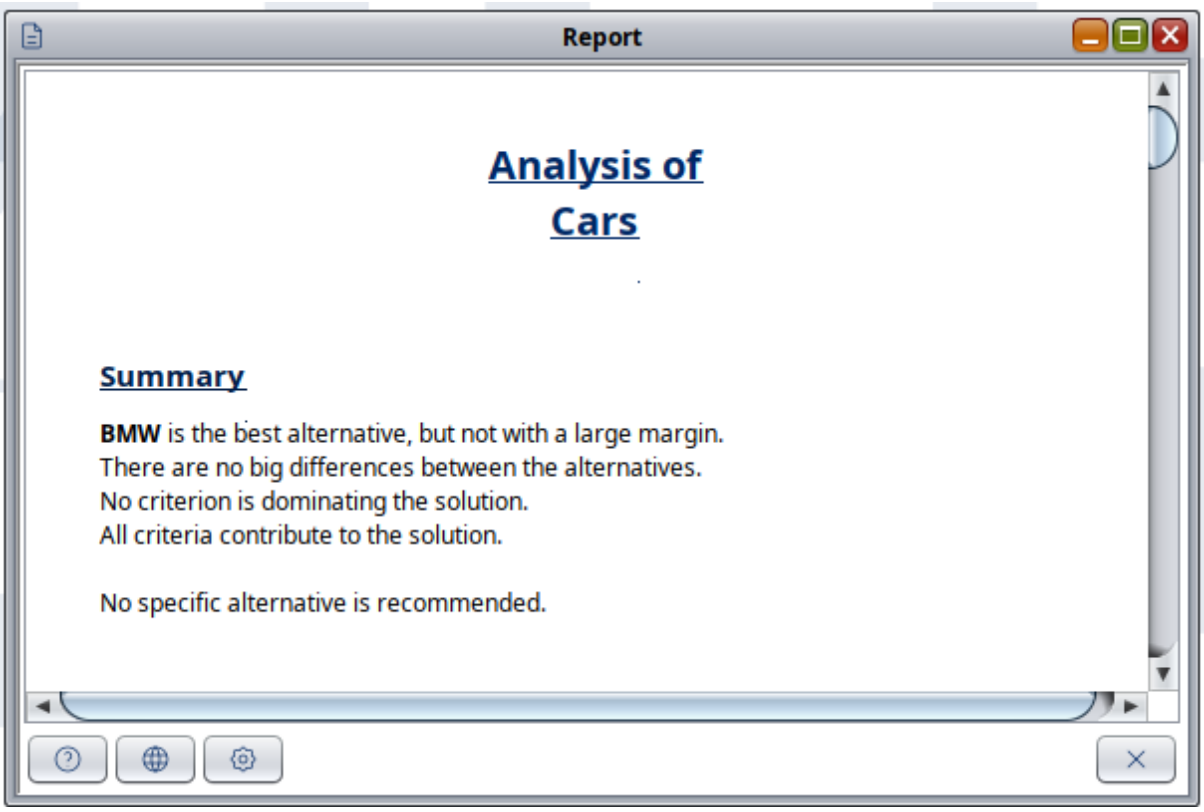

Figure 36: Report

The generated report includes multiple sections, such as:

- **Basic Information** – Provides an overview of the MCDA process.
- **Stability Analysis** – Evaluates the robustness of the solution.
- Ensemble Evaluation – Information on Monte Carlo simulation in case of uncertainties are included in the MCDA
- Several more...

Users can **enable or disable** specific sections through the tool's options, allowing for a tailored report based on their needs.

Exporting the Report

Using the *Export Results* menu in the main window, the report can be saved either as an **HTML file**, preserving the same content displayed on-screen for easy sharing and further analysis, or a Word document

Specific results

This window displays additional information for ELECTRE III method. Results for concordance flows, discordance flows and net flows are presented.

Source: (Sarmas et al., 2020)

Result matrix

Description will be provided soon

Result graph

Description will be provided soon

Weight sets analysis

The Weight Sets Analysis provides a visual representation of the weight sets included in the assessment (see Figure 39). Using Ctrl + Select, multiple weight sets can be chosen for display in the graph. Larger bubbles indicate higher importance of a criterion compared to others. For better visualization and comparison, the Options button at the bottom left of the window allows selecting Scale Range. To modify or add weight sets, use the Edit > Weight Sets menu.

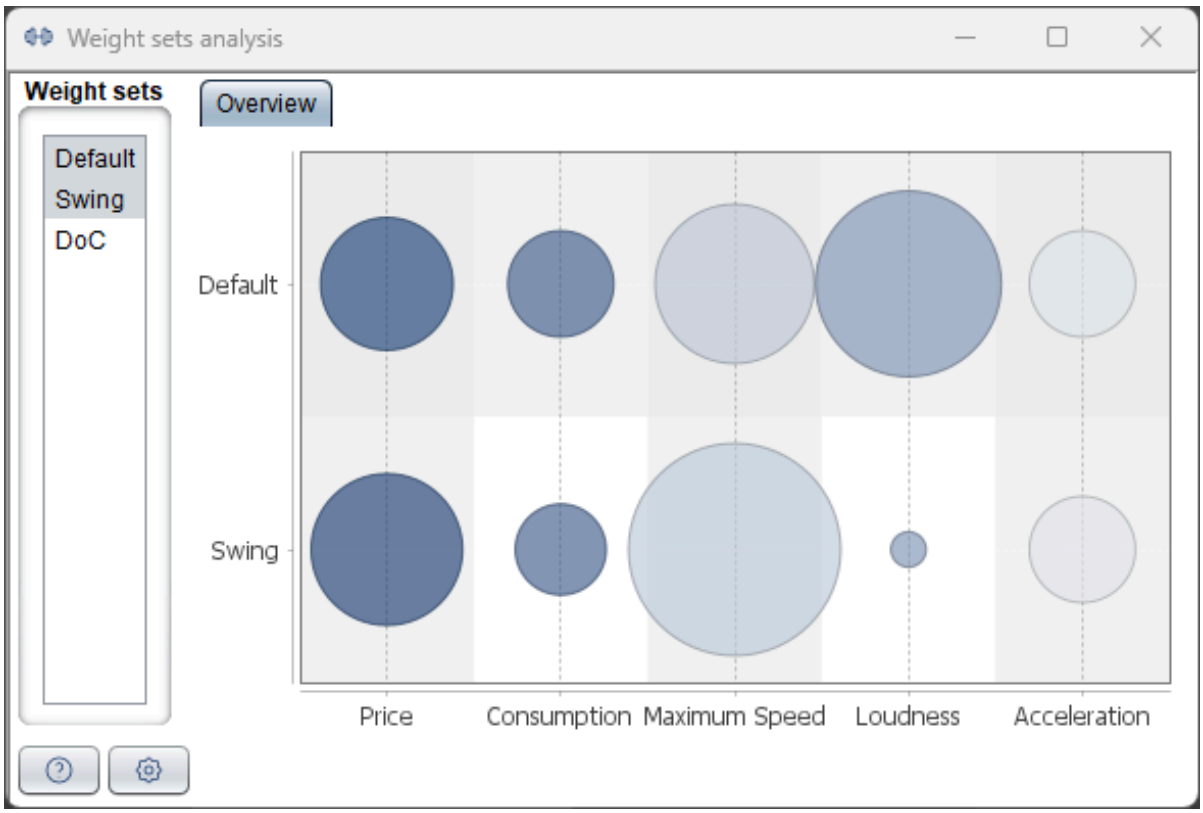

Figure 37: Weight sets analysis

Sensitivity

Weights

This information helps to assess the stability of the results by systematically analyzing how changes in preferences (weights) impact the MCDA outcome as seen in Figure 34.

Adjusting the weight of a criterion directly influences the outcome, particularly the ranking of alternatives. The analysis offers two selectable approaches:

1. **Varying Relative Weight** – The weight of a criterion is adjusted within a range of 0.0 to 10.0 comparable to manually drag sliders in the relative weight frame
2. **Gradual Inclusion** – The relative weight remains unchanged, but the criterion's contribution to the MCDA is progressively included from 0.0 to 1.0, The value 0.0 can be interpreted as the criterion is not part of the MCDA at all.

Key insights from the analysis can be derived by observing intersections in the graph, where curves cross each other, signaling a shift in the ranking of alternatives. The example shows that when changing the weight of the criterion Price, the ranking is stable until closing in at 10.0, where the curves for BMW and Audi connect and finally cross.

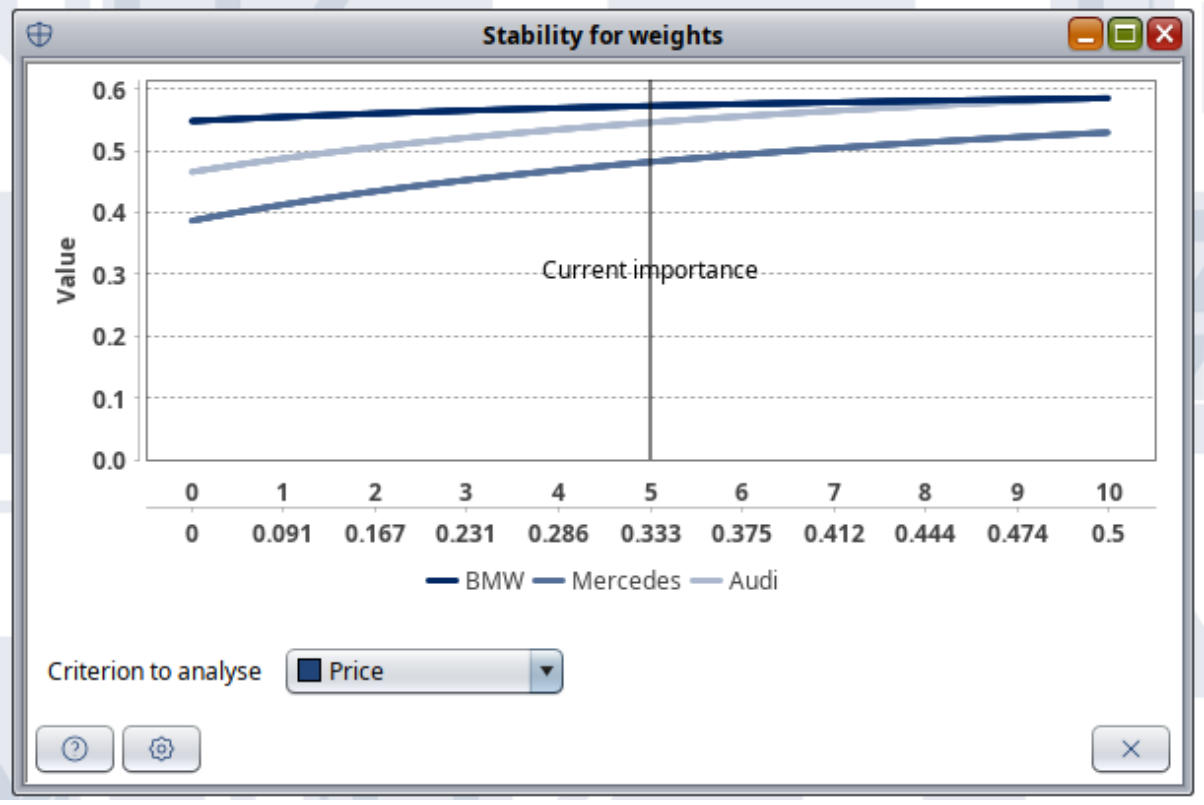

Figure 38: Sensitivity for weights

Values

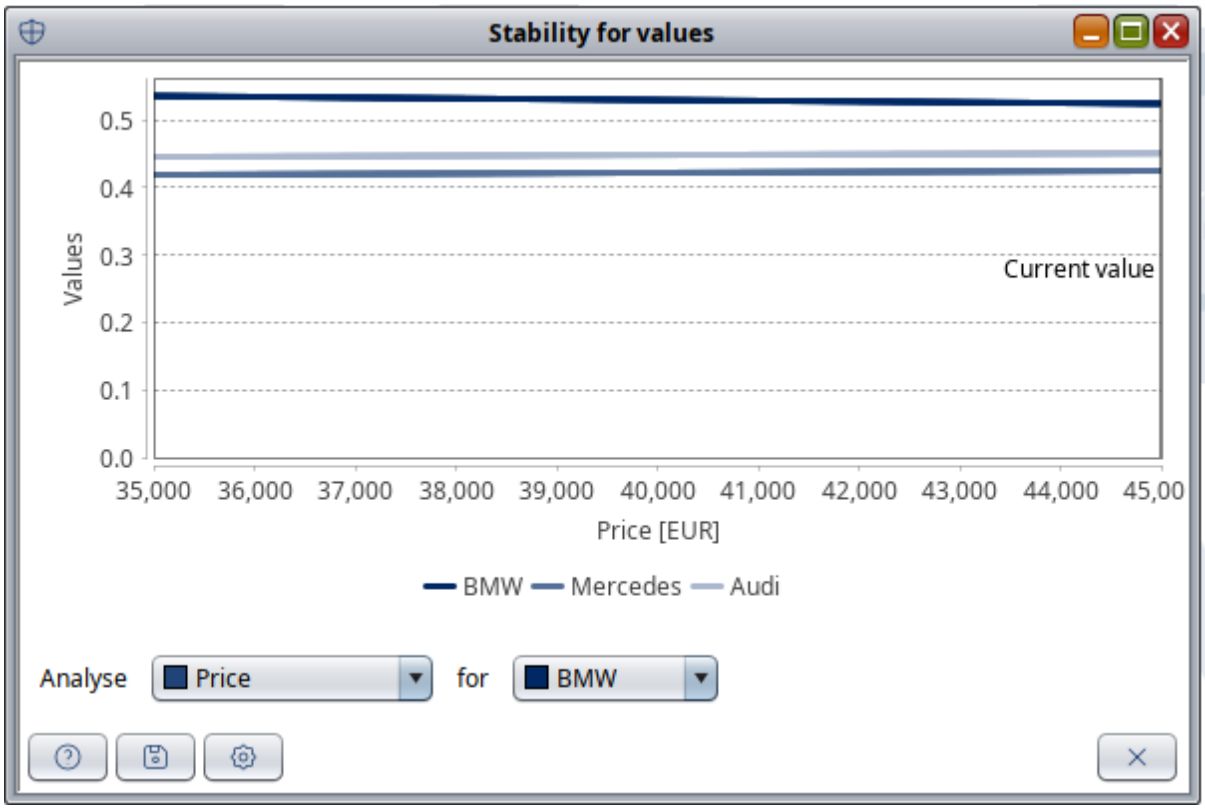

Figure 39: Sensitivity for values

This tool helps understanding about the stability of the results, i.e. what will happen if the value of the criteria for a specific alternative is changed. Changing the value of a criterion could influences the result of the MCDA and especially the ranking of the alternatives.

The intersections indicate a change in the ranking of the alternatives (see Figure 35).

Plugins

Plugins are distributed as a zip file containing everything required for it. To install a plugin, place this .zip file (e.g., OnlineSurvey-3.0.1.zip) in the software's plugin folder. Manual extraction is not required. The software automatically detects and unzips the latest version. To update, add or overwrite the new versions .zip file; the software prioritizes the newest version. To remove a plugin, delete its .zip file from the folder. This allows for easy installation, updating, and management of plugins.

Online survey – *Will be released soon*

To select the plugin, follow the path Plugins > Sustainability Assessment > Stakeholders > Online Survey.

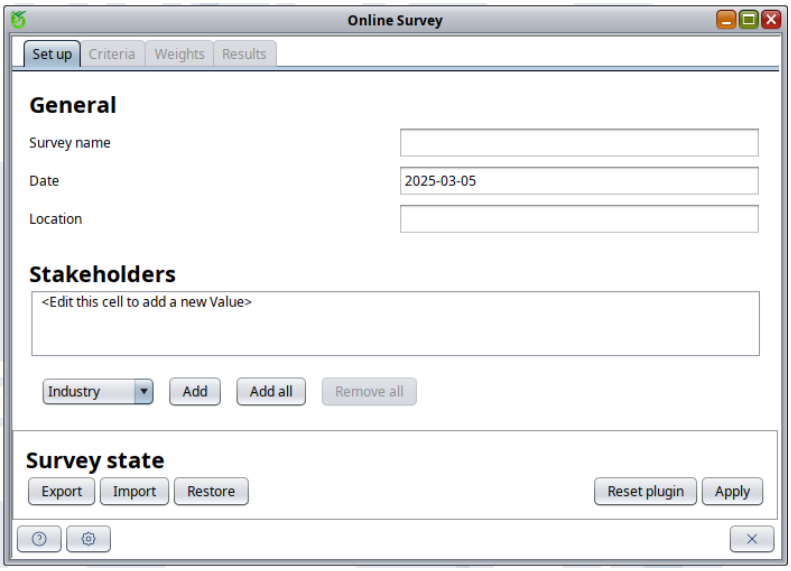

Figure 40: Set up tab of Plugin for online surveys

The **Set up tab** (see Figure 40) allows users to configure survey details and manage stakeholders. In the General section, users can enter a survey name, modify the date if needed, and specify a location. The Stakeholders section enables adding different types of stakeholders. There are several options to add the stakeholder's categories. First, users can manually enter a stakeholder. Second, select a type of stakeholders from the predefined categories in the dropdown, and click Add to include it. Third, clicking Add all automatically adds the pre-defined categories Industry, Academia, and Government. The button Remove all clears the list. In the Survey State section, users can Export to save, Import to load a previously exported survey, and Restore to revert the survey to a previous state. The Reset plugin button reloads the active plugin. Once the settings are adjusted in General section and the stakeholder categories are added, clicking Apply finalizes the configuration of the surveys.

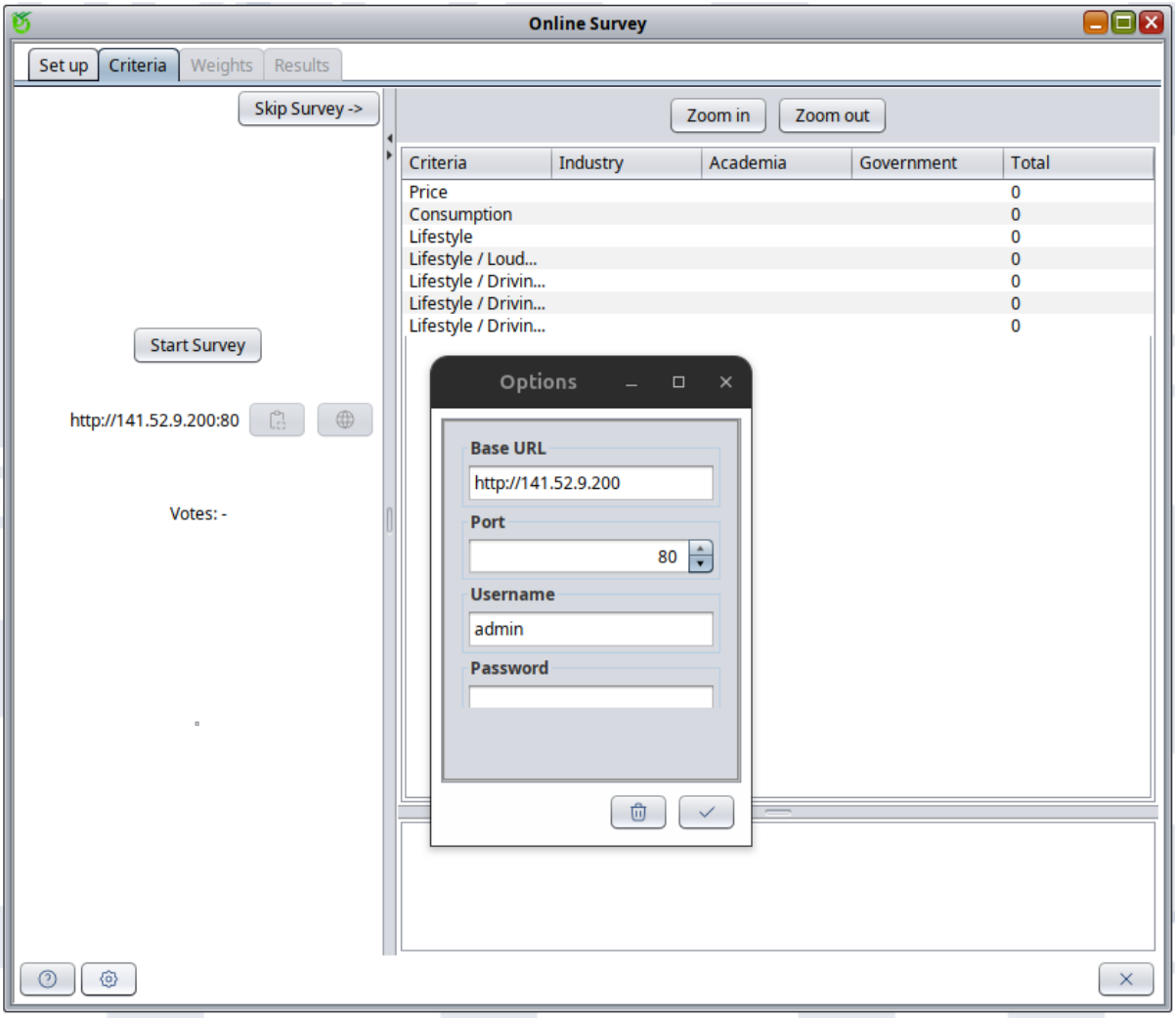

Figure 41: Criteria tab of Plugin for online surveys - Options

The **Criteria tab** (see Figure 41 and Figure 42: Criteria tab of Plugin for Online Surveys – Running survey) allows the creation of surveys to ask stakeholders on their acceptance (in a voting format) of every criterion included in the decision analysis. This interface manages

online surveys, allowing you to start, stop, or skip this type of survey and monitor responses in real-time. By clicking on Start survey, a survey URL and a QR code are generated to redirect stakeholders to the created online survey (see Figure 42). The right-side table tracks stakeholder response counts across various criteria like Price, Consumption, and Lifestyle. The surveys created with the plugin have no limitation in the time in which they can receive input from stakeholders. If the user wants to have a survey open for a month, then simply export the current status of the plugin in the Set up tab and save. To check the progress of the survey, simply import the exported file using the Import button in Set up tab. When the survey is finished, simply click on Stop survey to close the survey, i.e. not receive more information from stakeholders. The Options window opens via the cogwheel button, allowing users to set the Base URL, Port, Username, and Password for authentication.

The option Skip survey is created for instances in which only weights elicitation is conducted, then the user is redirected to the next tab Weights.

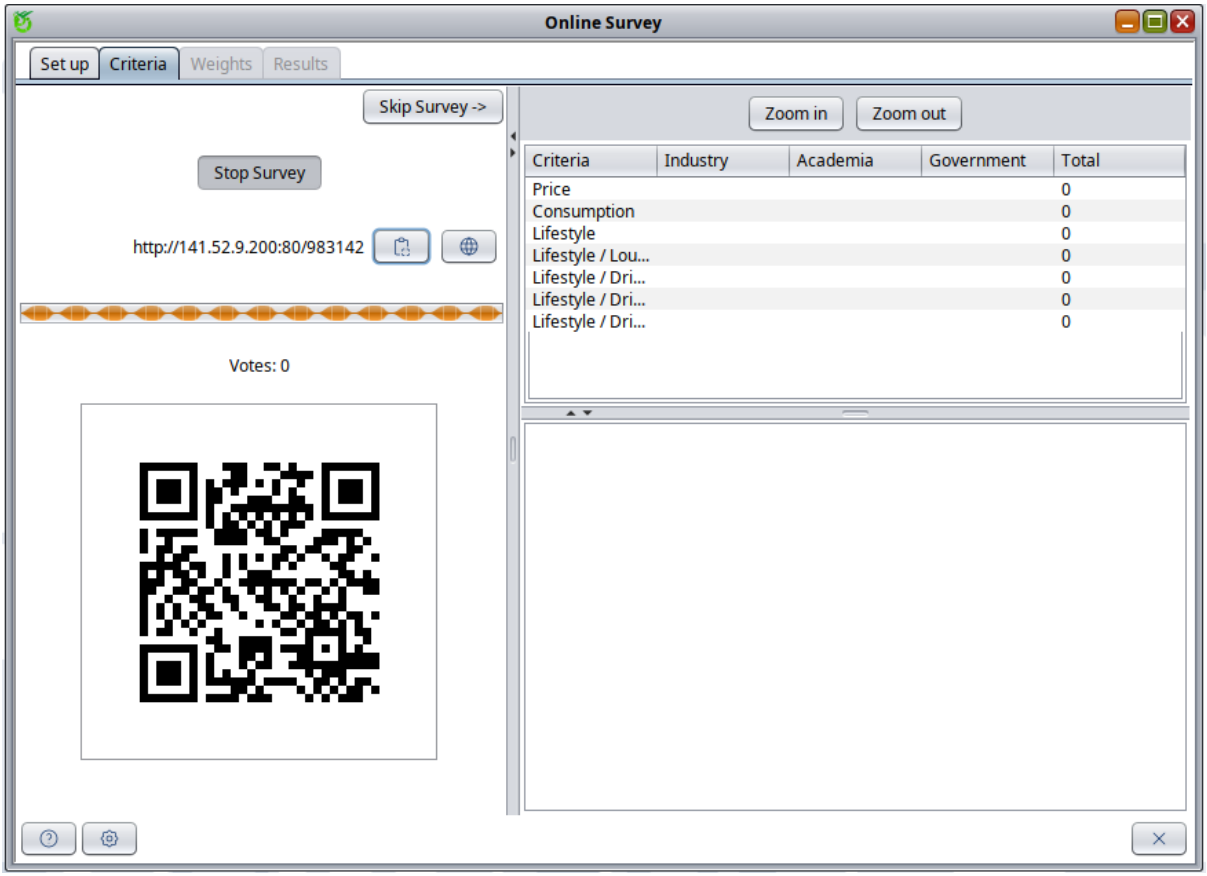

Figure 42: Criteria tab of Plugin for online surveys – Running survey

The **Weights tab** allows the creation of surveys of preference elicitation for the criteria included in the decision analysis. The plugin uses a direct weighting method in which the stakeholders can perform a relative assessment of the importance of the criteria set. The plugin creates surveys for both flat and hierarchical structures of criteria. The user can set the range of the weighting scale using a slider to set values from 1 to 10. There is an option to

request the survey participants to use the full range of scale. When the user decides to not request for a full range of scale, the obtained results are normalized using the minimum and maximum value given by the participant. There is an option to update weighting during the survey, meaning that the model in HELDA is being updated with the average of weights given by the survey participants and the changes can be observed in real time.

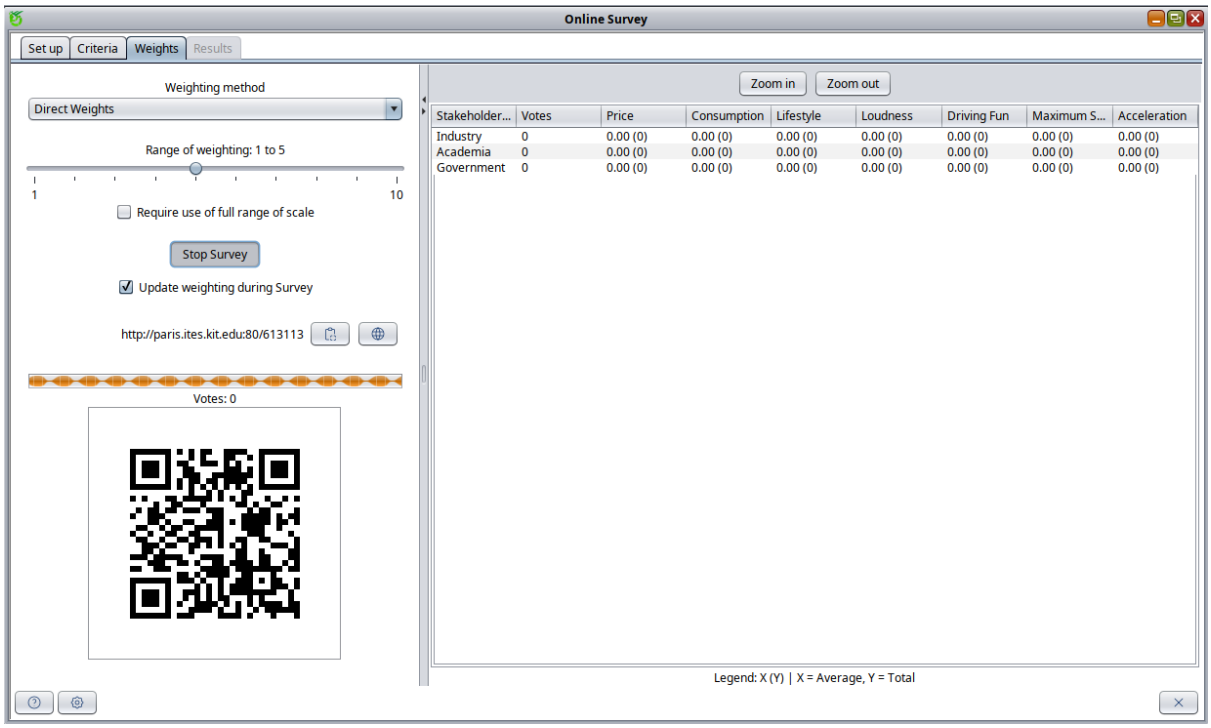

Figure 43: Weights tab of Plugin for online surveys – Running survey

This interface manages online surveys, allowing you to start, stop, or skip this type of survey and monitor responses in real-time. By clicking on Start survey, a survey URL and a QR code are generated to redirect stakeholders to the created online survey. The right-side table tracks stakeholder responses by stakeholder category and relative weights assigned according to the scale selected. Two information is presented in the columns of the criteria using two numbers as described in the legend at the bottom of the plugin. The surveys created with the plugin have no limitation in the time in which they can receive input from stakeholders. If the user wants to have a survey open for a month, then simply export the current status of the plugin in the Set up tab and save. To check the progress of the survey, simply import the exported file using the Import button in Set up tab. When the survey is finished, simply click on Stop survey to close the survey, i.e. not receive more information from stakeholders. The Options window opens via the cogwheel button, allowing users to set the Base URL, Port, Username, and Password for authentication.

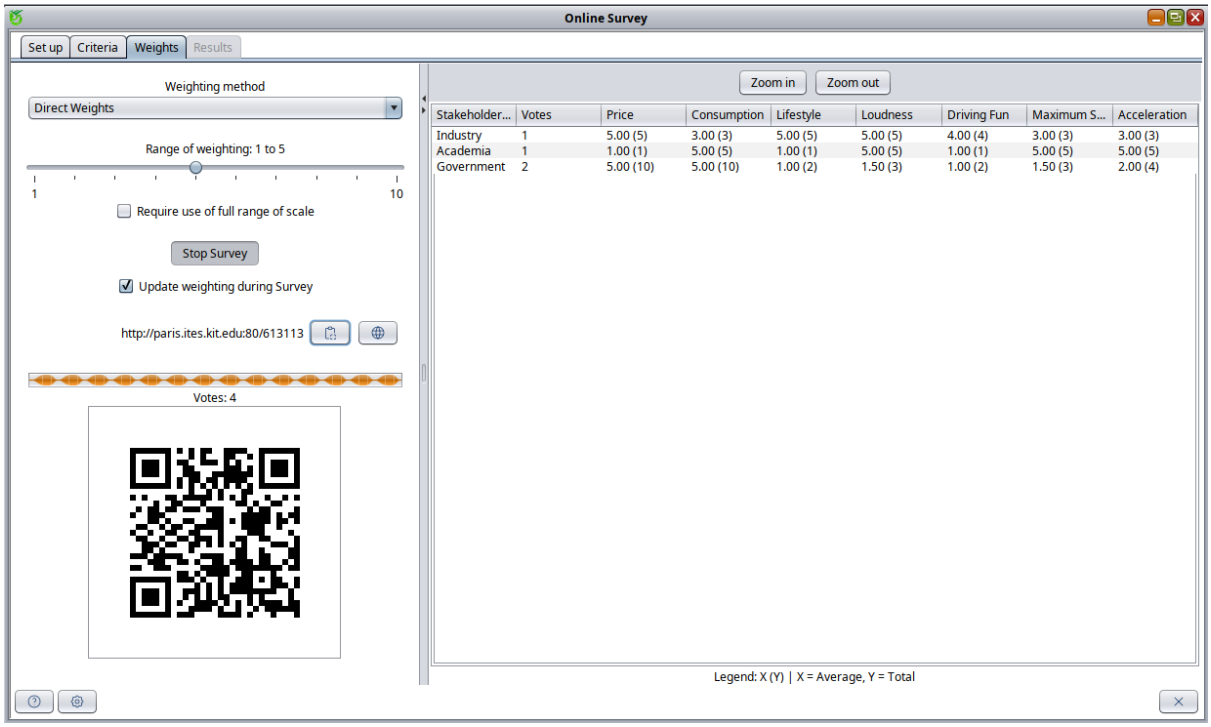

Figure 44: Weights tab of Plugin for online surveys – Completed survey

The **Results tab** is activated when a survey is stopped. Figure 45 shows an example the results of a weights survey. The button “Create histograms” serves to send the weights results to HELDA for further processing of the survey data.

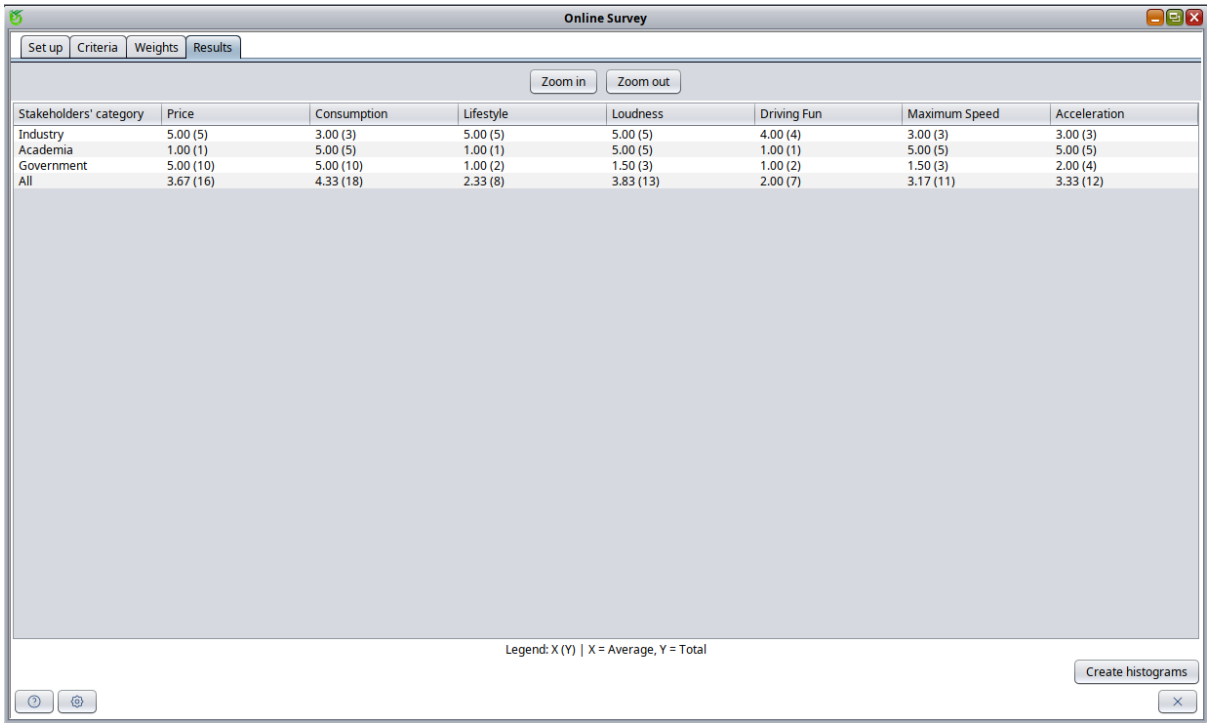

Figure 45: Results tab of Plugin for online surveys

The **Statistics for criteria tab** allows the visualization of distributed frequencies of stakeholders participating in the active criteria survey. User can visualize easily the distribution of participants that submitted responses. Additionally, users can track the distribution of the "votes" given by each stakeholder category on every criterion.

Screenshot will be added soon.

The **Statistics for weights tab** allows the visualization of distributed frequencies of stakeholders participating in the active criteria survey. User can visualize easily the distribution of participants that submitted responses. Further analysis of the data is performed in HELDA after finalizing the survey and creating the histograms in the tab **Results**.

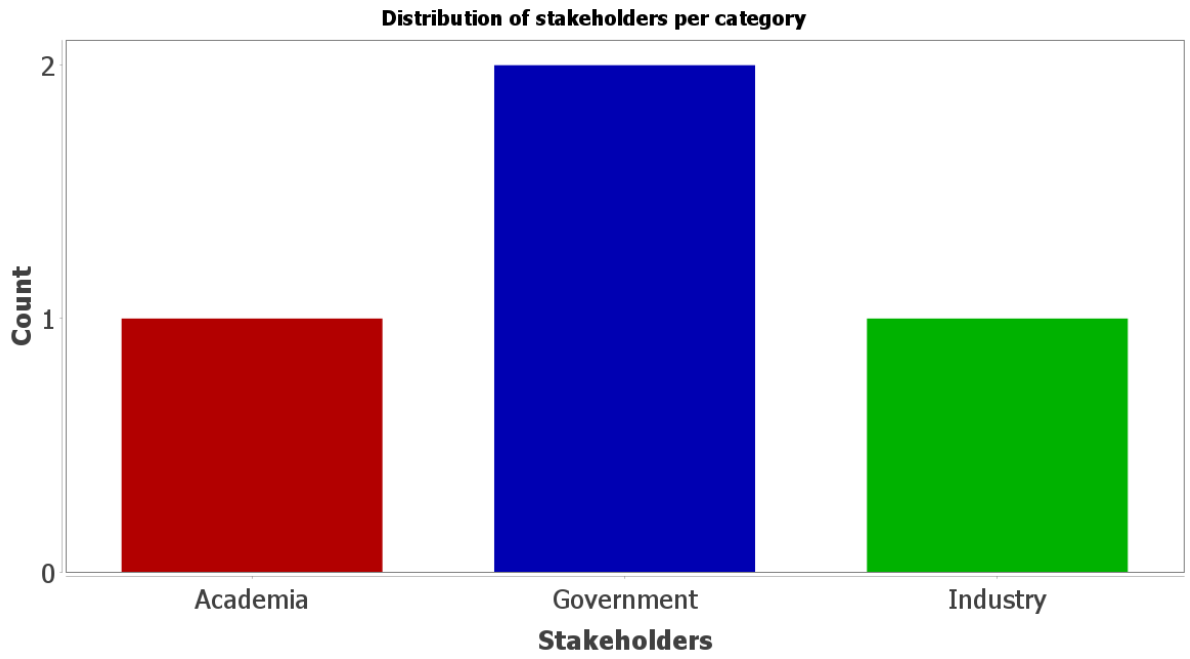

Figure 46: Statistics for weights tab of Plugin for online surveys – Running survey

References

Brans, J.-P.& De Smet, Y. (2016). Promethee methods. In S. Greco, M. Ehrgott, & J. R. Figueira (Eds.), *Multiple criteria decision analysis: State of the art surveys* (pp. 187-219). New York, NY: Springer New York.

Edwards, W. (1977). How to use multiattribute utility measurement for social decisionmaking. *IEEE transactions on systems, man, and cybernetics, 7*(5), 326-340.

Figueira, J.R.,Mousseau, V.& Roy, B. (2016). Electre methods. In S. Greco, M. Ehrgott, & J. R. Figueira (Eds.), *Multiple criteria decision analysis: State of the art surveys* (pp. 155-185). New York, NY: Springer New York.

Figueira, J.R.& Roy, B. (2002). Determining the weights of criteria in the electre type methods with a revised simos' procedure. *Eur. J. Oper. Res., 139*, 317-326.

Greco, S.,Figueira, J.& Ehrgott, M. (2016). *Multiple criteria decision analysis: State of the art surveys* (Vol. 37): Springer.

Kumar, A.,Sah, B.,Singh, A.R.,Deng, Y.,He, X.,Kumar, P.& Bansal, R.C. (2017). A review of multi criteria decision making (mcdm) towards sustainable renewable energy development. *Renewable and Sustainable Energy Reviews, 69*, 596-609. doi:https://doi.org/10.1016/j.rser.2016.11.191

Roy, B.,Figueira, J.R.& Almeida-Dias, J. (2014). Discriminating thresholds as a tool to cope with imperfect knowledge in multiple criteria decision aiding: Theoretical results and practical issues. *Omega, 43*, 9-20. doi:https://doi.org/10.1016/j.omega.2013.05.003

Sarmas, E.,Xidonas, P.& Doukas, H. (2020). *Multicriteria portfolio construction with python*: Springer.