(FRS) FUTURE RESILIENT SYSTEMS 未来韧性系统

PAUL SCHERRER INSTITUT PSI

ETH zürich

MCDA INDEX TOOL

AN INTERACTIVE SOFTWARE TO DEVELOP INDICES AND RANKINGS

User Manual v.1

January 2020

Yiwen Zhang[1], Matteo Spada[2], Marco Cinelli[1,3], Wansub Kim[1], Peter Burgherr[2,*]

[1] *Future Resilient Systems (FRS), Swiss Federal Institute of Technology (ETH) Zürich, Singapore-ETH Centre (SEC), Singapore*

[2] *Paul Scherrer Institut (PSI), Laboratory for Energy Systems Analysis, Villigen PSI, Switzerland*

[3] *Institute of Computing Science, Poznań University of Technology, Poznań, Poland*

[*] *Corresponding author:* email: peter.burgherr@psi.ch

Cite as: Zhang, Y., M. Spada, M. Cinelli, W. Kim, and P. Burgherr (2020). *MCDA Index Tool: An Interactive Software to Develop Indices and Rankings. User Manual.* Future Resilient Systems (FRS), Swiss Federal Institute of Technology (ETH) Zürich, Singapore-ETH Centre (SEC) & Paul Scherrer Institut (PSI), Laboratory for Energy Systems Analysis

CREATE

Campus for Research Excellence And Technological Enterprise

Table of Contents

1. MCDA Index Tool General Information

1.1 Introduction

Multiple Criteria Decision Analysis (MCDA) is a process that supports decision-making by leading the identification/creation of the alternatives, the selection of the evaluation indicators and the comprehensive comparison of these alternatives (with e.g., a ranking, a classification) to work out a decision recommendation (Bouyssou et al. 2006, Cinelli 2017). It is commonly applied to support decision-making when discrete alternatives are compared with respect to multiple indicators. A main family of MCDA methods is represented by composite indicators (CI), or indices (Diaz-Balteiro et al. 2017, El Gibari et al. 2018, Greco et al. 2018), which aggregate the performance of the alternatives and the preferences of the decision makers in a single score, which can then be used to easily rank them.

Until now, there has not been any tool that can support the development of indices by constructing them in a stepwise fashion. This manual describes the *MCDA Index Tool*, which is a web tool consisting of five main steps that guide the analyst in the development of indices starting from data loading, to weighting, normalization, aggregation and ample results visualization, which aid a robustness assessment of the indices/rankings. Each component of the tool is presented in detail in this document. This web tool aims to provide a practical and straightforward guide on the selection of normalization methods and aggregation functions to obtain scores and rankings for the alternatives under interest in a graphical and printout manner. In particular, it is based on a set of steps that can help developing indices by learning and assessing the quality of the outputs. The manual shows how to use this tool to conduct a MCDA on the data under the user interests.

1.2 Overall features

The tool contains 10 different features:

1. Input Data
2. Settings and Weighting
3. Construction of the indices
4. Normalization
5. Results: Indices and rankings
6. Results: Rank Frequency Matrix
7. Results: Scores bar charts
8. Results: Rankings comparisons
9. About
10. Background material.

These features are listed on the left side menu (Figure 1) and briefly described below.

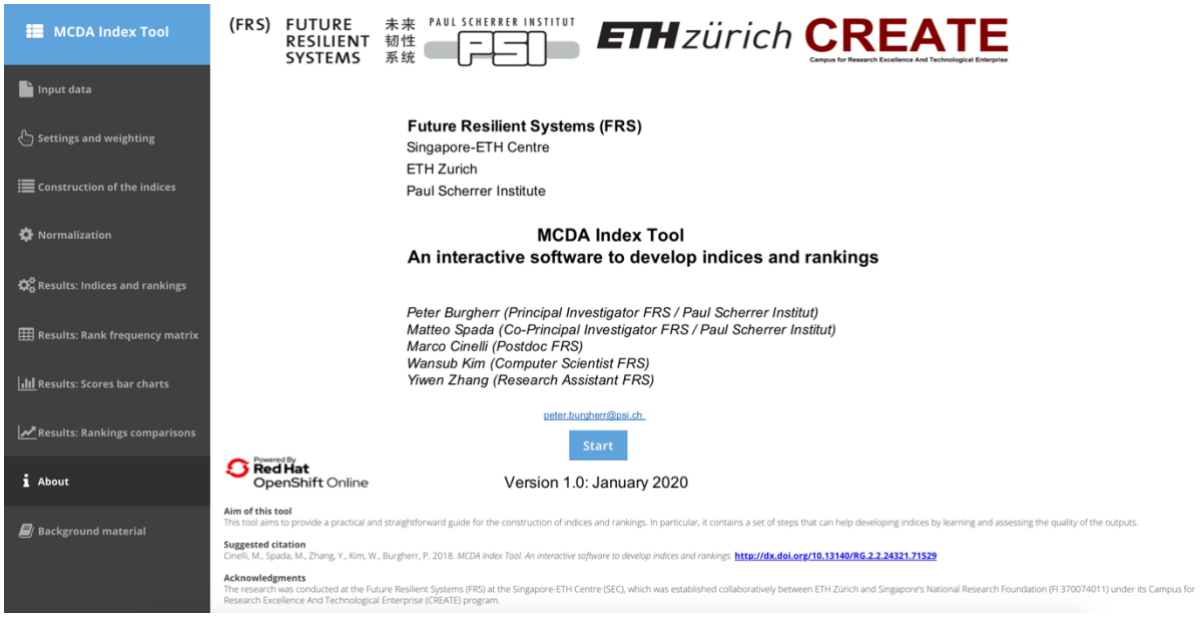

FIGURE 1: OVERVIEW OF THE MCDA INDEX TOOL LAYOUT

Input data: Here, the user can select a CSV (Comma-Separated Values) data file that contains the dataset for the analysis and upload it for later processing. The structure and format of the CSV is discussed in the next section.

Settings and weighting: The polarity and weight for each indicator can be assigned by the user in the setting panel. Besides this, the unit can also be added, if desired.

Construction of the indices: The user can select the normalization methods and aggregation functions to be used for the data processing. After confirming the choices, a combination table is shown in the same page to depict the validity of each combination method.

Normalization: The normalized data values are shown on the tabs for each normalization method selected in the "Construction of the indices" page. The user can skip this section and jump to the results page directly.

Results: Indices and rankings: This page provides the results of the valid normalization + aggregation combinations selected by the user in the "Construction of indices" page.

Results: Rank frequency matrix: The rank frequency matrix table is shown, with the proportion (in %) of indices which rank alternative *x* at the k-th position.

Results: Scores bar charts: After selecting the combinations of normalization + aggregation methods for comparison, the bar charts showing the normalized scores for each combination appear accordingly.

Results: Rankings comparisons: The line graphs of the combination normalization + aggregation for each alternative is shown. The user can select and deselect the combination(s) to be plotted in the legend.

About: This page shows the basic information about the tool, including the team involved in the project.

Background materials: The six tabs present the normalization methods and aggregation functions programmed in the tool, the valid combinations, the swing weighting method, and the reference papers.

2. Steps of the MCDA Index Tool

2.1 Registration and Logging in

The *MCDA Index Tool* is an online tool that can be accessed at the webpage: http://www.mcdaindex.net/. In order to access the tool, a new user should register an account by clicking on "Join us"; a new window will then appear to input the requested information (i.e., name, e-mail, password) for the registration; once registered a confirmation e-mail will be send to the user. After an account has been created, the user can access the tool by logging into it (see Figure 2).

FIGURE 2: MCDA INDEX TOOL LOGIN PAGE

2.2 Tool interface overview

After logging in successfully, the user is redirected to the "About" page, which contains information about the tool and the developing team (see Figure 1). The user should then click on "Start" to begin using the tool.

2.3 Data preparation

Once the "Start" button has been clicked, the tool redirects the user to the "Input data" page. In that page, the dataset to be analysed can be uploaded to the tool in CSV format. If the user is using MS Excel, it is highly recommended to set the data format as "General" to show all the decimals of the actual values before converting the file to CSV. Furthermore, it is important to note that the CSV should be comma-separated and thus the user needs to be sure that this is the default separation character for the operation system (e.g., Windows, Mac OS, Linux, etc.) default language. In fact, for example, the separation for a system default language in German is semi-colon (";", while for English it is comma (",") . Therefore, in the German case, the system preferences need to be updated by the user.

In the CSV file, the format should be of the type as shown for example in Figure 3. The first row consists of the header, which contains in the first column the alternatives type (e.g., countries) and from the second column on, the indicators names (e.g., Electricity as a business constraint, Control of corruption, SAIDI, etc.). From the second row, the actual dataset to be used in the tool needs to be included, where the first column needs to contain the names of the alternative and from the second column on the values of each indicator for the respective alternative. Except for both first row and first column, the rest of the table should be always populated by numbers, as shown in Figure 3.

	A	B	C	D	E	F
1	Scenarios	CO2 emissions world (t CO2 / c	CO2 emissions EU27 (t CO2 / c	Energy expenditure world (USD	Energy expenditure EU 27 (USD	Cumulated number of fatalities
2	BL	5.174693274	9.046484783	0.053781246	0.081594782	2130.104101
3	MT	3.819941762	6.54659621	0.055317007	0.080795715	1617.757387
4	EA	3.536957595	3.307686975	0.056573004	0.097447705	1526.410435
5	FT 1	1.282256789	1.639241254	0.079570971	0.112966867	965.0672657
6	FT 2	1.280740815	2.517729358	0.093384375	0.125402561	926.7994152
7	BL Nuc	5.423476958	9.299701768	0.054682127	0.082691835	2217.621395
8	MT Nuc	4.121992632	6.976895222	0.057415084	0.083879005	1745.846909
9	FT Nuc	1.366859942	3.1118879	0.093384375	0.125402561	1123.362397
10	BL Sh	4.243045567	5.807437935	0.05681289	0.083266607	1806.073246
11	MT Sh	3.279237929	4.626891423	0.058578046	0.082236961	1433.853936
12	EA Sh	3.209852705	3.007257856	0.058493984	0.098722004	1444.153936
13	MT CCS	3.923768666	6.895979719	0.055375334	0.080948148	1596.65294
14	EA CCS	3.672655643	3.7167295	0.056681753	0.098100839	1498.371454
15	FT CCS	1.432841471	2.954240001	0.09578754	0.128844029	635.4888652

FIGURE 3: SAMPLE OF AN INPUT DATASET FOR THE MCDA INDEX TOOL

2.4 Data import

In the "Input data" page, to import the dataset for analysis, the user needs to click "Browse", select the CSV data file and upload the file. After this operation the dataset should be shown in the same page, under the heading "Data" (see Figure 4).

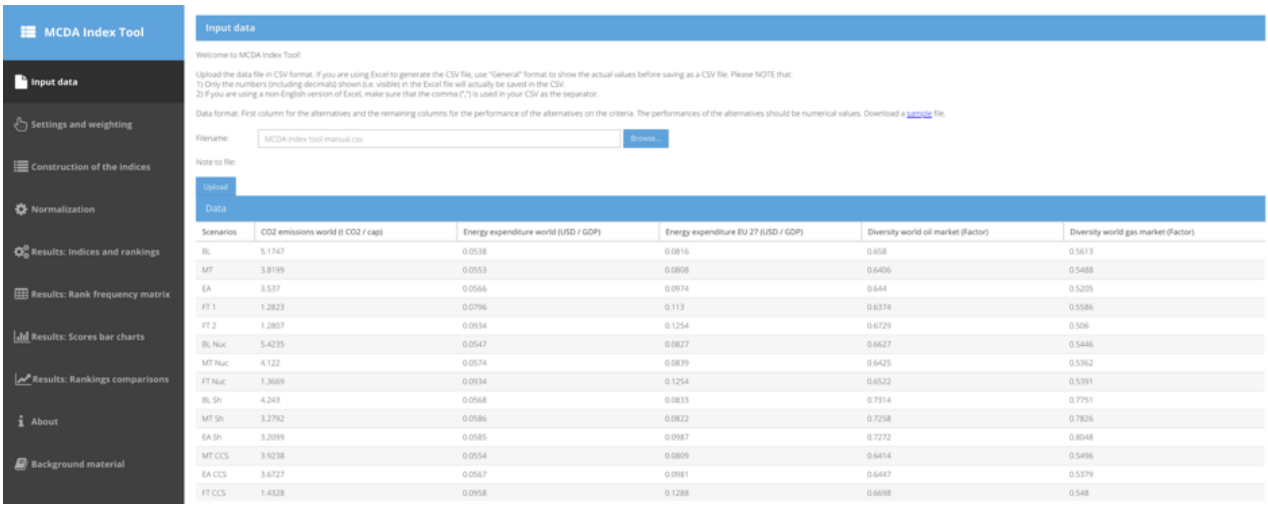

FIGURE 4: IMPORTED DATASET FOR ANALYSIS

2.5 Selection of indicators' settings and weighting

In the "Settings and weighting" page (Figure 5), for each indicator its polarity, unit, and weight can be assigned in the setting panel.

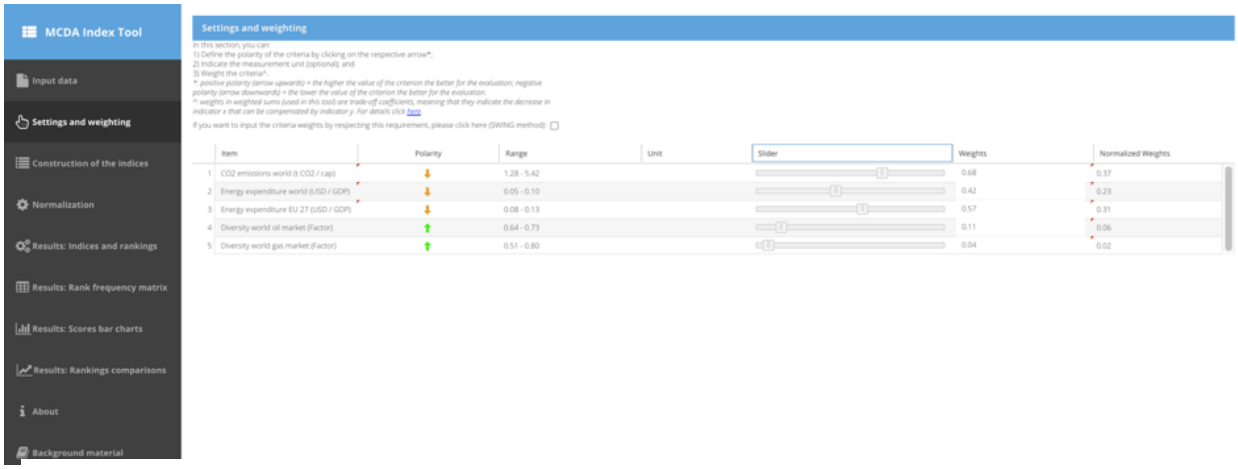

FIGURE 5: SETTINGS AND WEIGHTING PAGE

The user can define the polarity of each indicator by clicking on the respective arrow. A positive polarity (arrow upwards, green color) means the higher the value of the criterion the better for the evaluation, while a negative polarity (arrow downwards, red color) indicates that the lower the value of the criterion the better for the evaluation.

Next, the user can indicate the measurement unit for each indicator. This is not a mandatory field, but its use is recommended. Furthermore, the user can slide the bar to assign indicator weights. The scale of the weights for each indicator is not fixed, but it is automatically normalized by the tool to sum up to 1.0 (see last column of Figure 5). In the Weighted Sum Approach (WSA), the weights are trade-off coefficients, meaning that they indicate, for example, that a decrease in indicator *x* can be compensated by an increase in indicator *y*. The user could also use the so-called SWING method to assign weights (Riabacke et al. 2012). The SWING method consists of a set of three tasks (Figure 6):

- *Task 1*: rank the indicators from the most (at the top) to the least important (at the bottom);
- *Task 2*: select importance level by assigning the highest number of points (e.g., 100) to the most important criterion;
- *Task 3*: assign points to each subsequent criterion to reflect the increase in the overall value for the change from the worst to the best performance on the selected criterion in comparison (%) to the increase from the worst to the best performance of the most important criterion.

Finally, once the weights have been assigned, either manually or using the SWING method, the normalized weights will be automatically calculated in order to keep the sum of the weights equal to 1.

FIGURE 6: EXAMPLE OF THE APPLICATION OF THE SWING METHOD TO THE SAMPLE DATA

2.6 Selection of normalization methods and aggregation functions

In the page "Construction of the indices", the user can select the normalization methods and aggregation functions to be used to build the indices (Figure 7). Normalization methods transform all the indicators on the same scale and make them comparable. There are 8 normalization methods implemented in the tool:

1. Rank;
2. Percentile Rank;
3. Standardized;
4. Minmax;
5. Target;
6. Logistic;
7. Categorical (-1; 0; 1);
8. Categorical (0.1; 0.2; 0.4; 0.6; 0.8; 1).

Aggregation functions integrate all the indicators on the same scale into an index. Five aggregation methods available: Additive, Geometric, Harmonic, Minimum, and Median. The user can select the

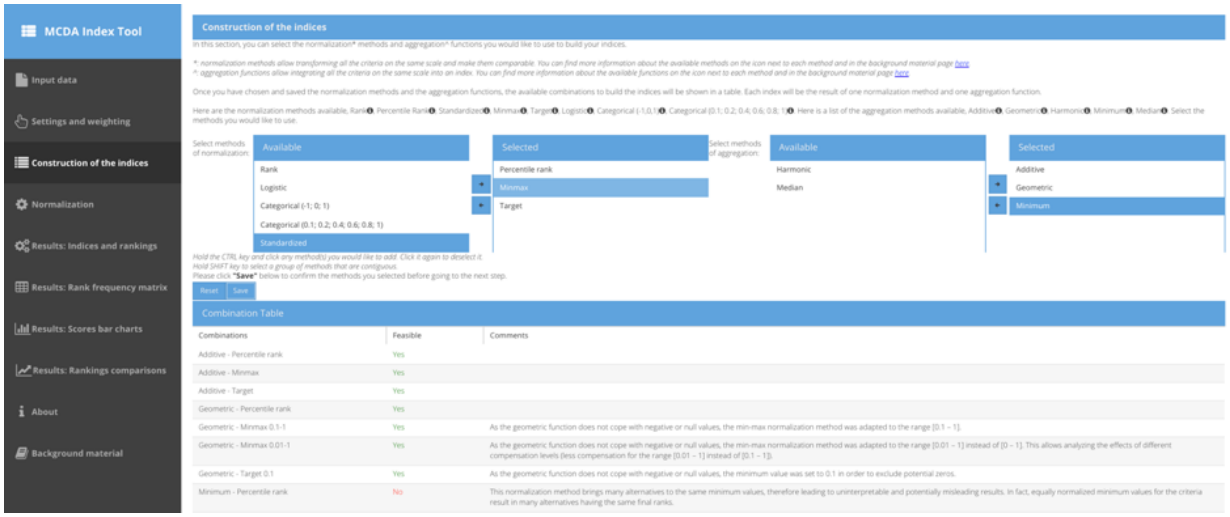

FIGURE 7: SELECTION WINDOW OF THE NORMALIZATION METHODS AND AGGREGATION FUNCTIONS

aggregation functions in the same way as the normalization. For each of the options, the user can find more information on the icon next to the method name or in the “Background material” page.

Once all the methods under interest have been selected, the user should click on the “Save” button to confirm the choices before continuing to next step. At this point, the tool will request through a pop-up window (Figure 8) whether the user is interested to save (by clicking “OK”) or not (by clicking “Cancel”) the original data, the configuration settings and the selected methods in a CSV file (Figure 9).

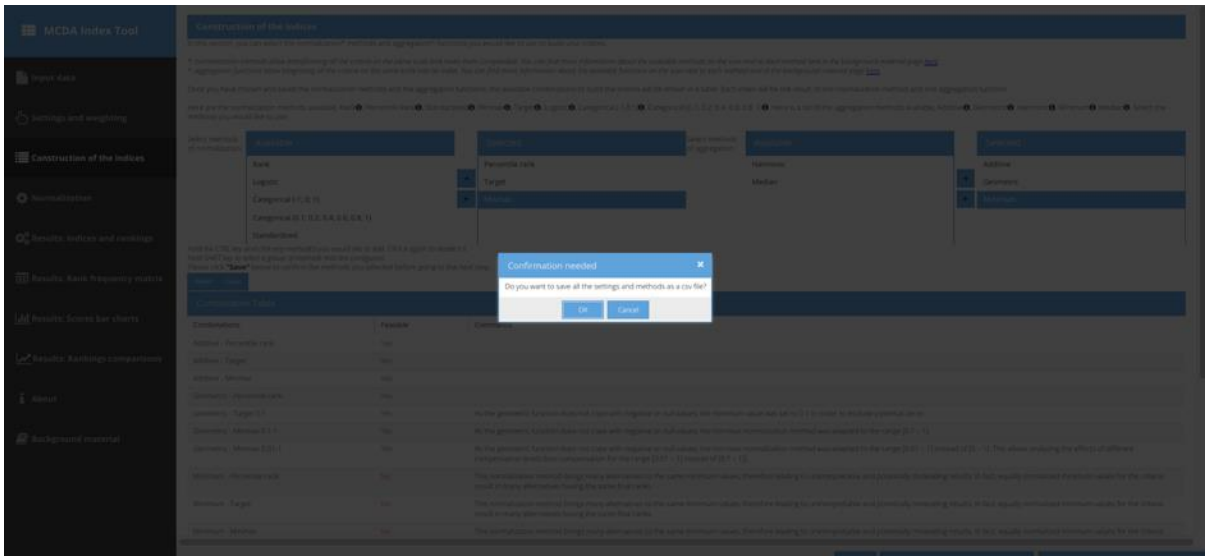

FIGURE 8: CONFIRMATION OF THE NORMALIZATION AND AGGREGATION METHODS FOR THE DATA UNDER INTEREST

This file is used as “restore” point, meaning that the user could upload it at the “Input data” page in order to restore the current analysis. However, it is recommended that this file is not edited by the user because any erroneous modification may result in a non-successful restore process. After the user has confirmed his decision, all the available normalization-aggregation combinations to build the indices are shown in the combination table on the “Construction of the indices page” (Figure 9). Each index is the result of one normalization method and one aggregation function.

	A	B	C	D	E	F
1	Please do NOT edit or update anything if you want to upload this file to restore the settings.					
2	Polarity (True:'Upwards'/False:'Downwards')					
3	Normalizations (1:'Rank'/ 2:'Percentile rank'/ 3:'Standardized'/ 4:'Minmax'/ 5:'Target'/ 6:'Logistic'/ 7:'Categorical (-1;0;1)'/ 8:'Categorical (0.1;0.2;0.4;0.6;0.8;1)')					
4	Aggregations (1:'Additive'/ 2:'Geometric'/ 3:'Harmonic'/ 4:'Minimum'/ 5:'Median')					
5						
6	*configuration = 2 (1 = default weight	Polarity	Range	Unit	Weights	Normalized Weights
7	CO2 emissions world (t CO2 / cap)	FALSE	1.28 - 5.42		0.87	0.37826087
8	Energy expenditure world (USD / GDP	FALSE	0.05 - 0.10		0.67	0.291304348
9	Energy expenditure EU 27 (USD / GDP	FALSE	0.08 - 0.13		0.44	0.191304348
10	Diversity world oil market (Factor)	TRUE	0.64 - 0.73		0.28	0.12173913
11	Diversity world gas market (Factor)	TRUE	0.51 - 0.80		0.04	0.017391304
12	*normalizations	2	5	4		
13	*aggregations	1	2	4		
14	*data=0(0 default)					
15	Scenarios	CO2 emissions world (t CO2 / cap)	Energy expenditure world (USD / G	Energy expenditure EU 27 (USD / G	Diversity world oil market (Factor)	Diversity world gas market (Factor)
16	BL	5.174693274	0.053781246	0.081594782	0.658008224	0.561297191
17	MT	3.819941762	0.055317007	0.080795715	0.640580759	0.548819262
18	EA	3.536957595	0.056573004	0.097447705	0.643998586	0.520451571
19	FT 1	1.282256789	0.079570971	0.112966867	0.637424274	0.558553573
20	FT 2	1.280740815	0.093384375	0.125402561	0.672934495	0.505951367
21	BL Nuc	5.423476958	0.054682127	0.082691835	0.662650524	0.544618291
22	MT Nuc	4.121992632	0.057415084	0.083879005	0.642529767	0.536220945
23	FT Nuc	1.366859942	0.093384375	0.125402561	0.652192724	0.539056567
24	BL Sh	4.243045567	0.05681289	0.083266607	0.731363262	0.77506197
25	MT Sh	3.279237929	0.058578046	0.082236961	0.725820939	0.782645408
26	EA Sh	3.209852705	0.058493984	0.098722004	0.727165452	0.804785033
27	MT CCS	3.923768666	0.055375334	0.080948148	0.641356595	0.549630631
28	EA CCS	3.672655643	0.056681753	0.098100839	0.644697037	0.537930453
29	FT CCS	1.432841471	0.09578754	0.128844029	0.66977586	0.548000151

FIGURE 9: FORMAT OF THE CONFIGURATION CSV FILE

2.7 Normalization output

These tabs show the normalized dataset according to the normalization methods that the user selected (Figure 10). It is possible to directly compare the alternatives with respect to one or several indicators. The user can also save the results by clicking on the button “Save as CSV” at the bottom of the page.

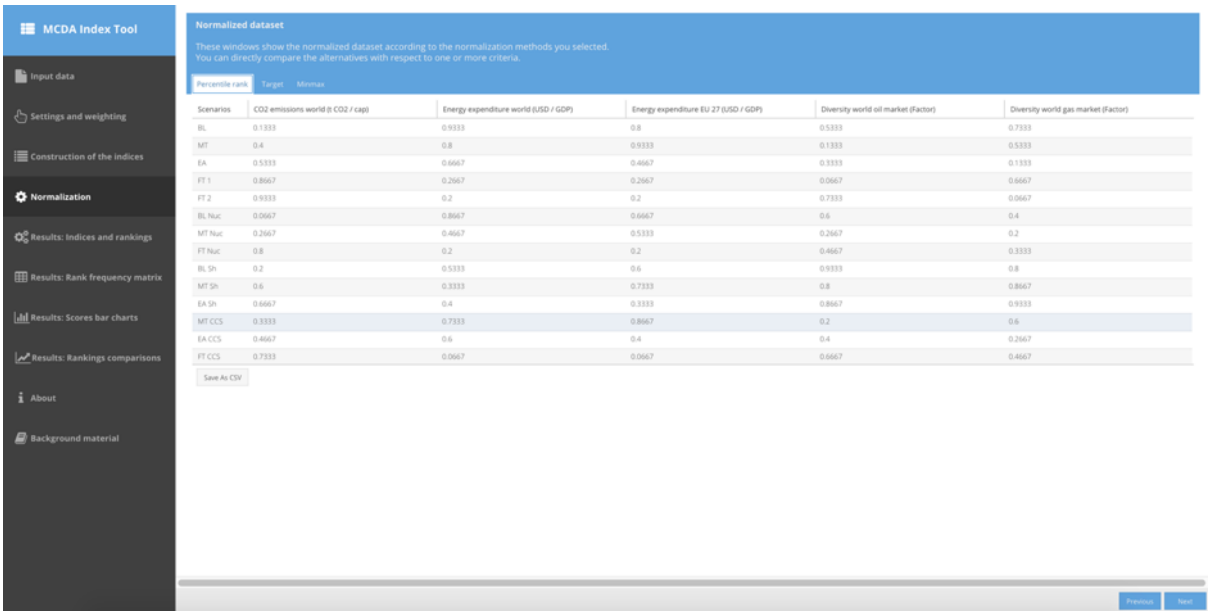

FIGURE 10: RESULTS OF THE DATASET NORMALIZATION. EACH TABLE CORRESPONDS TO ONE OF THE SELECTED NORMALIZATION METHODS

2.8 Results: Indices and rankings

These panels show the raw scores of the indices, their normalized scores and the rankings for each of the previously selected normalization-aggregation combinations (Figure 11). The user can directly compare the alternatives with the latter two tabs. The user can also save the results by clicking on the button “Save as CSV” at the bottom of the page.

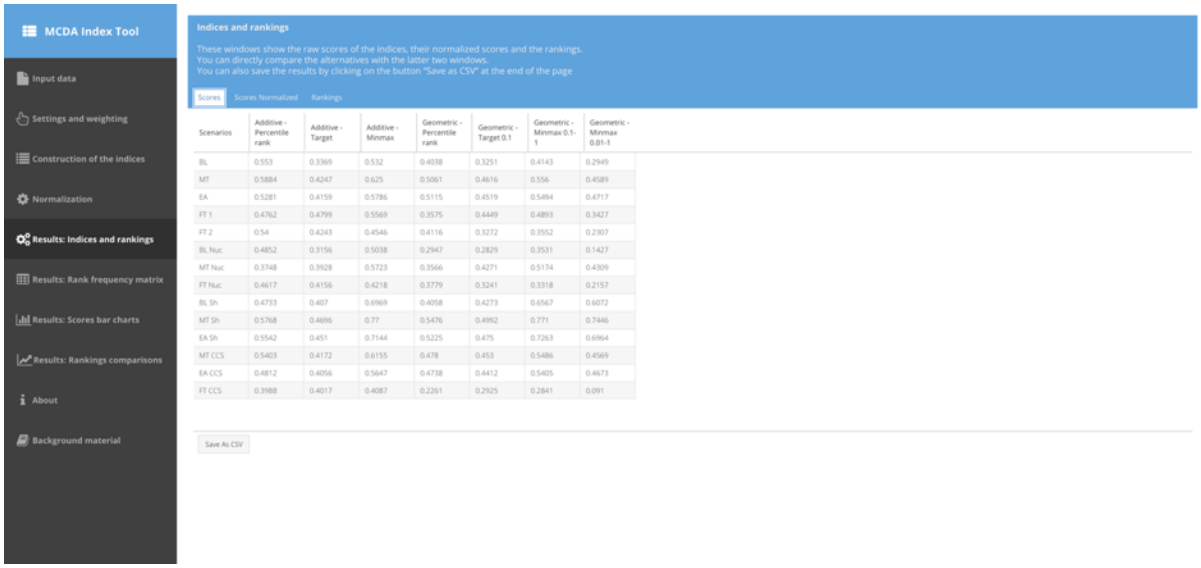

FIGURE 11: RESULTS OF THE AGGREGATION METHODS. THE FIRST TABLE INCLUDES THE RAW SCORES, THE SECOND SHOWS THE NORMALIZED SCORES AND THAT LAST TABLE PRESENTS THE RANKINGS ACCORDING TO EACH COMBINATION.

2.9 Display frequency matrix (tooltip for each frequency value)

In this page, the rank frequency matrix is displayed. This plot shows the proportion (in %) of the combinations in each rank position (Figure 12). It is the number of the combinations that lead to that specific rank divided by the total number of the combinations. The user can move the cursor on the number in each box to learn which combination(s) rank the alternative under interest at that position, as example see the yellow box in Figure 12.

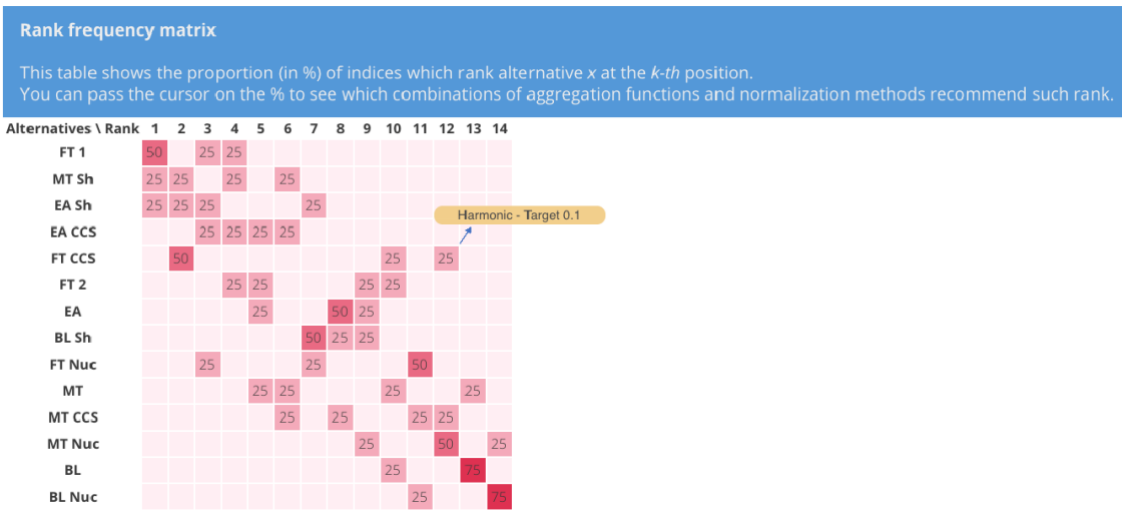

FIGURE 12: EXAMPLE OF RANK FREQUENCY RESULTS

2.10 Display bar graph (combo box to compare normalizations or aggregations)

This page shows the bar graph comparing the indices according to the selected normalization methods or aggregation functions (Figure 13).

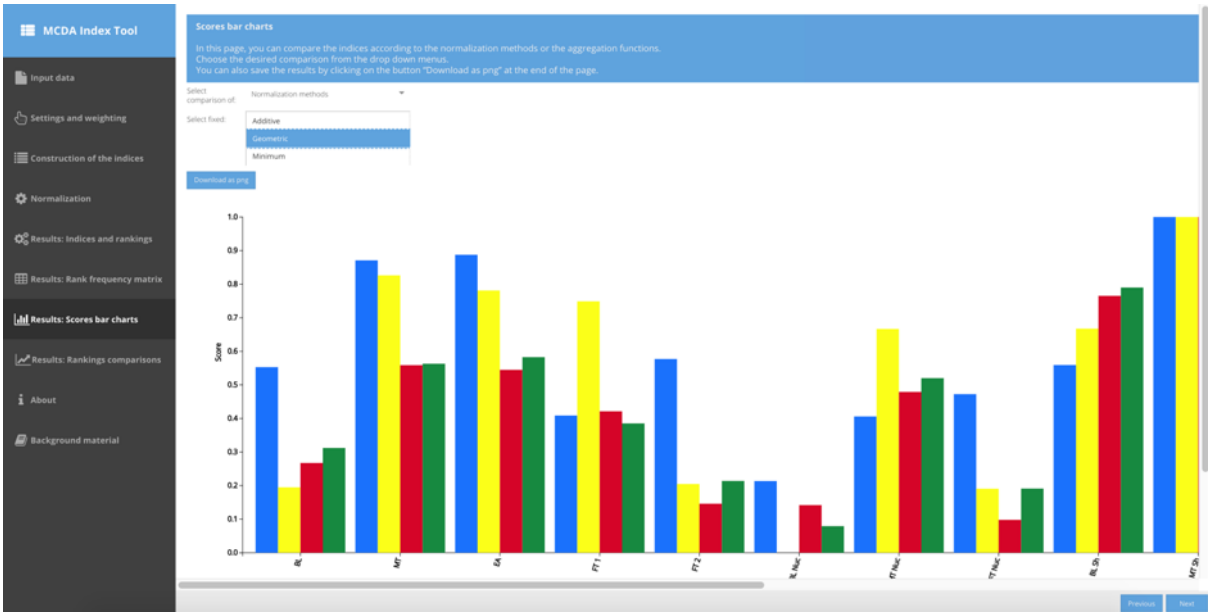

FIGURE 13: EXAMPLE OF BAR CHARTS FOR THE NORMALIZATION METHODS AND ADDITIVE AGGREGATION FUNCTION

In the drop down list, the user can select either “Normalization methods comparison” or “Aggregation methods comparison”. If the user selects “Normalization methods comparison”, then one aggregation

method should be selected from the second drop down list in the “Select fixed” option (Figure 13). On the contrary, if the user selects “Aggregation methods comparison”, then one normalization method should be selected.

2.11 Display line graph (checkbox to turn on/off each line)

In this section, the line graph is displayed according to the rankings of the feasible combinations (Figure 14). The alternatives are listed in an increasing order of expected rank based on all the ranks in all the combination ranks. The user can choose to show a specific line (i.e. combination) or not by selecting or deselecting the checkbox in the legend.

FIGURE 14: RANKING OF EACH ALTERNATIVE FOR ANY ALTERNATIVE FOR ONE OF THE FEASIBLE COMBINATIONS NORMALIZATION + AGGREGATION

2.12 Supplementary pages (explanations for MCDA methods)

In the Background Materials page, five tabs with the background information are present (Figure 15). These tabs include the descriptions of the implemented methods and other practical information for the user:

1. Normalization methods;
2. Aggregation functions;
3. The feasible combinations among 1. and 2.;
4. The SWING weighting method;
5. The reference papers for the tool.

The user can check them in detail by clicking on each of them.

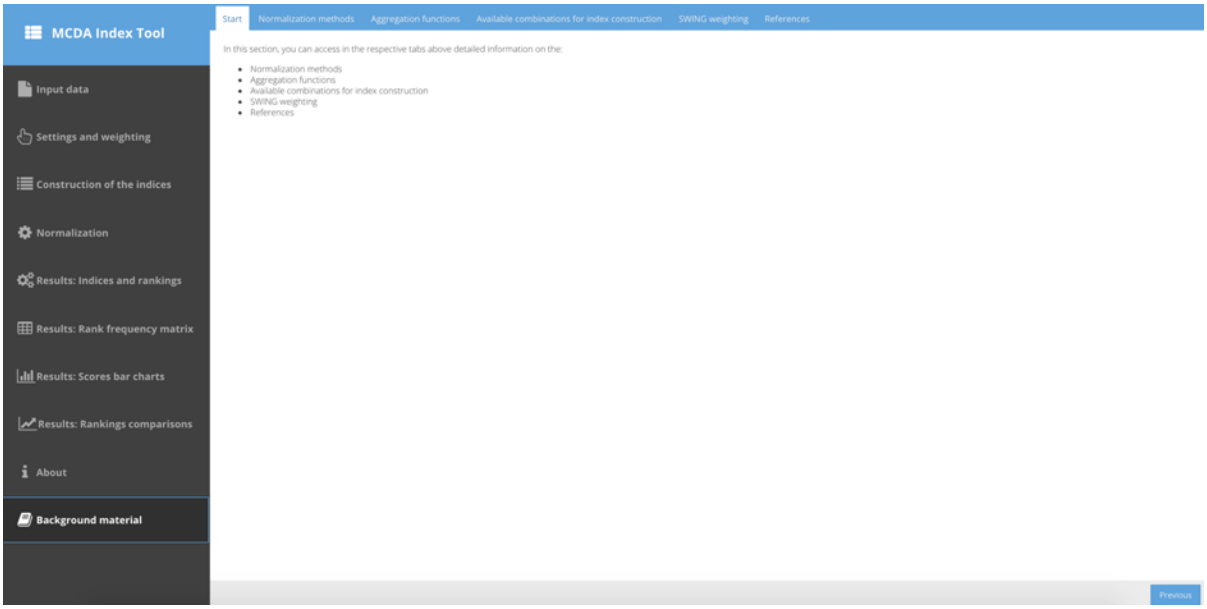

FIGURE 15: BACKGROUND MATERIALS PAGE INCLUDING SIX TABS

References

Bouyssou, D., T. Marchant, M. Pirlot, A. Tsoukiàs, and P. Vincke. 2006. Problem Formulation and Structuring: The Decision Aiding Process. Pages 19-65 Evaluation and Decision Models with Multiple Criteria: Stepping stones for the analyst. Springer US, Boston, MA.

Cinelli, M. 2017. The Art of Supporting Decision-Making. Exchanges: the Warwick Research Journal **4**:298-308.

Diaz-Balteiro, L., J. González-Pachón, and C. Romero. 2017. Measuring systems sustainability with multi-criteria methods: A critical review. European Journal of Operational Research **258**:607-616.

El Gibari, S., T. Gómez, and F. Ruiz. 2018. Building composite indicators using multicriteria methods: a review. Journal of Business Economics **https://doi.org/10.1007/s11573-018-0902-z**.

Greco, S., A. Ishizaka, M. Tasiou, and G. Torrisi. 2018. On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness. Social Indicators Research **https://doi.org/10.1007/s11205-017-1832-9**:1-34.

Riabacke, M., M. Danielson, and L. Ekenberg. 2012. State-of-the-Art Prescriptive Criteria Weight Elicitation. Advances in Decision Sciences **2012**:24.