REPORT

# SURE MCDA DECISION SUPPORT SYSTEM: OVERVIEW AND TECHNICAL DESCRIPTION

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# SURE MCDA DECISION SUPPORT SYSTEM: OVERVIEW AND TECHNICAL DESCRIPTION

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# SWEET Call 1-2020: SURE

# Deliverable report

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## Table of contents



sweet swiss energy research for the energy transition

SURE

## List of Figures



## List of Tables

## List of Abbreviations

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| BWM | Best Worst Method |
| DM | Decision Maker |
| DSS | Decision Support System |
| ELECTRE | ÉLimination Et Choix Traduisant la REalité |
| EVAMIX | Evaluation Matrix |
| GDM | Group Decision Making |
| MAVT | Multi-Attribute Value Theory |
| MCDA | Multi-Criteria Decision Analysis |
| PROMETHEE | Preference Ranking Organization METHod for Enrichment of Evaluations |
| PSI | Paul Scherrer Institut |
| SMART | Simple Multi-Attribute Rating Technique |
| SMARTS | Simple Multi-Attribute Rating Technique using Swings |
| SMARTER | Simple Multi-Attribute Rating Technique Exploiting Ranks |
| SRF | Simos-Roy-Figueira method |
| SURE | SUstainable and Resilient Energy for Switzerland |
| TODIM | Interactive and Multicriteria Decision Making |
| TOPSIS | Technique for Order of Preference by Similarity to Ideal Solution |
| VIKOR | VIseKriterijumska Optimizacija I Kompromisno Resenje |

## Executive Summary

**The Challenge:** Achieving net-zero by 2050 means Swiss policymakers face some critical decisions. Every pathway involves trade-offs, e.g., balancing GHG emissions with other environmental impacts, energy security with land use, costs today with future climate targets, etc. Furthermore, there are questions of resilience linked to geopolitical tensions, more frequent and extreme weather events, and other factors. Analytical tools and reports often either hide these trade-offs or discuss only which factors and assumptions may matter most. This makes it really hard to have transparent, honest discussions with stakeholders about difficult choices. Different groups have different preferences and priorities, and without a transparent process to compare options, finding a broadly acceptable solution or even consensus remains a huge challenge.

**The Solution:** The modular, web-based platform developed in SURE helps stakeholders and decision-makers work through this process together and identify consensual solutions. It can be considered a structured *conversation* tool that translates complex results from energy systems and other models into clear comparisons. It makes trade-offs visible, fosters discussions about what matters most, and how a pathway's resilience is affected by diverse shock events. However, the process does not aim to propose a single, optimal solution. Instead, it methodically unveils and organises the options available to decision-makers, highlighting how individuals with divergent values can identify shared objectives and formulate a pragmatic, actionable plan for the future.

**How it works:** The users are guided through four straightforward steps.

- First, one has to select the pathways to compare, along with potential shocks (disruptive events, for example, financial or social shocks, extreme weather). The Decision Support System (DSS) directly connects to the SURE database, from which it receives curated indicator data from the various models used in the project.

- Second, one must define the criteria that matter in the given context and decision. The tool also provides a default criteria set established in several stakeholder workshops, which covers 20 criteria equally distributed across the three sustainability (environment, economy, society) and resilience dimensions. Third, stakeholders' preferences are systematically and consistently elicited. This prioritization results in a set of weights for the chosen criteria. It is carried out using gamified approaches such as card-sorting exercises, where criteria cards are arranged from least to most important, or simple Eurovision-style voting, where the three most important criteria are selected for each dimension. Despite its deceptive simplicity, it relieves stakeholders of the mathematical operations that run in the background. Instead, it focuses on identifying disagreements within a group and encouraging discussions about values, something that spreadsheets or more complex representations could never achieve.

- Finally, the results can be explored in detail. The MCDA calculator can analyze selected pathways and shocks against selected criteria and preferences using numerous analytical methods (including state-of-the-art approaches such as PROMETHEE, TOPSIS, and VIKOR, and assess how each pathway performs under shocks. More importantly, it enables testing of the consequences of changing assumptions. For example, the weights may be uncertain, or the indicator values may have uncertainty ranges. The Scenario Analyzer addresses these types of questions and shows which recommendations are robust and which change depending on choices or uncertainty in the data.

**Three integrated tools:** The SURE DSS is organized into three modules that work together seamlessly. The MCDA Calculator is already live at https://mcda-calculator.psi.ch/. It is designed so that users (including workshop participants) can adjust parameters on the fly and see results update immediately. There is no need to be a modeling expert because the interface guides you through the process, and you can switch between different analytical methods with a single click to cross-check the effects on the

results and conclusions. In Weight Elicitor, stakeholders assign their importance preferences to quantitative and qualitative criteria. It has been tested in real workshops with Swiss stakeholders using the card-sorting module for smaller groups and the voting module for larger ones. The Scenario Analyzer answers *what-if* questions that keep stakeholders and decision makers up at night. It systematically tests variations using Monte Carlo simulations to explore different weights, different assumptions, data uncertainty, and various shocks to identify how robust each pathway performs. For example, it shows how much weights can shift before conclusions and recommendations change. This is crucial when one is making decisions with time horizons of 20 to 30 years.

**Real-world use:** The tools have been applied in SURE stakeholder workshops to test their practical functionality. In one workshop, participants used the card-ranking method to assess future risk scenarios for evaluating Swiss energy pathways. The voting tool was also deployed, using both paper ballots and live online surveys to capture group preferences on criteria importance. These initial applications helped us refine the interface and identify what works in real group settings. For example, things like how to explain the card-ranking exercise clearly, or how much time groups actually need to discuss weights before voting. The feedback loop between workshop testing and tool development has been valuable for making the DSS-platform more understandable and practical, which ultimately is a prerequisite to achieve trust in the generated results, conclusions, and recommendations. The outcomes of both analyst-focused evaluations and stakeholder-driven approaches can be used in subsequent analysis and documentation. Finally, the DSS maintains full traceability and reproducibility, meaning that every calculation can be traced back to its input data, parameter choices, and preferences, which is important for accountability in research and policy contexts.

**Why this matters:** The use of world-class energy system models in Switzerland has a long tradition. However, there has always been a gap between sophisticated technical analysis and practical decision-making: models provide data, not decisions. The SURE DSS aims to bridge that gap by making trade-offs explicit and values transparent. It shifts discussions from «What does the model say?» to «What do we value, how do pathways reflect those values, and react to external disturbances?» This creates a common foundation for informed and democratic decision-making, especially on complex and controversial topics such as the energy transition. The robustness assessment is equally important because every model involves assumptions, and the future is inherently uncertain. Rather than pretending to know the future or making predictions, this approach acknowledges uncertainty and identifies pathways that work across multiple plausible futures, allowing for building resilience into long-term strategy.

**The way ahead:** The MCDA Calculator is fully operational, and we are actively developing the other software modules. The modular architecture means we can keep adding capabilities, including new criteria, new analytical methods, and new visualization tools, without disrupting existing workflows. The approach is replicable and scalable beyond Switzerland, as the energy transition worldwide faces similar challenges, including balancing multiple objectives, engaging diverse stakeholders, and making decisions under uncertainty. Ultimately, it helps address the core tension between rigorous technical analysis and stakeholder-driven deliberation.

# 1 Introduction

Switzerland's route to net-zero must be designed with several emerging risks in mind, including geopolitical tensions, supply-chain volatility, and climate-driven extreme events. In this context, scenarios are not just narratives but instruments for evaluating strategies and exposing trade-offs between security of supply, affordability, environmental performance, and social acceptance (Vögele et al., 2023). Their value depends on converting modelled evidence into actionable choices. This is precisely where Multi-Criteria Decision Analysis (MCDA) and an interactive Decision Support System (DSS) strengthen the SURE modeling framework. MCDA makes value judgements explicit and comparable across heterogeneous indicators, while the DSS turns those judgements into a transparent, repeatable, and personalized process for analysis and discussion with stakeholders (Cinelli et al., 2022).

SURE's modelling toolbox delivers harmonized evidence-based pathways, quantified by multiple models at national and sub-national scales and expressed through a consistent set of indicators. MCDA transforms this heterogeneous evidence into decision-relevant insight by structuring alternatives (pathway/shock combinations) against clearly defined criteria, capturing stakeholder preferences as weights, and aggregating indicators with different directions and units into comparable performance measures (Neofytou et al., 2019). Just as importantly, MCDA supports group reasoning: it helps stakeholders articulate priorities, examine trade-offs, and evaluate robustness, which is an essential ingredient for legitimacy in contested policy choices (Siskos et al., 2025).

Task 1.4 operationalizes this evaluation step through a web-based DSS that connects directly to the Task 1.1 data backbone and implements the MCDA framework, developed in Task 1.2 and reported in D1.1. The system is intentionally modular and centered on three core building blocks that compose a coherent, workshop-ready workflow. First, the Weight Elicitor captures stakeholder preferences and converts them into justifiable weight vectors. The tool is designed with guided elicitation for pairwise comparisons and ranking-based inputs with consistency checks. Second, the MCDA Calculator consists of a multi-method kernel, e.g., including SMART(Olson, 1996) , TOPSIS (Behzadian et al., 2012), PROMETHEE (Brans & De Smet, 2016), and VIKOR (Mardani et al., 2016), and offers guidance and the tools needed to apply the most suitable MCDA method in each decision problem at hand through a uniform scheme that computes scores of alternatives(Huang & Burgherr, 2024). This design allows users to iterate quickly by adjusting criteria parameters or weights and switching methods without re-importing data, which is essential in facilitated sessions. Finally, the Scenario Analyzer closes the loop by treating scenarios explicitly under uncertainty. It provides sensitivity and robustness analyses on top of the computed rankings, including one-at-a-time weight variation, threshold/interval stability checks, and Monte-Carlo style exploration to quantify how conclusions shift under plausible changes in preferences and data. In other words, while the Weight Elicitor and MCDA Calculator translate evidence and values into an ordered set of choices, the Scenario Analyzer tests the stability of those choices, highlighting which decisions are robust and to what degree, and which decisions are highly sensitive depending on some uncertain assumptions or future scenarios.

The remainder of this deliverable explains how MCDA is put into practice within the DSS and why this matters for SURE's pathways and shocks evaluations. It then introduces the SURE MCDA DSS, covering the modular architecture and shared data backbone, followed by concise descriptions of the three core modules: Weight Elicitor, MCDA Calculator, and Scenario Analyzer. It also introduces how these modules work together in a workshop-ready flow. We briefly illustrate data handling, showcase a didactic example, summarize the current implementation status, and close with next steps and practical guidance.

## 2 MCDA operated by the DSS

Evaluating Switzerland's energy pathways is intrinsically a multi-objective problem, as also shown in Task 1.3. Every pathway and its shock-stressed variants perform differently across environmental, techno-economic, social acceptance, and resilience dimensions. These dimensions are measured by heterogeneous indicators with different units, scales, and desired directions, often with conflicting objectives (e.g., cost vs. resilience, land use vs. decarbonization speed). Any attempt to collapse this complexity into a single metric risks obscuring trade-offs, embedding implicit value judgments, and undermining legitimacy. This can be addressed with an MCDA approach as it:

- Structures the problem explicitly as alternatives and criteria, aligning SURE's pathways (with/without shocks) to a transparent indicator system.
- Makes values explicit by representing stakeholder priorities as weights (and, where relevant, preference functions/thresholds), rather than leaving them implicit in the modelling pipeline.
- Enables commensurability without distortion, via normalization and preference modelling that respect indicator polarity (benefit vs. cost) and scale.
- Handles disagreement and plurality, accommodating group decision-making: different stakeholder weight sets can be compared, aggregated, or analyzed for consensus and divergence.
- Supports method pluralism and cross-validation, where various perspectives reveal when conclusions are robust to the choice of decision rule.
- Evaluates robustness under uncertainty, linking seamlessly to scenario analysis (shock vs. no-shock) and to sensitivity around weights and indicator variability.

For SURE, MCDA is the evaluation core that converts model outputs and indicator facts into decision-relevant evidence with traceable value judgments (Greco et al., 2016). It provides the formal backbone for discussing trade-offs, preferred pathways under different priorities, and the stability of recommendations.

While MCDA provides the methodology, applying it credibly at project scale and in participatory settings requires more than formulas. Analysts and stakeholders must retrieve and verify data, specify preferences, run multiple methods, test sensitivity in a way that is fast, transparent, and repeatable. Spreadsheets or ad-hoc scripts struggle to meet these demands during workshops or iterative policy dialogues. A Decision Support System (DSS) is therefore essential. It operationalizes MCDA by providing an integrated environment. An MCDA DSS is a software platform that operationalizes MCDA end-to-end, turning decision-makers (DMs) preferences into transparent, reproducible recommendations (Razmak & Aouni, 2015). Whereas MCDA is the methodology for comparing alternatives across multiple, often conflicting criteria, a DSS is the practical environment that makes this methodology usable in real settings by connecting to data, guiding users through preference elicitation, running one or more MCDA methods, and exposing results, sensitivity in an integrated workflow (Giove et al., 2009).

A typical MCDA DSS follows the logic of the decision process from problem structuring through model building to the critical examination of results (Belton & Stewart, 2010). In the first stage, the system helps users articulate goals, stakeholders, alternatives, criteria, and contextual uncertainties, often through templates or guided prompts and with channels to collect inputs from multiple actors. In the second stage, it streamlines model construction by importing structured data, usually an alternatives-by-criteria matrix, supporting weight elicitation beyond raw numeric entry, and exposing one or more MCDA methods. In the third stage, it enables "challenging thinking" by coupling visual analytics with export functions for audit and further analysis, and by embedding sensitivity and robustness tools that vary weights, probe stability thresholds, or explore scenarios. Also, some DSS enable the involvement of multiple DMs to participate in group decision-making (GDM) (Huang et al., 2025).

# 3 Proposing and designing the modularized MCDA DSS

Most available MCDA DSSs are effectively single-method systems (Huang & Burgherr, 2024). They wrap one MCDA paradigm and optimize the interface around that choice. This creates two practical problems. Specifically, it requires the analyst to become proficient in a dedicated DSS for every distinct MCDA method. If they wish to apply a different method, they must again learn a new system, resulting in a steep learning curve. Moreover, existing DSSs are often designed independently and lack consistency in structure and terminology, making it difficult for users to cross-check or compare results across different MCDA methods within a unified workflow. As a result, users cannot systematically control or document decisions made at each step, and sensitivity/robustness exploration is shallow or ad hoc.

Therefore, in this project, we propose to develop a modularized DSS in which the different steps of the decision process operate as separate modules, as illustrated in Figure 1. The SURE MCDA DSS is a modular, web-based platform that turns model outputs and DM values into transparent, robustness-tested recommendations. It orchestrates three specialized modules: Weight Elicitor, MCDA Calculator, and Scenario Analyzer, which are connected to the SURE Database. At the data layer, the SURE Database provides two streams. It provides DMs references for subjective judgment in the weight elicitation, helping them to identify trade-offs and the relative importance of indicators. On the other hand, it provides the quantitative alternatives × criteria matrix for selected pathway/shock combinations and years. Because every module pulls from the same repository, semantics and numbers stay aligned and fully traceable.

The Weight Elicitor is the entry point for preference modelling. It helps DMs elicit criteria weights using several elicitation modes, including the Simos–Roy–Figueira (SRF) method suite, and pairwise-comparison tool for methods such as the Analytic Hierarchy Process (AHP) (Vaidya & Kumar, 2006) and the Best-Worst Method (BWM) (Rezaei, 2015). These two are separated because they adopt different weight elicitation philosophies, and the meaning of "weight" differs between them, so they cannot be combined. Furthermore, when multiple DMs are involved, as in the SURE stakeholder workshops, we designed a voting tool that allows participants to collectively express the importance of each criterion. The aggregated votes are then used to derive a set of final weights that reflect the group's shared preferences. The output of Weight Elicitor tools is a validated, normalized weight vector (with an optional imprecise weight-feasible space considering uncertainty) that flows downstream unchanged regardless of the MCDA method later chosen.

The MCDA Calculator is a preference elicitation tool that includes various MCDA methods. Using the indicator performance matrix from the database and the weight vector from the Weight Elicitor, it computes rankings for multiple methods, such as PROMETHEE, TOPSIS, and VIKOR, through a single, consistent workflow. Method-specific parameters, e.g., preference functions and thresholds for PROMETHEE, are exposed where relevant, without requiring the data and weights to be re-entered. The calculator returns a results object comprising scores and ranks.

The Scenario Analyzer completes the loop by turning a single evaluation into insight under uncertainty. It ingests the calculator's results and the underlying data/weights to deliver rich visualizations, sensitivity analysis, and robustness analysis across shock scenarios. This shows when a preferred pathway is robust and when conclusions hinge on contested assumptions.

The benefits of this architecture are threefold: a single, unified workflow for diverse MCDA methods, fine-tuning at each stage through dedicated modules, and end-to-end provenance that makes every recommendation auditable and easy to reproduce across national and cantonal/sectoral case studies.

At this stage, the MCDA Calculator is the first production-ready component of the DSS. The Weight Elicitor is in active development, with two modules: the modularized SRF software and a pairwise-comparison tool currently being implemented. The Scenario Analyzer will follow in the next development cycle. In the next subsection, we first present the core of the DSS, the MCDA Calculator, and then provide a concise status update on the two Weight Elicitor tools. Finally, we discuss the prototype of the Scenario Analyzer.

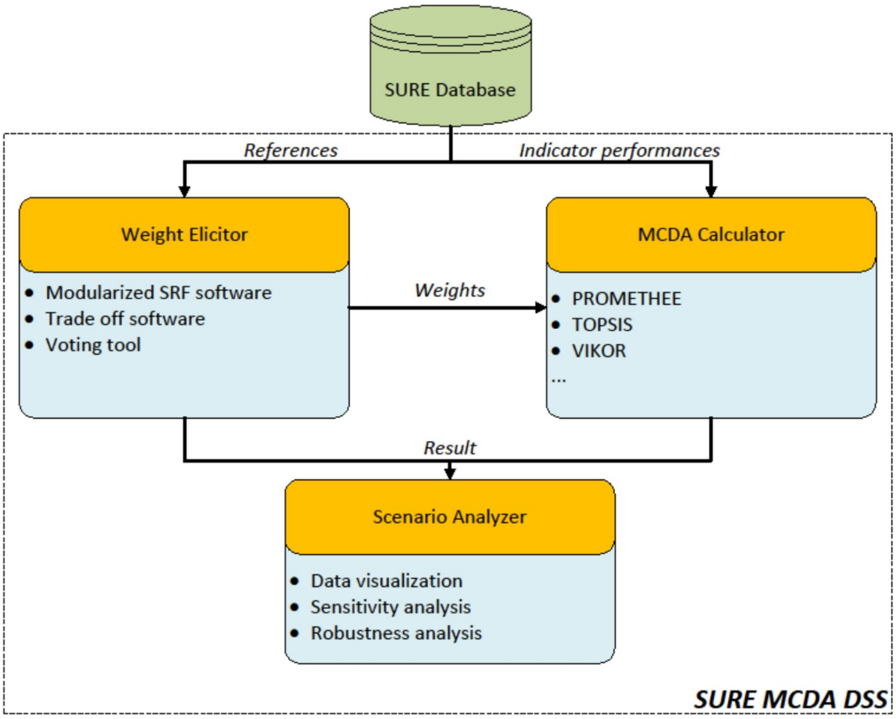



Figure 1 Workflow of the SURE MCDA DSS. Three main tools are being developed. They are interconnected and allow data exchange.

### 3.1 MCDA Calculator

The MCDA Calculator (See Figure 2) is a web-based computation kernel that consolidates several ranking-oriented MCDA methods into a single, coherent framework. It was designed to reduce two recurrent frictions in practice: fragmentation across single-method tools that force analysts to switch platforms to triangulate conclusions, and slow, step-wise wizards that burden experienced users who need to iterate rapidly in meetings and workshops. The Calculator's central idea is that many widely used methods can share a single interaction pattern without sacrificing their method-specific parameters. It therefore provides a unified computational surface while remaining faithful to each method's logic and diagnostics. Technically, the Calculator is implemented in Dash (Python) and deployed as a single-page web application. The one-page design ensures that the entire path, from data import to result export, occurs within a single, cohesive view, which is especially valuable in facilitated workshops.

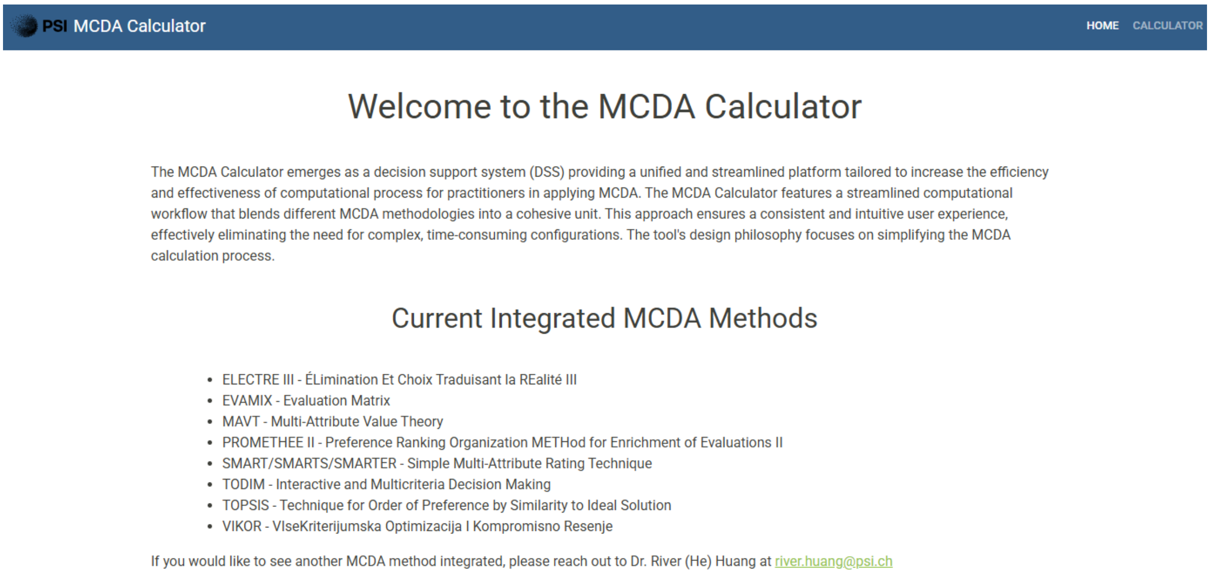



Figure 2 The homepage screenshot of MCDA Calculator (https://mcda-calculator.psi.ch/). It is hosted under the high-security PSI server.

The Calculator targets problems in which the objective is a full ranking of alternatives; the sets of alternatives and criteria are predetermined; and the aggregation of multiple criteria proceeds through scoring or outranking functions. More information on the theoretical foundations of MCDA and the mathematical representation of an MCDA problem can be found in D1.1. Within this scope, we identify a set of popular MCDA methods that can be integrated into the consistent computational treatment across paradigms. These methods are as follows

- ELECTRE III - ÉLimination Et Choix Traduisant la REalité III (Roy, 1991)
- EVAMIX - Evaluation Matrix (Voogd, 1982)
- MAVT - Multi-Attribute Value Theory (Keeney & Raiffa, 1993)
- PROMETHEE II - Preference Ranking Organization METHod for Enrichment of Evaluations II (Brans & De Smet, 2016)
- SMART/SMARTS/SMARTER - Simple Multi-Attribute Rating Technique (Olson, 1996)
- TODIM - Interactive and Multicriteria Decision Making (Autran Monteiro Gomes & Duncan Rangel, 2009)
- TOPSIS - Technique for Order of Preference by Similarity to Ideal Solution (Behzadian et al., 2012)
- VIKOR - VIseKriterijumska Optimizacija I Kompromisno Resenje (Opricovic & Tzeng, 2007)

Users can thereby switch methods to validate their assumptions or define new ones, cross-check conclusions, and gain insights into potentially new results, without rebuilding the model or re-importing data. This capability is explicitly addressed by the tool-switching and continuity issues documented for existing DSS.

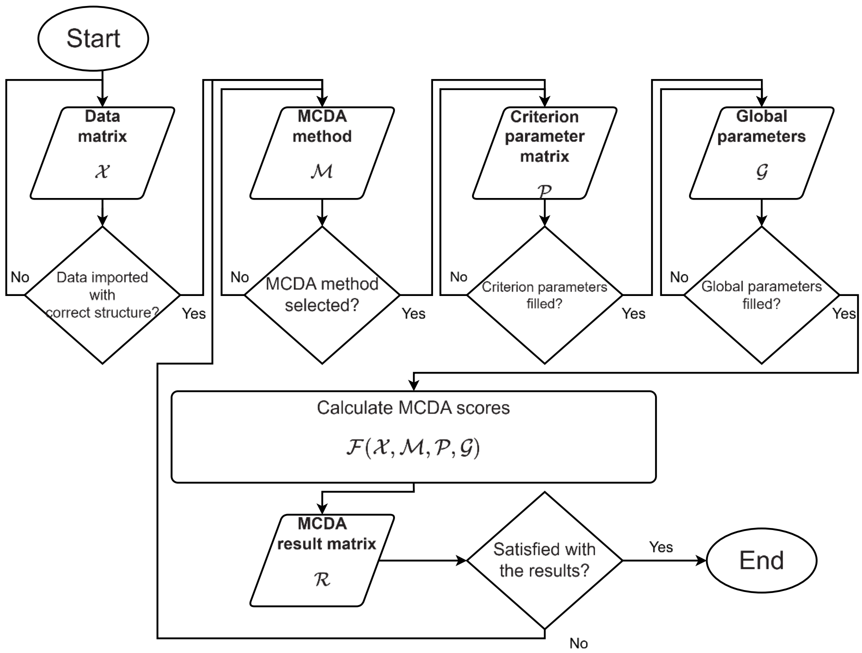



Figure 3 MCDA Calculator flowchart.

The flowchart of the calculation process is presented in Figure 3. At the heart of the Calculator is a high-level computational model, expressed as $F(X, M, P, G)$. Here, $X$ is the performance matrix of the alternatives on the criteria; $M$ denotes the chosen MCDA method; $P$ is a matrix of criterion-level parameters (such as polarity, weights, and, where applicable, method-specific thresholds or preference-function settings); and $G$ captures optional global parameters at the method level (for example, the v compromise parameter in VIKOR). The function returns a structured results object $R$ that contains aggregate scores and rankings, as well as any method-specific outcomes, such as positive/negative/net flows in PROMETHEE or distances to the ideal and the nadir in TOPSIS. In this way, the modeling inputs and outputs permit a method-neutral interface while preserving the particularities of each algorithm.

The matrices $X$ and $P$ are defined broadly to accommodate heterogeneous data types (numeric and non-numeric), with the "matrix" form primarily serving to organize data for robust validation and transformation. Computations extend beyond elementary matrix algebra and invoke the specialized mappings each MCDA method requires. Treating the method-specific outputs as matrices within $R$ improves comprehensiveness and eases integration with the programming environment that underpins the Calculator.

Finally, it is worth noting that the Calculator implements a linear, but reversible workflow within a single web page. Users first import $X$ as an $m \times n$ matrix of $m$ alternatives by $n$ criteria; the system validates structure and types and prompts for correction if needed. The user then selects a method $M$, provides the required criterion parameters $P$ and any global parameters $G$, and computes the results $R$. If the analyst later adjusts a parameter or changes the method, the system recomputes immediately, without requiring a new data import, thereby supporting rapid iteration and side-by-side triangulation in live sessions. This design intentionally minimizes unnecessary configuration steps while enforcing validation at stage boundaries.

### 3.1.1 Data handling, parameterization, and validation

The MCDA Calculator standardizes how inputs are defined, checked, and transformed so that different methods can run through the same interaction pattern without re-preparing the data. We now present a didactic example to provide a full walkthrough of the working process in the MCDA Calculator.

Suppose we are evaluating four pathways on four different criteria. A $4 \times 4$ data matrix needs to be provided, as illustrated in Table 1. We assume that the performance of the criteria is evaluated qualitatively using a 10-point scale. Without loss of generality the evaluation criteria are assumed of increasing nature, meaning that the higher the score, the better the performance of the alternative.

Table 1 Didactic SURE pathway evaluation example data table.

| Alternative name | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 |
|---|---|---|---|---|
| **Pathway 1** | 2 | 7 | 2 | 3 |
| **Pathway 2** | 5 | 4 | 1 | 6 |
| **Pathway 3** | 2 | 5 | 3 | 8 |
| **Pathway 4** | 9 | 2 | 1 | 7 |

In the MCDA Calculator (see Figure 4), users have two convenient ways to provide the performance matrix $A$. First, they can upload a spreadsheet using a predefined template, downloadable from the interface; filling this template ensures the data are correctly formatted. Second, they can enter or edit values directly in the pre-populated table on the web page; the table supports in-place modification after an initial import as well. Once the data are in place, the user selects the MCDA method. In this example we choose SMART. The SMART workflow asks for three types of information on the criteria: polarity (positive or negative), plausible minimum and maximum performance values for normalization, and the weight of each criterion.

Suppose we have a set of alternatives $A=\{\alpha_1,\ldots,\alpha_j,\ldots,\alpha_m\}$ and a set of criteria $G=\{g_1,\ldots,g_i,\ldots,g_n\}$. Denote by $g_i(a_j)$ the performance of alternative $\alpha_j$ on criterion $g_i$. For each criterion $g_i$, define the normalization bounds $\min_{j\in m}(g_i(a_j))$ and $\max_{j\in m}(g_i(a_j))$. The single-criterion normalized score $s_i(a_j)$ is calculated in the following form:

$$s_i(a_j)=\begin{cases} \dfrac{g_i(a_j)-\min\limits_{j\in m}(g_i(a_j))}{\max\limits_{j\in m}(g_i(a_j))-\min\limits_{j\in m}(g_i(a_j))}, \text{for positive criterion} \\ \dfrac{\max\limits_{j\in m}(g_i(a_j))-g_i(a_j)}{\max\limits_{j\in m}(g_i(a_j))-\min\limits_{j\in m}(g_i(a_j))}, \text{for negative criterion} \end{cases}, \forall i=1,\ldots n;\ \forall j=1,\ldots,m$$

The overall SMART score of one alternative is calculated as:

$$S(a_j) = \sum_{i=1}^{n} [s_i(a_j) \cdot w_i]$$

where $w_i$ denotes the weight of criterion $g_i$. This setup makes polarity explicit, keeps normalization transparent via performance boundaries, and aggregates performance through the weighted sum.

Once users supply all the parameters, clicking Calculate runs the MCDA and returns the results. For SMART, the output includes the normalized per-criterion scores and the overall SMART score (with the corresponding ranking). For transparency and reuse, the data matrix, the parameter table, and the results table can be exported as spreadsheets for audit, reporting, or later recalculation.

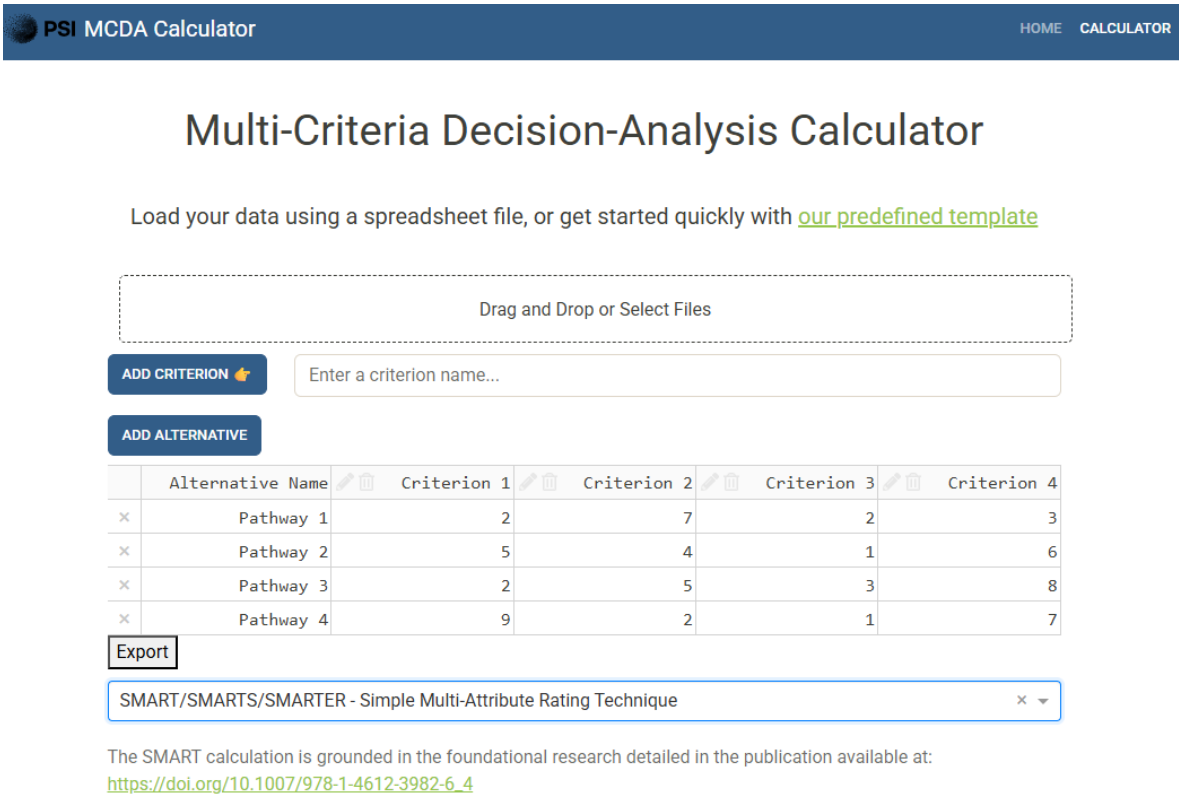
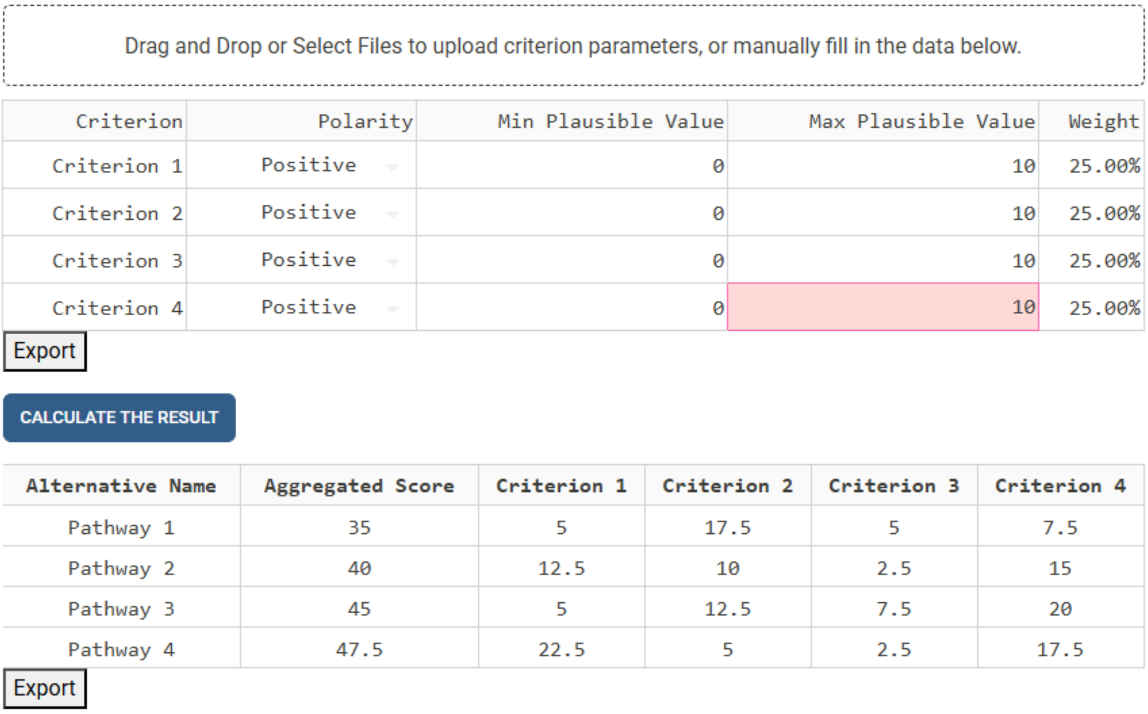


Figure 4 Data import and MCDA method selection in the MCDA Calculator.



Drag and Drop or Select Files to upload criterion parameters, or manually fill in the data below.

| Criterion | Polarity | Min Plausible Value | Max Plausible Value | Weight |
|---|---|---|---|---|
| Criterion 1 | Positive | 0 | 10 | 25.00% |
| Criterion 2 | Positive | 0 | 10 | 25.00% |
| Criterion 3 | Positive | 0 | 10 | 25.00% |
| Criterion 4 | Positive | 0 | 10 | 25.00% |

Export

CALCULATE THE RESULT

| Alternative Name | Aggregated Score | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 |
|---|---|---|---|---|---|
| Pathway 1 | 35 | 5 | 17.5 | 5 | 7.5 |
| Pathway 2 | 40 | 12.5 | 10 | 2.5 | 15 |
| Pathway 3 | 45 | 5 | 12.5 | 7.5 | 20 |
| Pathway 4 | 47.5 | 22.5 | 5 | 2.5 | 17.5 |

Export

Figure 5 Parameter setting and result calculation in the MCDA Calculator.

## 3.2 Weight Elicitor

The Weight Elicitor is the bridge between the performance of the alternatives on the criteria and the subjective assessment of the preferences of a DM. It turns DMs' priorities into a defensible weight vector that the MCDA Calculator can use across methods. We provide two complementary tools under this module because eliciting preferences is not a one-size-fits-all task. The modularized SRF software is designed to apply SRF (Huang et al. 2026). It captures the order of importance and the perceived gaps between ranks, yielding, in the end, the criteria's importance. By contrast, a trade-off–based elicitation, required in other MCDA methods, asks stakeholders to quantify trade-offs, which reflect substitution ratios between the criteria (Keeney & Raiffa, 1993). Both tools produce normalized weights in the same parameter schema $P$, and run within the same web framework as the MCDA Calculator, so users can move seamlessly from elicitation to computation and, later, to robustness analysis.

### 3.2.1 Modularized SRF software

The SRF procedure is a structured, low-cognitive-load approach for turning qualitative judgements of importance into a defensible vector of criteria weights (Figueira & Roy, 2002). Instead of asking users to assign numbers directly, SRF asks them to rank-order criteria from least to most important using "cards", allowing ties by grouping cards at the same rank, and to insert "blank" cards between two ranks when the gap in importance should be larger than a simple step. Finally, the user specifies a single parameter $z$, which expresses how many times more important the most important criteria are than the least important ones. From these inputs, SRF computes importance weights that are consistent with the ordering, the perceived gaps, and the overall spread, dictated by the value of $z$. It requires a low-cognitive load, and is ideal for workshops with many criteria, limited time, and mixed expertise. The same method was applied in the 2nd SWEET SURE Indicator Workshop, on the 5th November 2024, to assess future risk scenarios that serve as criteria for evaluating the SWEET SURE pathways (see Figure 6).


Figure 6 Rank-ordering of the shocks in the SURE stakeholder workshop using the SRF protocol

Over time, SRF has evolved into a family of variants, revised mappings from gaps to weights, interval or "robust" formulations that return ranges rather than point weights (Siskos & Tsotsolas, 2015), hierarchical SRF for criteria trees (Corrente et al., 2017), and versions that elicit $z$ indirectly (Abastante et al., 2022). Despite their mathematical differences, these extensions all retain the same deck-of-cards elicitation protocol. That common interaction pattern is the key design insight for our software: we can build a single, modular SRF software that presents one familiar user experience and swaps in the appropriate computational kernel behind the scenes. In other words, the user never changes how they handle cards; only the rules that translate decks into criteria weights.

Currently, the envisioned SRF software is being developed under the same web framework, and the layout is illustrated in Figure 7. At the top, a selector invites the user to choose the SRF variant. The default is the classic SRF formulation, but the dropdown includes its extensions, such as the robust SRF, that can be swapped in without changing how users interact with the software. A short methodological reference and expandable user guidelines have been provided to the Selector to support users along the procedure. On the right, two card stacks represent the criterion cards and the blank cards. Criterion cards are dragged onto the central canvas to build the rank order; blank cards are inserted between ranks whenever the perceived gap in importance should be larger than one step. Users arrange the cards horizontally from least to most important; placing multiple criterion cards at the same horizontal position creates an ex aequo group (criteria of equal importance). When the setup is ready, the user clicks the calculate button to convert the deck into weights, and the export function allows the user to save the resulting weight vector for audit and reuse.

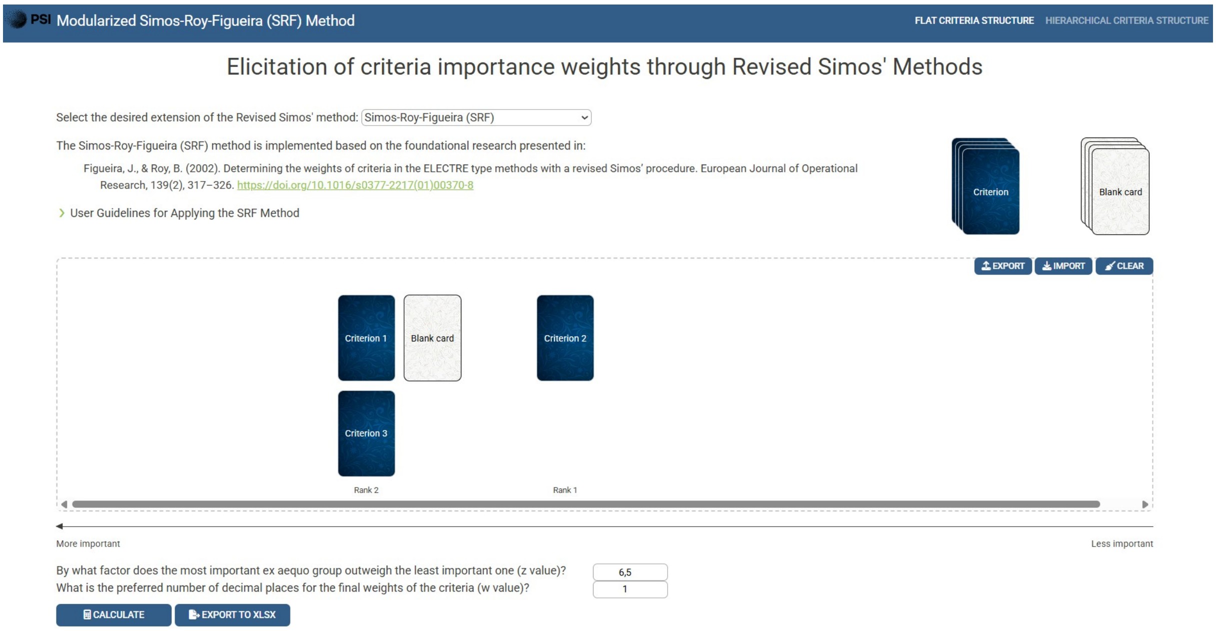


Figure 7 The modularized SRF software is currently under development.

The workflow is especially beneficial for decision support workshops. In practice, a facilitator can begin a session with classical SRF to establish a baseline that the group understands. Then, in case of uncertainty or disagreement by the DM(s), the facilitator can switch to a robust SRF variant to examine weight intervals without touching the deck itself. If the discussion requires a different emphasis, the deck can be edited in place, or a saved layout can be imported to compare successive rounds. The resulting weights are exported to an Excel file for record-keeping and handed off to the MCDA Calculator to run the desired outranking method(s), such as PROMETHEE or ELECTRE. The SRF module preserves the intuitive, tactile logic of card ranking while providing precise, reproducible inputs to the rest of the DSS. Its modular design ensures that new SRF variants can be added without altering the user experience.

### 3.2.2 Pairwise-comparison tool

The pairwise-comparison elicitation module is intended for cases when stakeholders can express how strongly one criterion should outweigh another. Two well-known approaches are supported: the AHP and the Best–Worst Method (BWM). Both are widely used in facilitated sessions because they convert pairwise comparison into defensible numbers while providing a quick quality check on the coherence of those judgments. The first method in this module is Analytic Hierarchy Process (AHP, (Saaty, 1987)), which captures the importance through pairwise comparisons and derives a cardinal weight vector with built-in consistency diagnostics. Formally, AHP elicits a pairwise comparison matrix $X=\left[x_{ii'}\right]$. Each element $x_{ii'}$ encodes the judged importance of criterion $g_i$ relative to $g_{ii'}$ on a verbal–numeral scale; the matrix is reciprocal with $x_{ii'}=\frac{1}{x_{i'i}}$ and has ones (1) on the diagonal. The priority vector $w=\left(w_1,\ldots,w_n\right)^T$, with $w_i>0$ and $\sum_{i=1}^{n} w_i=1$ is obtained as the principal right eigenvector of $X$:

$$Xw=\lambda_{max}w$$

and is then normalized to sum to one. Deviation from perfect consistency is summarized by the consistency index $CI=\frac{\left(\lambda_{max}-n\right)}{n-1}$ and by the consistency $CR$; a $CR$ near or below $0.10$ is commonly taken as acceptable.

The pairwise-comparison tool presents these comparisons in a clean, single-page flow: users can work in a guided “question” view that asks one comparison at a time, or in a matrix view where entries can be edited directly and reciprocals are filled automatically (see Figure 8). Live feedback shows the resulting weight profile and a simple consistency indicator, so participants can see when their inputs conflict with each other and where small adjustments would help.

**Editable Pairwise Matrix**

| | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 |
|---|---|---|---|---|
| Criterion 1 | 1 | 9 | 5 | 1 |
| Criterion 2 | 1/9 | 1 | 1/6 | 1 |
| Criterion 3 | 1/5 | 6 | 1 | 1 |
| Criterion 4 | 1 | 1 | 1 | 1 |

Figure 8 The pairwise-comparison tool is currently under development with the AHP matrix.

BWM further reduces the number of questions by first asking the group to identify the most and the least important criteria. The tool then collects judgments comparing the best criterion to all others and all others to the worst criterion. From this compact set of inputs, the software derives a complete set of weights and an accompanying fit indicator. In practice, this is attractive when time is short or the criterion list is long, because it minimizes the cognitive load while still producing a robust outcome. The interface mirrors the AHP experience: a short, linear sequence of prompts, immediate preview of weights, and gentle guidance when answers are inconsistent.

The envisioned pairwise-comparison module is also an embedded part of the developed software, so that users do not need to resort to other software and suites. Criteria and their descriptions are pulled from the same data layer to avoid mismatches, and results are produced in the same parameter format used elsewhere in the DSS.

In summary, the interface favors clarity: plain-language prompts, optional condensed scales e.g., a shorter verbal scale for non-expert audiences), and unobtrusive explanations of what the quality indicators mean without overwhelming users with excessive mathematical formulas. Moreover, the pairwise-comparison tool offers another way to model user preferences on the weights that is still simple enough for live facilitation. AHP offers a familiar pairwise comparison experience with continuous feedback; BWM offers a more streamlined alternative that reaches stable weights with fewer questions. Both can be accessed in the same single-page, browser-based environment as the other modules, produce the same kind of output, and carry the same provenance, so analysts can move from values to calculations and then to sensitivity analysis without changing tools or re-entering information.

### 3.2.3 Voting tool

The voting tool is a lightweight way to derive group weights when multiple DMs participate, as was the case in the 2nd SWEET SURE Indicators Workshop. It is not a standalone software product; rather, it is a simple procedure with a flexible front end (paper ballot or online survey) and a minimal back end (short script in any programming language or a pre-built Excel sheet). The aim is to capture collective judgements on the importance of each criterion and convert those judgements into a normalized weight vector for use in the MCDA Calculator, which represents the preferences of the whole group of DMs.

The first step is designing the ballot and voting rules. Before the session, researchers/facilitators agree on the voting rules: how many criteria can be voted on and how many points each vote is worth. A common rule is ranking-based “points for place”. In a points-for-place scheme, each DM ranks the criteria from most important to a certain position; the top ranked criterion receives a fixed top score (e.g., 5 points, if there are five criteria, or a chosen cap such as 3 or 5), the next rank receives one point less, and so on. After setting up the rules, it is necessary to collect responses. The front end can be paper ballots or an online form (see Figure 9). Ballots list the criteria with brief descriptions to ensure a shared understanding. To reduce anchoring biases, the criteria can be shown in randomized order across ballots.

After collecting the input, the weights can be calculated by aggregating and normalizing. For each criterion, points or ratings are summed across DMs to obtain a group score. These group scores are then normalized (e.g., divided by the total across criteria) to produce criteria weights that sum to one.

The back end can be a short script (Python/R/Julia/Matlab) that reads a CSV export from the survey tool, computes sums and normalized weights, and writes a results file for the MCDA Calculator. Alternatively, a locked Excel workbook with a “Votes” sheet and a “Weights” sheet can implement the same logic with simple formulas. Both approaches produce a small, transparent record: raw ballots, aggregate scores, normalized weights, timestamps, and session identifiers. The simplicity and traceability make them ideal for workshops, allowing quick aggregation, display of results, and seamless transition to computation.

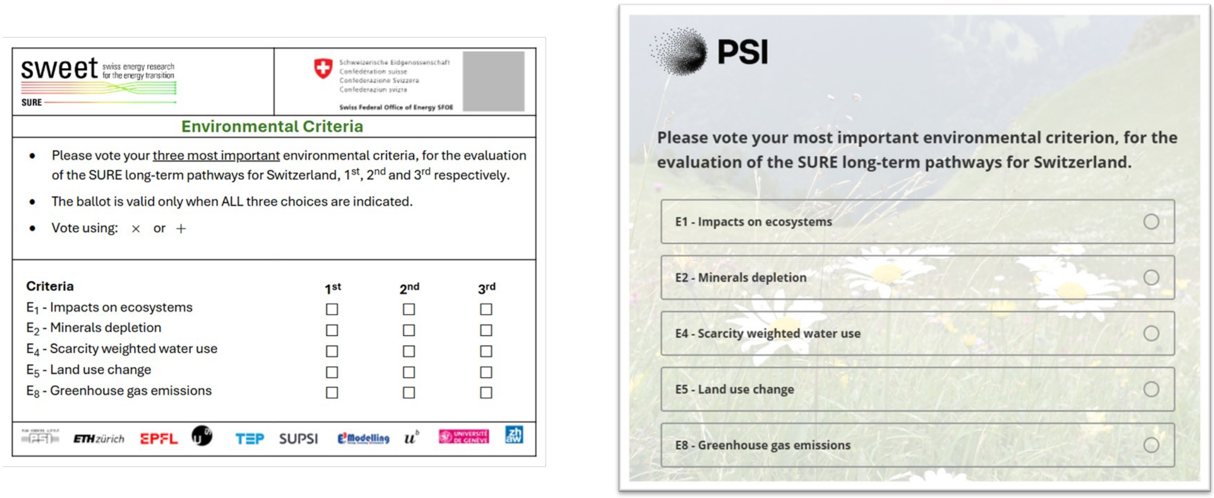



Figure 9 Voting tool used in the SURE stakeholder workshop. Left: paper ballot; right: live online survey.

### 3.3 Scenario Analyzer

The Scenario Analyzer is a dedicated module in the MCDA DSS that tests the robustness and sensitivity of the evaluation results under varying assumptions. Its purpose is to ensure that MCDA outcomes, i.e., alternative rankings, remain reliable when criteria weights, input data, or contextual conditions change. This module takes as input the initial MCDA results, the defined criteria weights, and any predefined scenarios. Using these inputs, the Scenario Analyzer performs a suite of analyses: weight sensitivity, Monte Carlo uncertainty simulations, shock scenario comparisons, etc., to provide richer insights into result stability. It produces visualizations and summary tables to help both analysts and stakeholders understand how sensitive the scenarios rankings are to uncertainties. By integrating seamlessly after the MCDA computation step, the Scenario Analyzer becomes an essential part of the DSS workflow, feeding its findings back into the decision process so that decision-makers can identify robust policies with confidence.

One core function of the Scenario Analyzer is weight sensitivity analysis, which examines how changes in criteria weights affect the MCDA results. This includes one-at-a-time weight sweeps analysis. The weight of a single criterion is systematically varied across its feasible range, while the remaining weights are adjusted proportionally to preserve the normalization constraint (i.e., the weights must sum to one). The analysis then evaluates how these variations impact the final scores and ranking positions of the alternatives (Paradowski et al., 2024). The module can, for example, increase a weight from 0% to 100% and track whether and when a different pathway alternative becomes the top-ranked option. The output is typically an interactive plot or series of plots showing how each alternative’s score or rank changes as a particular weight is adjusted. These analyses highlight critical “tipping points” where small weight shifts cause rank reversals, thereby pinpointing criteria that heavily influence the decision outcome.

In addition, the Scenario Analyzer computes stability intervals for each criterion’s weight, i.e., the range of weight values within which the current ranking of alternatives remains unchanged. A weight stability interval (WSI) defines the range within which a given weight can increase or decrease before the preferred alternative or overall rank order would change (Mareschal, 1988). By calculating these intervals for each criterion, the module identifies which criteria have tight stability ranges, indicating the ranking is very sensitive to that weight, and which have broad ranges, indicating higher robustness to weight changes. Such results can be presented in a chart like Figure 10, allowing analysts to quickly see the most influential weights. This one-at-a-time sensitivity capability ensures that stakeholders understand how much their weight judgements can vary before the decision recommendation would differ. In short, the weight sensitivity analysis helps validate the robustness of the MCDA outcome by revealing any fragile criteria assumptions and by encouraging discussion on weight prioritization.

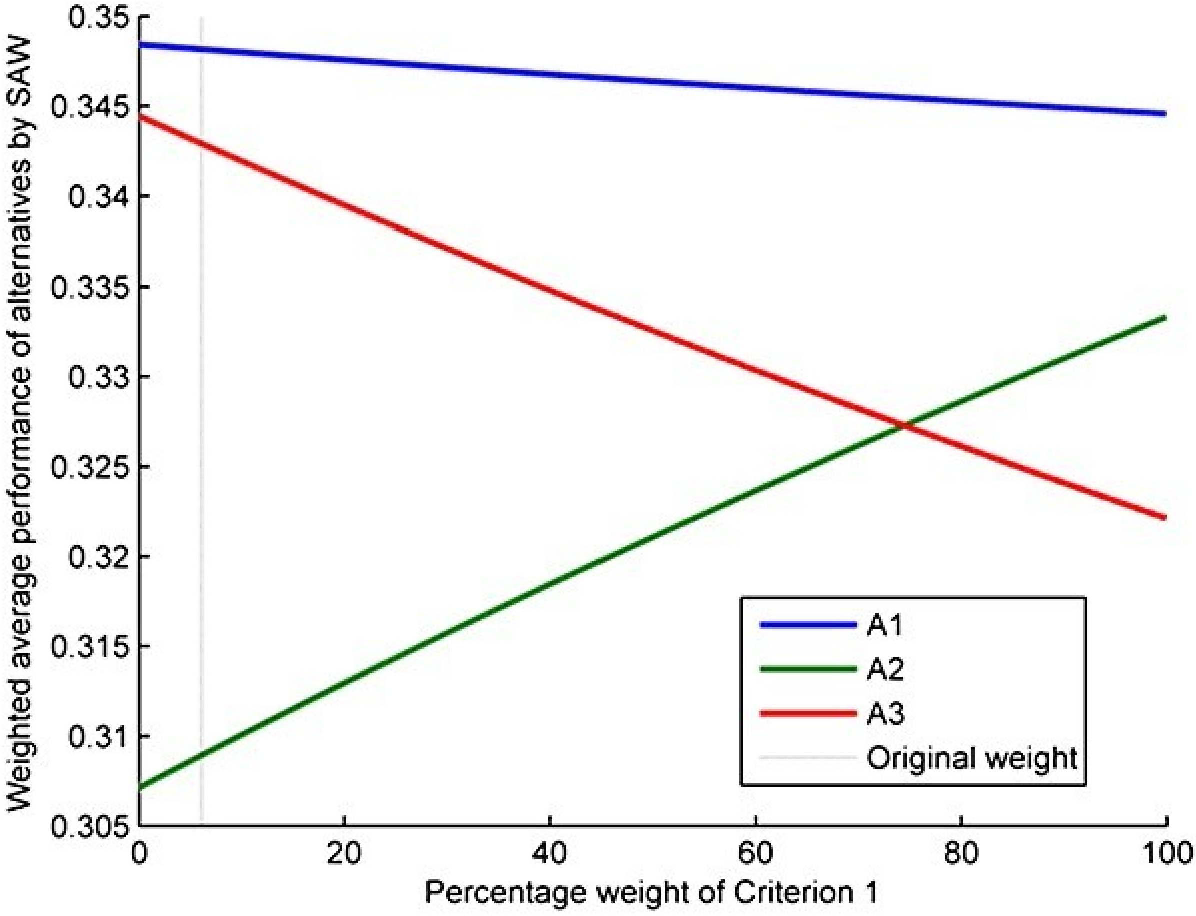



Figure 10 Example of a weight stability interval (WSI). The x-axis shows the weight assigned to the selected criterion; the vertical bar indicates the baseline weight. Blue lines trace each alternative's preference score as that weight varies.

Beyond deterministic weight sweeps, the Scenario Analyzer supports Monte Carlo simulations to account for uncertainty in both weights and indicator values. In this mode, the module treats weights or performance scores as uncertain variables, for example, defined by distributions or confidence ranges, and performs a large number of runs of the chosen MCDA method with randomized inputs. To assess the robustness of results against weight uncertainty, the tool performs Monte Carlo simulations by generating randomized, normalized weight vectors. By default, these weights are sampled from a uniform distribution. This approach minimizes the cognitive burden on stakeholders, though the system allows advanced users to specify custom probability distributions if required. Similarly, to address performance uncertainty, the module samples alternative indicator values based on user-defined probability distributions. Each Monte Carlo iteration utilizes these sampled inputs to recalculate the alternatives' scores and rankings. Over numerous iterations, this process yields a probabilistic distribution of outcomes rather than a single deterministic ranking.

The output of the Monte Carlo analysis is a statistical characterization of assessing robustness (Pelissari et al., 2020). The Scenario Analyzer can report the frequency with which each alternative ranks 1st, 2nd, 3rd, etc., across all simulation trials, essentially estimating a probability that each policy is the optimal choice under random variations. It may visualize these as bar charts or histograms (often called rank acceptability distributions in MCDA literature) for each alternative. For instance, one alternative might be ranked best in 85% of simulations. Conversely, an alternative with a uniformly distributed probability across multiple ranks exhibits high sensitivity to variations in weights or performance data. To further synthesize these findings, the module provides summary statistics—such as the expected rank and score variance for each alternative—often presented via box-and-whisker plots. By simultaneously varying multiple parameters, these Monte Carlo simulations complement one-at-a-time sensitivity analyses, providing a comprehensive global sensitivity assessment.

The outputs from Scenario Analyzer might be a final recommended ranking of alternatives tagged as a "robust ranking," along with transparency about how it was derived. The Scenario Analyzer can report, for instance, that Alternative $a_j$ is the top robust choice because it consistently ranks near the top in every scenario (even if it wasn't always number one in each). In technical reports, this could be presented as a table of alternatives with their rank in each scenario and their overall aggregated rank or score. By providing a single compromise ranking or a set of robust alternatives, the module helps reconcile divergent scenario outcomes and can guide DMs toward solutions that offer good moderate performance across all future scenarios (French, 1986). This feature aligns with best practices in robust decision-making, where instead of betting on a single scenario, the goal is to prioritize decisions that perform reasonably well across all plausible scenarios. The Scenario Analyzer delivers a synthesized perspective that can be taken forward in the DSS for final decision support. Its inputs (MCDA results, weight ranges, scenario data) are drawn from earlier modules, and its outputs (stability visuals, compromise rankings) feed into subsequent reporting and decision phases.

The Scenario Analyzer is currently at the prototyping stage, where its conceptual design and core functionalities are being specified and tested with sample data. While not yet fully implemented, the module will be developed within the same programming framework as the MCDA Calculator and Weight Elicitor, ensuring a consistent user interface, shared data contracts, and seamless interoperability across the DSS. This common framework will allow users to move smoothly from preference elicitation to computation and finally to robustness analysis without changing tools or re-entering information, while also simplifying maintenance and future extensions of the system.

# 4 Conclusion

This deliverable sets out the rationale, architecture, and the current status of a modularized MCDA DSS that operationalizes SURE's evidence base for evaluating long-term energy pathways under various shock scenarios. In a context where Switzerland must steer toward net-zero amid uncertainty and shocks, the DSS translates complex, multi-indicator model outputs into preference-aware, robustness-tested recommendations. It does so by cleanly separating three concerns: elicitation of values, multi-method computation, and robustness under uncertainty, while keeping a single, workshop-ready workflow tied to a common data backbone.

The first production component, the MCDA Calculator, demonstrates that diverse methods can be executed within a single interaction pattern without sacrificing method-specific controls or diagnostics. This consolidates analysis that would otherwise require multiple tools, reduces configuration error, and accelerates iteration in facilitated settings. The Weight Elicitor, implemented as two complementary tracks, provides defensible, auditable weight vectors suited to different stakeholder contexts and levels of granularity. The Scenario Analyzer, now in prototype, will elevate sensitivity and uncertainty treatment to a first-class step, offering weight sweeps, stability intervals, Monte Carlo exploration, and scenario aggregation to quantify when conclusions are robust and when they hinge on contested assumptions.

There are, nonetheless, clear next steps. On the methodological side, we will expand the Calculator's method catalogue and finalize the variants of the weight elicitation method. Then, the Calculator can also be applied to the pathways evaluation problem in T1.2, on the basis of the actual pathway-shock data stemming from the SURE models and the preference input received from the stakeholders. On the product side, we will strengthen data connections to the backbone of the Indicator Database (Task 1.1) and complete the Weight Elicitor and Scenario Analyzer.

In summary, Task 1.4 provides a coherent pathway from SURE's modeling evidence to decisions that are explicit about values and credible under uncertainty. By anchoring the DSS into a modular architecture, and by releasing the MCDA Calculator while advancing the Weight Elicitor and Scenario Analyzer, we provide a durable foundation for iterative pathway analysis, stakeholder engagement, and transparent reporting. This positions SURE to support DMs with recommendations that are fast to compute, easy to explain, and robust enough to withstand scrutiny in a rapidly changing energy landscape.

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