Visual PROMETHEE
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Introduction

Visual PROMETHEE 1.4 Manual
September 5, 2013.

This is the Visual PROMETHEE 1.4 Manual and Help file.

The content and the layout are regularly updated. Check the www.promethee-gaia.net web site for the latest version.

- Welcome
- What is it about
- What is Visual PROMETHEE?
- What is PROMETHEE?
- What's new?

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Welcome to Visual PROMETHEE

Bienvenue!  
Welkom!  
Willkommen!  
¡Bienvenido!  
Benvingut!  
Bem-vindo!  
Benvenuto!  
Dobrodošli!  
добродошли!  
Witamy!  
Sveiki atvykę!  
Добро пожаловать!  
Fáiłte!  
Hoşgeldiniz!  
בֵּרוּ לְבָא  
بوحبا  
اِحْنِ لَمْ دَيْد  
ようこそ！  
歓迎！  
आपका स्वागत है!  
Grata!

What is it about

Visual PROMETHEE is a multicriteria decision aid (MCDA) software.

It is designed to help you to:

- Evaluate several possible decisions or items according to multiple often conflicting criteria.
- Identify the best possible decision.
- Rank possible decisions from the best to the worst one.
- Sort items into predefined classes such as for instance: bad customers, good customers, exceptional customers.
- Visualize decision or evaluation problems to better understand the difficulties in making good decisions.
- Achieve consensus decisions when several decision-makers have conflicting points of view.
- Justify or invalidate decisions based on objective elements.

Here are some examples of fields of application and of how Visual PROMETHEE can help you:

- **Purchase of an equipment:**
  Q: Which equipment is best? The cheapest? The most reliable one? The most technology advanced one? Or more probably a good compromise between price, quality and performance?
  A: Define your criteria (cost, reliability, performance, look, ...). They can be quantitative ($, kg, mph, ...) or qualitative (reliability, quality, design, ...). Model your preference (scales, thresholds, ...) and priorities (weight the criteria). The PROMETHEE rankings will then show you what is (are) the best possible choice ($).

- **Procurement - Evaluation of suppliers:**
  Q: Who is your best supplier for a type of product or service?
  A: The best supplier should provide you with a best quality level at a most reasonable price. Price is thus one criterion that has to be confronted to quality. And quality should be evaluated on multiple criteria (quality of the products, quality of maintenance, respect of delivery terms, ...). The PROMETHEE rankings will show you who are the best suppliers. And the GAIA analysis can help you to negotiate better terms with your suppliers.

- **Definition of Key Performance Indicators (KPI):**
  Q: How to evaluate performance of units (shops, logistic centers, teams, departments, ...) ?
  A: Visual PROMETHEE allows for combining several indicators into a single performance score. The Performance Analysis module makes it possible to perform an Input/Output analysis and to obtain efficiency measurements.

- **Human resources management:**
  Q: How to evaluate collaborators? How to select the best candidate for a job?
  A: PROMETHEE rankings can help you identify the best candidate for a job or promotion. The GAIA analysis can be used to identify typical collaborators profiles, to identify personal weaknesses and to elaborate training programs.

- **Evaluation of projects:**
  Q: How to manage a portfolio of e.g. R&D projects taking into account the expected return as well as the risk level and budget constraints?
  A: The PROMETHEE rankings allow to evaluate different projects according to multiple criteria including return as well as risk. The PROMETHEE V selection method can then be used to elaborate a complete portfolio taking into account additional constraints such as budget limits, sectoral or geographical diversification, size, etc.

- **Investment selection:**
  Q: What is the best investment solution or the best portfolio of investments taking into account return
and risk?
A: Here again the PROMETHEE rankings and the PROMETHEE V method can help you to find best balanced solutions suited to your preferences and priorities.

- **Location problems:**
  Q: Where to build a new plant, a warehouse or a shop?
  A: Different possible locations can be compared on many criteria such as for instance: investment cost, surface available, distance to customers, distance to suppliers, availability of transportation networks, environmental or social impacts, ... Use the PROMETHEE rankings to identify the best compromise solution(s).

- **Quality assessment:**
  Q: How to evaluate the quality of products, of services, of procedures, of units?
  A: Visual PROMETHEE allows you to define multiple evaluation criteria and to generate global quality scores (using the PROMETHEE II net flow Phi). The GAIA analysis and the GAIA Webs make it possible to make a full quality diagnosis.

- **Health care:**
  Q: What is the best therapeutic choice?
  A: Many health care decision problems are also multicriteria problems and can be handled by Visual PROMETHEE.

- **Environmental impacts and sustainable development:**
  Q: How to make decisions in the context of sustainable development?
  A: Visual PROMETHEE allows you to structure the criteria into clusters (for instance economical, environmental and social criteria) and groups (for instance air, water and soil impacts within the environmental criteria) of criteria. This makes it easier to perform sensitivity and what-if analyses. For instance giving more weight to the environmental criteria or less to the social ones is done very easily and the corresponding results are directly available with tools like the Walking Weights and the Visual Stability Intervals.

- **Negotiation and group decision making:**
  Q: How to conciliate different and often conflicting points of view and to achieve a good consensus decision?
  A: GDSS PROMETHEE provides extensions of the PROMETHEE and GAIA methods to the case were multiple decision makers are involved in the decision process. The multi-scenarios model enables to compare points of view, to pinpoint the sources of conflict and engage in a dynamic to solve the conflicts and to identify the best consensus decision(s).

More information about possible applications can be found at the Decision Drive web site.

Visual PROMETHEE is based on the PROMETHEE and GAIA methods that have been developed at the ULB and VUB universities of Brussels and have been widely used worldwide in many different decision or evaluation problems.

A detailed explanation of MCDA and the PROMETHEE and GAIA methods is available in the last chapter of this manual.

**What is Visual PROMETHEE**

Visual PROMETHEE is the last and most complete and up-to-date software implementation of the PROMETHEE and GAIA multicriteria decision aid (MCDA) methods.

Visual PROMETHEE is developed by VPSolutions under the supervision of Professor Bertrand Mareschal from the Solvay Brussels School of Economics and Management of the Université Libre de Bruxelles (ULB).

Professor Bertrand Mareschal has been developing and applying the PROMETHEE and GAIA methods for 30 years together with Professor Jean-Pierre Brans at the ULB and VUB universities in Brussels.
With **Visual PROMETHEE** you can share the expertise of a worldwide expert in the field of multicriteria decision aid and of one of the original authors of the **PROMETHEE** and **GAIA** methods.

**PROMETHEE Software**
Here is a short chronological history of **PROMETHEE**-based software.

**1985 - Back in the 1980’s**
The first **PROMETHEE** implementation was made by Bertrand Mareschal on the ULB mainframe computer in FORTRAN around 1984. It was very different from today’s software. And it was very difficult to adapt programs to different computers. The University of Split was a pioneer: they got a stack of punched cards and had the software running on their Vax system in a matter of days. Later the software was ported to the IBM PC. It was the basis for **PromCalc**.

**1990 - PromCalc**
The **PromCalc** software was developed around 1990 as an MS-DOS application by Bertrand Mareschal and Jean-Pierre Brans. **PromCalc** was one of the first truly interactive and graphical software available in the field of MCDA. Many universities and companies worldwide started to use it. At the end of the 1990’s Windows 95 and 98 had changed the way of computing. It was time to move on.

**2000 - Decision Lab**
The **Decision Lab 2000** software has been developed as a joint project between ULB and the Canadian company Visual Decision. **Decision Lab** took the **PromCalc** ideas and implemented them in a MS Windows program. It was a huge step forward with respect to software usability. It is now discontinued.

**2010 - D-Sight**
D-Sight is a software that was developed a few years ago under the lead of Yves De Smet from ULB. The main objective was to develop MCDA business in a spin-off named Decision Sights. It is still available but lacks a good theoretical background.

**2012 - Smart Picker Pro**
This is a recent project led by Philippe Némery. Philippe got his PhD at ULB in the field of multicriteria sorting methods. His software emphasizes this aspect.

**2012 - Visual PROMETHEE**
The development of **Visual PROMETHEE** started in 2010 at **VPSolutions** under the supervision of Bertrand Mareschal in order to provide an adequate replacement for **Decision Lab 2000**. Most development was done from 2011 to 2012. A strong emphasis is given to the quality and consistency of the user interface, to visual aspects and to the ease of use of the software, while implementing the latest and most advanced developments of multicriteria decision aid. **Visual PROMETHEE** is the only **PROMETHEE**-based software backed by the authors of the methodology: Prof. Jean-Pierre Brans and Prof. Bertrand Mareschal.

**Visual PROMETHEE** is available in four different editions:

- **Demo Edition**
- **Academic Edition**
- **Business Edition**
- **On-line Edition**

Custom Editions are also available on request.

Additionally localized versions are available for the **Academic** and **Business Editions** (go to [visual.promethee-gaia.net](http://visual.promethee-gaia.net) to download local versions). Currently, the following languages are available:

- English (available)
- French (available)
- Dutch (available)
- German (available - thanks to Prof. Lioba Markl-Hummel, University of Goettingen, Germany)
- Hungarian (available - thanks to Dr. Sándor Bozóki, University of Budapest, Hungary)
- Italian (available)
- Polish (available - thanks to Dr. Elżbieta Tracz, Jagiellonian University, Cracow, Poland)
- Serbian (available - thanks to Dr. Drazenko Glavíc, University of Belgrade, Serbia)
- Spanish (available - thanks to Prof. Dr. Carlos Escobar Toledo, UNAM, México)

Other languages will be made available in the future. If you are interested in helping us to translate Visual PROMETHEE in your language send us a mail at bmaresc@ulb.ac.be. First time translators will be entitled to a life-time Business Edition license for free.
**Demo Edition**

The **Visual PROMETHEE Demo Edition** is fully functional with the following limits:

- It is not possible to save decision problems.
- Only the supplied tutorial problems can be loaded.
- Report generation, data import/export and PROMETHEE Certificate are not available.
- The analysis is limited to user-defined decision problems involving a maximum of 6 actions, 6 criteria and 2 scenarios.

The Demo Edition can be upgraded to the **Business Edition** through registration.

**Academic Edition**

The **Visual PROMETHEE Academic Edition** is fully functional without any limits. It is available for free for non-profit research and teaching only. This includes but is not limited to:

- Ph.D. students thesis work.
- Non-profit research work made in academic institutions and research centers.
- Non-profit course support.

If you are not sure whether you are eligible for using the **Visual PROMETHEE Academic Edition**, please contact us at bmaresc@ulb.ac.be

As a courtesy the use of the **Visual PROMETHEE Academic Edition** software should be mentioned in all related publications.

**Business Edition**

The **Visual PROMETHEE Business Edition** is the complete and unrestricted edition of Visual PROMETHEE.

To use the **Business Edition**, you need a proper license. Otherwise it reverts to the Demo Edition.

**Online Edition**

To be announced later.

**What are PROMETHEE and GAIA**

The **PROMETHEE** and **GAIA** methods are among the most widely used multicriteria decision aid methods.

**PROMETHEE** stands for Preference Ranking Organization METHod for the Enrichment of Evaluations.

**GAIA** stands for Graphical Analysis for Interactive Aid.

The PROMETHEE I and II ranking methods were first developed by Professor Jean-Pierre Brans in 1982. Two years later Jean-Pierre Brans and Bertrand Mareschal developed **PROMETHEE III** (ranking based on intervals) and **PROMETHEE IV** (continuous decision problems). These two variants are not implemented. In 1988 **GAIA** was introduced which is a graphical complement to the PROMETHEE rankings. In 1992 **PROMETHEE V** was proposed as a solution for multiple selection under constraints. And in 1994 **PROMETHEE VI** (the "Decision-Maker Brain") was implemented in the **PromCalc** software.

In 30 years, several hundreds of scientific papers related to **PROMETHEE** and **GAIA** have been published in scientific journals all around the world. You can check the on-line Bibliographical Database at [http://biblio.promethee-gaia.net](http://biblio.promethee-gaia.net). As of August 2013 more than 460 references were available.
Many organizations (private companies, public administrations, research centers, universities, individuals, ...) worldwide have been using PROMETHEE-based software for their decision-making or evaluation problems in various fields such as: banking, location of facilities, human resources management, water resources, investment, medicine and health care, chemistry, procurement, environmental problems, planning, project management, ...

If you want to discuss the potential of Visual PROMETHEE for your own decision or evaluation problems, please contact Bertrand Mareschal at bmaresc@ulb.ac.be.

What's new

Currently (August 12, 2013), the Visual PROMETHEE 1.4 Demo, Academic and Business Editions are available in eight different languages.

Additional localized versions are expected later in 2013.

There is a new tutorial available that shows you how to define and analyze a decision problem step by step from the beginning.

Version 1.2 introduced two main new features:

- Network display of the PROMETHEE I Partial Ranking (improved with respect to Decision Lab and PromCalc).
- Decision stick display in the GAIA plane.

Version 1.3 introduced additional features:

- MS Excel interface for import/export of data.
- PDF and XLS(X) reports.
- Improved localization.

Version 1.4 now introduces:

- A completely rebuilt and much improved Weighing Assistant.
- A redesigned PROMETHEE Table window.

Structure of the manual

This Visual PROMETHEE Manual is organized in several sections as follows:

- **Introduction**
  This is the place where you are now. ;-)

- **Getting started**
  This section includes general information about installing and using Visual PROMETHEE.

- **Terminology**
  A comprehensive list of terms used in the software.

- **Tutorial**
  The tutorial provides the user with the basic elements to use Visual PROMETHEE. It includes an overview of the user interface and of the most important analyses available. There is also a complete walk-through for starting and analyzing a new problem.

- **How to**
  This section contains more detailed "how to" information about specific situations:
  - Define a new problem
  - Rank different actions
  - Use the GAIA analysis
• **User interface**
  This section describes the main elements of the user interface: the main menu, the toolbars and the local menus.

• **Dialogs**
  This is a detailed description of all the dialogs in Visual PROMETHEE. Use it to find information specific to a dialog.

• **Assistants**
  The five assistants available in Visual PROMETHEE:
  - Problem Creation
  - Preference Function
  - Criteria Hierarchy
  - Weighing
  - Analysis

• **Windows**
  This is a detailed description of all the windows in Visual PROMETHEE. Use it to find information specific to a window.

• **PROMETHEE and GAIA methods**
  This section is devoted to a deeper methodological (and thus more mathematical) description of the PROMETHEE and GAIA methods:
  - MCDA: What is multicriteria decision aid?
  - PROMETHEE Rankings: How the PROMETHEE rankings are computed.
  - GAIA: How the GAIA plane is computed and what information it does contain.
  - Sensitivity Analysis: Why and how to perform a sensitivity analysis.
  - GDSS PROMETHEE: How the PROMETHEE and GAIA methods are extended to the GDSS dimension.
  - PROMETHEE V Selection: How to make multiple selection under constraints.
  - PROMETHEE Sort: How to sort actions in predefined classes.
  - Bank Adviser: How to use PROMETHEE to perform reference-based evaluation.
  - Performance Analysis: How to measure performance by comparing input and output criteria.

• **Additional examples and exercises**
  Four additional example datasets are introduced and analyzed. Exercises are provided for a better practice with Visual PROMETHEE.

• **Useful links**
  Links to useful websites and sources of information.
Getting Started

Thank you for using Visual PROMETHEE.

Here are some information about the software and its use.

- System requirements
- Getting help

System requirements

Visual PROMETHEE is a MS-Windows program. It runs on Windows XP, Vista, 7, 8 and later.

It is possible to run Visual PROMETHEE on Linux or MacOS systems using a virtual machine (e.g. WINE for Linux systems). All functionalities are not necessarily available in this case. Native MacOS and iOS versions of Visual PROMETHEE are considered as a possible future development.

The GIS PROMap feature requires an Internet connection.

There are no other special requirements.

Installation

Visual PROMETHEE is available for download either as a Windows installation file (VPsetup.msi) or an archive file (PROMETHEE.zip).

We recommend downloading the Windows installation file as it makes the full installation process much easier. Also some features such as file association are not available when installing from the archive. The archive should thus only be used when the Windows installation file cannot be used (for instance on a Linux computer).

Installing from the Windows installation file

Double-click the VPsetup.msi file to launch the installation and then follow the instructions. During the installation process you will have to read and agree with the Visual PROMETHEE license.

Installing from the archive

Double-click the PROMETHEE.zip file to open the archive.
1. Unzip the contents of the archive into a folder.
2. Create the following folders:
   - C:\Users\<yourname>\AppData\Local\VPSolutions
   - C:\Users\<yourname>\AppData\Local\VPSolutions\Images
3. Copy the PROMETHEE.ini, VPimage.gif and VPimage.jpg files into the VPSolutions folder.

Size limits

Visual PROMETHEE has the following limits (Business and Academic Editions) relative to the dimensions of the decision problems it can handle:

- Maximum number of actions: 10000
  - Maximum number of categories: 50
- Maximum number of criteria: 10000
  - Maximum number of groups: 50
  - Maximum number of clusters: 50
- Maximum number of scenarios: 10
  - Maximum number of coalitions: 10
- Maximum number of evaluations: 100000
(the number of evaluations is the product of the number of actions by the number of criteria by the number of scenarios)

- Maximum number of **PROMETHEE Sort classes**: 10
- Maximum number of **PROMETHEE V constraints**: 50

Larger dimensions are available to **Custom Editions**. Please contact bmaresc@ulb.ac.be for inquiries.

**Getting help**

Help related to **Visual PROMETHEE** or to the use of the **PROMETHEE** and **GAIA** methods can be found:

- In this help file/manual. The manual is also available in PDF, ePub and Mobi formats.
- In the **PROMETHEE-GAIA FAQ** at [http://faq.promethee-gaia.net](http://faq.promethee-gaia.net)

Additional information can also be found:

- On the LinkedIn **PROMETHEE Decision Aid Methods group**

And you can follow us on Twitter at @bmaresc
**Terminology**

This is an alphabetical list of the main terms used in this document. Click a term to access its definition.

- **Action**
- **Category**
- **Class**
- **Cluster**
- **Coalition**
- **Constraint**
- **Criterion**
- **Decision-maker**
- **Decision problem**
- **Group**
- **Hierarchy**
- **Incomparability**
- **Preference function**
- **Profile**
- **Qualitative scale**
- **Reference set**
- **Scenario**
- **Weight**

**Action**

The term **action** is used to designate either a possible decision or an item to evaluate. **Visual PROMETHEE** compares different actions that are evaluated on several criteria.

Synonyms are: alternative, decision, item.

Actions can be created or modified from the **Actions** dialog. Click "Model | Actions..." to open the dialog.

**Category**

An action **category** defines a subset of actions that share the same symbol and colors in the analysis.

Categories can be created or modified from the **Action Categories** dialog. Click "Model | Action Categories..." to open the dialog.

**Class**

Classes represent types of actions (**profiles**) in the context of **sorting**. The objective is to assign each **action** to one class.

In **Visual PROMETHEE** classes can be:

- ordered from the best to the worst (for instance good customers, average customers and bad customers in a context of credit allocation),
- unordered (for instance different consumer profiles such as e.g. switchers, variety seekers, deal-prone, trend-setters, ...).

Classes can be created or modified from the **Classes** dialog. Click "Model | Classes..." to open the dialog.
A **cluster** defines a subset of criteria within one or several **criteria groups**. It is at the top level of the **Visual PROMETHEE hierarchy** of criteria.

A cluster can also be "grouped" to simplify the analysis and to facilitate sensitivity analyses: "grouped" clusters appear as a single item in all **Visual PROMETHEE** analyses.

Clusters can be created or modified from the **Clusters** dialog. Click "**Model | Clusters**..." to open the dialog.

**Coalition**

A coalition is a group of **decision-makers**. **Scenarios** in the same coalition share a same color, fill color and shape for easier identification in the **PROMETHEE** and **GAIA** analyses.

Coalitions can be created or modified from the **Coalitions** dialog. Click "**Model | Coalitions**..." to open the dialog.

**Constraint**

Constraints are used in the **PROMETHEE V** multiple selection procedure.

They are linear equations or inequalities that the **PROMETHEE V** selection must fulfill according to the requirements of the decision-maker.

**Criterion**

A **criterion** is an attribute associated to each action that makes it possible to compare the actions and to determine the best ones.

It can be quantitative (a number is associated to each action, such as the price of an item) or qualitative (in this case, a qualitative scale must be defined with a number of ordered levels such as for instance: very bad, bad, average, good, very good).

Criteria can be created or modified from the **Criteria** dialog. Click "**Model | Criteria**..." to open the dialog.

**Decision-maker**

In the context of **Visual PROMETHEE** a **decision-maker** is a person or an organization that is responsible for a decision or implied in the decision process.

For a given decision problem there can be either a single or multiple decision-makers.

In **Visual PROMETHEE** each decision-maker has to be associated to one **scenario** and thus can express his/her preferences and priorities independently from the other decision-makers.

Synonyms are **actor** or **stakeholder**.

**Decision problem**

In **Visual PROMETHEE** a **decision problem** is defined by:

- A set of **actions**: These are the possible decisions or choices, or are items to evaluate.
- A set of **criteria**: These are the attributes that are used to compare the actions. They represent the objectives of the **decision-maker**.
- One or several **scenarios**: Each scenario contains specific evaluations and preference information. Scenarios can represent the points of view of different decision-makers or different hypotheses.

General information related to the decision problem can be edited in the **Problem Info** dialog.

**Group**

A **criteria group** defines a subset of **criteria** that share the same outline color within a cluster in the analysis. A criteria group can also be "grouped" to simplify the analysis and to facilitate sensitivity
analyses: "grouped" criteria groups appear as a single item in all Visual PROMETHEE analyses.

Each criteria group belongs to a cluster. It is the intermediate level of the Visual PROMETHEE criteria hierarchy.

Criteria groups can be created or modified from the Criteria Groups dialog. Click "Model | Criteria Groups..." to open the dialog.

**Hierarchy**

The criteria hierarchy in Visual PROMETHEE has three levels:

- At the top level are the clusters. They are identified by a shape and a fill color.
- At the intermediate level are the criteria groups. Each criteria group belongs to a cluster. They are identified by their cluster shape and fill color and by a specific outline color.
- At the bottom level are the individual criteria. Each criterion belongs to a criteria group.

The Hierarchy Assistant can help you to define the criteria hierarchy.

**Incomparability**

Incomparability arises when the comparison of two actions is difficult, usually because they have quite different profiles and one is better than the other on several criteria while the other is better on other criteria.

It doesn't mean that the two actions cannot be compared. It means that the comparison is difficult. The introduction of incomparabilities in the PROMETHEE I Partial Ranking makes it easier for the decision-maker to detect difficult choices.

**Preference function**

A preference function has to be associated to each criterion in Visual PROMETHEE.

The preference function defines how pairwise evaluation differences are translated into degrees of preference. It reflects the perception of the criterion scale by the decision-maker.

Six different shapes of preference functions are available in Visual PROMETHEE to accommodate most practical situations.

The Preference Function Assistant is available for helping to choose the right preference function.
Profile
A profile is an action that is used to define a class. It can be either an actual action or a fictive one.

There are two types of profiles that can be used in PROMETHEE Sort:
- boundary: in that case, the profile is representative of the upper bound of the class,
- central: in that case, the profile is representative of an action belonging to the class.

In Visual PROMETHEE profiles appear as regular actions in the spreadsheet. They should be associated to the action category of the corresponding class.

Qualitative scale
Qualitative criteria are evaluated on a qualitative scale rather than with numbers.

In Visual PROMETHEE a qualitative scale is defined by:
- a number of ordered levels (from worst to best),
- numerical values associated to these levels,
- whether the numerical values should be minimized or maximized (scale orientation).

Different qualitative scales can be defined with Visual PROMETHEE using the Qualitative Scales dialog.

Reference set
The notion of reference set is used in Bank Adviser: it is a set of reference actions to which each action is compared.

The reference set can be for instance:
- a set of well-known actions,
- a subset of actions (for instance geographically defined),
- a set of reference points (fictive actions),
- a peer-group.

In Visual PROMETHEE the reference set has to be a category of actions.

Scenario
A scenario is a set of evaluations and preference parameters that is defined for a decision problem.

Scenarios can represent:
- the point of view of different decision-makers,
- different hypotheses.

Scenarios can be created or modified from the Scenarios dialog. Click "Model | Scenarios..." to open the dialog.

Weight
The weight of a criterion is a positive number that represents the criterion relative importance.

The Weighing Assistant can be used to assess the weights of the criteria.

Weights can also be allocated to the scenarios for instance to represent different decision making levels in a group decision problem.

The Balance of Power window can be used to assess the weights of the scenarios.
In Visual PROMETHEE weights are always automatically normalized so that their sum is equal to 1 (100%). The user can enter any positive number as a weight.
Tutorial

After you have installed Visual PROMETHEE on your computer, a Visual PROMETHEE icon will appear on the desktop.

Double-click the icon to start Visual PROMETHEE.

The tutorial is organized in five sections in the following order:

- The main window
- A guided tour
- Working with multiple scenarios
- Advanced features
- Starting a new problem

Several additional tutorial examples including exercises are available in the last section of this manual.

The main window

When you start Visual PROMETHEE the main window is displayed.
The main window is organized as follows, from top to bottom:

- The **Main Menu** is displayed on the top of the window.
- There are two **Toolbars** with important commands:
  - Data management on the upper row.
  - Analysis management on the lower row.
- The main part of the window is the spreadsheet:
  - Most data are displayed and can be edited from the spreadsheet.
  - On the top section are the current scenario name ("Bertrand" in the above screen shot) and the criteria names together with check boxes for activating/deactivating the criteria and unit and cluster/group information. Click on the buttons to access scenario or criterion dialogs.
  - The spreadsheet contains three collapsible sections: Preferences, Statistics and Evaluations. Click on the small icons in the leftmost column to collapse/expand these sections.
    - Preferences: For each criterion, the following data are available:
      - Min/max: select whether the criterion has to be minimized or maximized.
      - Weight: enter the weight of the criterion (weights are automatically normalized...
by the software).

- Preference Fn.: select the preference function type (or select "Help me" to use the Preference Function Assistant).
- Thresholds: select either "absolute" (thresholds expressed on the criterion scale of measurement) or "percentage" (thresholds expressed as percentages).
  - S: Gaussian: Gaussian threshold.

- Statistics: For each criterion, the following statistics are computed from the active actions: minimum and maximum values, arithmetic average and standard deviation.
- Evaluations: There is one row for each action. The check box is used to control the activation/deactivation of the action. Click on the name button to open the action dialog. The shape identifies the action's category. Evaluations can be entered in different ways:
  - For quantitative criteria, enter the numerical value.
  - For qualitative scales, a drop-down list allows to choose the evaluation.
  - Missing values are allowed: enter "?" for a missing value. "n/a" (not available) stands for missing values.

- At the bottom of the spreadsheet are tabs:
  - For each scenario, there is a tab. Click on the tab to switch to that scenario.
  - The "All" tab switches to the multi-scenarios analysis.

- The bottom of the main window displays a status bar with some general information related to the current problem (dimensions, locale and save status). The status bar is clickable.
A guided tour

When starting Visual PROMETHEE a demo dataset is automatically loaded.

The demo dataset is about the purchase of a new car. This problem has been used as an example in many PROMETHEE presentations (check the resources section at http://www.promethee-gaia.net to download presentations) and it was also provided as a tutorial with the Decision Lab software. So previous users should be familiar with it.

Let us suppose that somebody (the decision-maker) wants to purchase a new car and hesitates between six possible models (the actions):

- Two cars that we name Tourism A and Tourism B. These are classical family sedans.
- A more economical car that we name Economic.
- Two more luxury cars: Luxury 1 and Luxury 2.
And a more powerful car that we call Sport.

The names are chosen on purpose to reflect the characteristics of each car and to make it easier to understand how PROMETHEE and GAIA can help the decision-maker. In actual decision problems, the characteristics of the actions are usually much less obvious at first sight and PROMETHEE and GAIA will help you to discover these.

We suppose that the decision-maker has identified five criteria as important for choosing his/her new car:

- **Price**: That is the price of the car, expressed in Euros (€). Obviously the decision-maker prefers a lower price so this criterion should be minimized.
- **Power**: That is the power of the car, expressed in kW. This criterion should be maximized as more power is preferable.
- **Consumption**: Gas efficiency is measured the European way: it is the number of liters of gas consumed per hundred kilometers. It has thus to be minimized.
- **Habitability**: The perception of space is subjective and this criterion calls for a qualitative scale. Here we use the classical 5-point scale: very bad, bad, average, good and very good.
- **Comfort**: The comfort of each car is evaluated on the same 5-point scale (very bad to very good).

As you see Visual PROMETHEE can handle quantitative as well as qualitative criteria.

There is a column for each criterion and a row for each action (at the bottom of the spreadsheet).

The **Preferences** section contains information about the preferences of the decision-maker:

- **Min/max**: indicates whether the criterion should be minimized or maximized.
- **Weight**: the weight of a criterion is a measure of how much it is important with respect to the other criteria. In the demo all the weights are equal so that the five criteria are considered to be equally important. The weights can be adjusted according to the priorities of the decision-maker, to the position of the GAIA decision axis or to the results of a sensitivity analysis.
- **Preference Fn.**: Here you can see what type of preference function has been associated to each criterion.
- **Thresholds**: Absolute thresholds have been selected for all the criteria. The corresponding thresholds are thus expressed on each criterion's scale.
  - Q: Indifference threshold.
  - P: Preference threshold.
  - S: Gaussian threshold.

The **Statistics** section displays some basic statistics for the criteria:

- **Minimum**: for instance the cheapest car has a price of 15,000 €.
- **Maximum**: the most expensive car has a price of 38,000 €.
- **Average**: the average price (over all active actions) is equal to 28,083 €.
- **Standard Dev.**: the standard deviation of the prices of the active actions is equal to 7,407 €.

For each criterion, the best value is displayed in green and the worst one in red: for instance the Economic car is the cheapest one while the Luxury 1 is the most expensive.

Actions, criteria and scenarios (in this dataset there is only one scenario named Bertrand) names are actually buttons that you can click to open the corresponding Actions, Criteria and Scenarios dialogs in order to display and edit specific data.

The check boxes on the top row and in the leftmost column of the spreadsheet allow to control which criteria and/or actions are active. If you un-check one box, the corresponding criterion or action will be removed from the analysis. It is thus very easy to make what-if analysis and to see the impact of one action or criterion on the results of the analysis.
The colored symbols (circles, squares or diamonds) associated to the actions and the criteria correspond to the defined action categories and to the criteria hierarchy.

Let us now start the analysis of the data.

- Have a look at the PROMETHEE rankings.
- Learn to use the GAIA plane.
- Make a sensitivity analysis.

The PROMETHEE rankings

There are two PROMETHEE rankings that are computed:

- The PROMETHEE I Partial Ranking is based on the computation of two preference flows (Phi+ and Phi-). It allows for incomparability between actions when both Phi+ and Phi- preference flows give conflicting rankings.
- The PROMETHEE II Complete Ranking is based on the net preference flow (Phi).

Visual PROMETHEE offers several ways to display the PROMETHEE rankings.

PROMETHEE Rankings

Click "PROMETHEE-GAIA | PROMETHEE Rankings" to open this window.

The PROMETHEE Rankings window has two tabs that can be selected at the bottom of the window:

- PROMETHEE I Partial Ranking
- PROMETHEE II Complete Ranking
On the PROMETHEE I Partial Ranking tab (left figure), the leftmost bar shows the ranking of the actions according to Phi+: Tourism B is on top, followed by Luxury 1, Economic, Luxury 2, Sport and Tourism A. The rightmost bar shows the ranking according to Phi-: Tourism B is still on top, but it is followed by Tourism A, Luxury 1, Luxury 2, Sport and Economic.

We can conclude that:

- Tourism B is preferred to all the other actions in the PROMETHEE I ranking.
- Luxury 1 is on top of Luxury 2 but they are very close to each other.
- Tourism A is incomparable with the Luxury cars because it has a worse score on Phi+ and a better one on Phi-.
- Sport and Economic are also incomparable with each other but they are lagging with respect to the other ones. Indeed even if their Phi+ score are similar to the previous cars, their Phi- scores are well behind.

This is confirmed by the PROMETHEE II complete ranking (right figure). Three groups of actions appear clearly:

- Tourism B has a higher Phi score.
- Luxury 1, Tourism A and Luxury 2 have lower scores and are all very close to zero. They are more average actions.
- Economic and Sport have also very close but negative scores. They are at the bottom of the PROMETHEE II ranking.

While the PROMETHEE II complete ranking is easier to explain it is also less informative as the differences
between Phi+ and Phi- scores are not visible anymore. Incomparability in the PROMETHEE I ranking is interesting because it emphasizes actions that are difficult to compare and thus helps the decision-maker to focus on these difficult cases.

**PROMETHEE Diamond**

Click PROMETHEE-GAIA | PROMETHEE Diamond to open this window.

The **PROMETHEE Diamond** is an alternative two-dimensional joint representation of both PROMETHEE I and II rankings.

The square corresponds to the (Phi+,Phi-) plane where each action is represented by a point. The plane is angled 45° so that the vertical dimension gives the Phi net flow. Phi+ scores increase from the left to the top corner and Phi- scores increase from the left to the bottom corner.

For each action, a cone is drawn from the action position in the plane.

As the **Tourism B** cone overlaps all the other ones this action is preferred to all the other ones in the PROMETHEE I partial ranking.

On the contrary the intersecting yellow cones corresponding to **Sport** and **Economic** indicate an incomparability.

An advantage of the **PROMETHEE Diamond** is that it is easy to visualize the proximity between Phi+ and Phi- scores globally.

**PROMETHEE Network**
Click "PROMETHEE-GAIA | PROMETHEE Network" to open this window.

The PROMETHEE Network representation of the PROMETHEE I Partial Ranking will feel familiar to the users of older PROMETHEE software such as PromCalc or Decision Lab. Actions are represented by nodes and arrows are drawn to indicate preferences. Incomparabilities are thus very easy to detect.

Visual PROMETHEE uses an enhanced network representation: instead of drawing the nodes at arbitrary locations the relative positions of the actions in the PROMETHEE Diamond are used. The network representation is like a close-up of the Diamond view where preferences are indicated by arrows. This makes it very straightforward to appreciate the proximity between actions and thus the degrees of incomparability in the partial ranking.

PROMETHEE Rainbow

Click "PROMETHEE-GAIA | PROMETHEE Rainbow" to open this window.

The PROMETHEE Rainbow is a disaggregated view of the PROMETHEE II complete ranking.
Actions are displayed from left to right according to the PROMETHEE II ranking: Tourism B to Sport.

For each action the stacked slices show the components of the action net flow. For instance:

- **Tourism B** exhibits no negative slices as all criteria contribute positively to its net flow score. This action presents no weaknesses with respect to the other actions. The larger red slice indicates that Consumption is the most important feature of this action. Its Phi score is positive.

- **Tourism A** has very small slices. It has no real weakness but also no real advantage. It is quite average. Its Phi score is close to zero.

- **Economic** is much more of a mixed bag with a very good Price (the upper red slice) and a very low Power (the lower blue slice). Globally, the negative slice more than compensate the positive ones and the Phi score is negative.

**PROMETHEE Table**

Click PROMETHEE-GAIA | PROMETHEE Table to open this window.

The PROMETHEE Table displays the Phi, Phi+ and Phi- scores. The actions are ranked according to the PROMETHEE II complete ranking. This can be handy when the number of actions is large or to export the data to another program such as e.g. Excel (right-click the table to open the local menu and select Copy to copy the data to the clipboard).
The **GAIA** plane

The **GAIA** plane is a descriptive complement to the **PROMETHEE** rankings.

Click "**PROMETHEE-GAIA | GAIA Visual Analysis**" to open this window.

The **GAIA** analysis displayed when **Visual PROMETHEE** launches is a standard 2D (U,V) analysis.

**GAIA** starts from a multidimensional representation of the decision problem with as many dimensions as the number of criteria (five in this tutorial). A mathematical method called the Principal Components Analysis is used to reduce the number of dimensions while minimizing the loss of information.

In **Visual PROMETHEE** three dimensions are computed:

- **U** is the first principal component, it contains the maximum possible quantity of information,
- **V** is the second principal component, providing the maximum additional information orthogonal to **U**,
- **W** is the third principal component, providing the maximum additional information orthogonal to both **U** and **V**.

The standard **GAIA** analysis includes **U** and **V** only, as in older software such as PromCalc, Decision Lab, D-Sight or Smart Picker Pro. **Visual PROMETHEE** adds a third **W** component to improve the analysis when the (U,V) representation quality is too low.

The **U**, **V**, **W** list boxes are not functional yet. Currently optimal representations only are available.
The 2D views controls allow to switch between three 2D views:

- **U-V**: This is the best possible 2D view. In this tutorial it gathers 90% of information.
- **U-W**: With respect to the U-V view, it is viewed from the side (W is orthogonal to both U and V), it is of lower quality and it gathers only 70% of information in this tutorial.
- **W-V**: With respect to the U-V view, it is viewed from the top, it is thus the lowest quality 2D view available in Visual PROMETHEE and it gathers here only 37% of information.

Look at how the quality level is displayed at the bottom right of the window: its color changes from green to red to indicate the level of quality. Lower levels such as in the W-V plane make it difficult to draw reliable conclusions from the GAIA plane. In practice the 2D GAIA analysis is reliable when the quality level is above or close to 70%.

The above screenshot shows the U-V plane. It contains three types of information:

1. **Actions** are represented by points.
2. **Criteria** are represented by axes.
3. The **weighing** of the criteria and the PROMETHEE II ranking are represented by the decision axis.

**Actions**

Each action is represented by a point in the GAIA plane. Its position is related to its evaluations on the set of criteria in such a way that actions with similar profiles will be closer to each other. In this tutorial example we can identify four different types of profiles:

- Luxury cars (Luxury 1 and 2) are very close to each other. They are quite similar actions.
- Tourism cars (Tourism A and B) are also close to each other. They are also similar actions.
- The **Economic** car is on its own. It seems quite different from the other actions.
- The **Sport** car is also very different from the other actions.

To better understand the differences between these four groups of actions, we can have a look at the criteria.

**Criteria**

Each criterion is represented by an axis drawn from the center of the GAIA plane. The orientation of these axes is important as they indicate how closely the criteria are related to each other:

- Criteria expressing similar preferences have axes that are close to each other.
- Conflicting criteria have axes that are pointing in opposite directions.

It is thus possible to identify groups of criteria expressing similar preferences and to better understand the conflicts that have to be solved in order to make a decision. In this tutorial, three such groups can be identified:

- **Habitability** and **Comfort** are close to each other. This means that based on the data cars exhibiting a higher comfort level have also a higher habitability level. It is thus possible to find solutions (cars) that are good on both criteria at the same time. These criteria could be associated to the general objective of "Luxury".
- **Price** and **Consumption** are also relatively close to each other. So we can expect cheaper car to be more fuel efficient. Or... more expensive cars to be less fuel efficient. These two criteria could be associated to a general objective of "Economy".
- Finally, **Power** is on its own and seems to be conflicting with most other criteria.

Given the different orientation of the three aforementioned groups, we can conclude that the decision maker will have to conciliate three conflicting objectives: luxury, economy and power.
The length of the criteria axes is also relevant. Indeed the longer an axis the more discriminant the criterion. For instance the axis for **Power** is longer than the axis for **Consumption**: the range for **Power** is 60 kW (twice the P threshold for that criterion) while the range for **Consumption** is 2L (once the P threshold). The variations observed on the **Power** criterion are thus felt more important for the decision maker than variations observed on criterion **Consumption**. Discrimination is different from the weight of the criterion. The **Price** criterion can be very important for the decision maker but if all prices are in a 100€ range this criterion will not be discriminant at all.

### Actions and criteria

The relative positions of actions and criteria are also interesting to analyze.

Indeed the orientation of a criterion axis indicates where the best actions for this criterion are located.

Let us take criterion **Price** as an example. Right-click on the **GAIA** plane to open the local menu and select "Show axis | Price". A line is drawn along the **Price** axis and the actions are projected orthogonally to that line.

What is important is not how far an action is from the criterion axis but rather how it projects itself on the direction of the axis. In this tutorial example, we see that:
- **Economic** is clearly the cheapest car as it project completely to the left side.
- **Tourism A and B** the second best choices with respect to **Price**. They are very close to each other.
- **Sport** is slightly more expensive than the Tourism cars.
- **Luxury 1 and 2** are very close to each other and are the most expensive cars.

This information is of course highly dependent on the quality of the GAIA plane. For lower quality level one can expect more distortions with respect to actual evaluations. Indeed a lower quality level means that it is more difficult to have an accurate 2D representation of the multicriteria problem.

Looking globally at the different criteria it is now possible to better explain the different action profiles:

- Luxury cars (**Luxury 1 and 2**) are good on **Comfort** and **Habitability** and not so bad on **Power**. But they are weak on **Price** (expensive) and **Consumption**.
- Tourism cars (**Tourism A and B**) are more average (central) cars.
- The **Economic** car is the best for **Price** (it is the cheapest), its is good on **Consumption** but really bad on the other criteria.
- The **Sport** car is the most powerful one. But that is its only good feature.

### Decision Axis

The decision axis (the thicker red axis) is a representation of the weighing of the criteria. It is similar to a criterion axis but for an important point: the representation of the decision axis is not optimal. When the weight of the criteria are modified, the GAIA plane is not. Only the decision axis is modified. Thus shorter decision axes are less reliable.

The orientation of the decision axis indicate which criteria are in agreement with the PROMETHEE rankings and which are not. In this tutorial, the decision axis is opposite to the **Price** and **Power** criteria which means that one can expect to find rather expensive and not so powerful cars at the top of the PROMETHEE rankings. If this is not consistent with the decision maker objectives it probably means that these criteria have been under-weighed.

The decision axis can thus be used as a tool to analyze the type of compromise corresponding to the current weighing of the criteria and to help to better define the weights of the criteria.

The decision axis is actually the projection of the Decision Stick (i.e. the axis representing the weights of the criteria in the criteria space) onto the GAIA Plane. A three-dimensional representation of the Decision Stick can be displayed in the GAIA window (at the lower right corner in the above screenshots).

### Additional analysis

The GAIA window includes many other analysis possibilities that are described in the corresponding page. More information about the theoretical foundations of GAIA can also be found here.

### The Walking Weights

Visual PROMETHEE provides you with several tools to perform an extensive weight sensitivity analysis on your data.

**Walking Weights**

Click "PROMETHEE-GAIA | Walking Weights" to open this window.
The **Walking Weights** window allows you to change the weights of the criteria and see the impact on the **Visual PROMETHEE** analysis.

The window is split into two parts:

- The upper part is a bar chart showing the **PROMETHEE II** Complete Ranking.
- The lower part is a bar chart showing the weights of the criteria.

The slider allows to change the weight of the selected criteria and to see the impact on the **Visual PROMETHEE** analysis. All opened windows are automatically updated.

A more precise and thorough weight stability analysis can be done using the **Visual Stability Intervals**. The screenshot below shows the visual stability analysis for criterion **Price**.
The horizontal axis is the weight of the criterion from 0% to 100%.

The vertical axis is the PROMETHEE net flow.

For each active action a line is drawn that shows how the net value change when the weight of the criterion is modified. In this case it can be seen that Tourism B is at the top of the PROMETHEE II ranking for a wide range of weight.

**Working with multiple scenarios**

To learn about working with multiple scenarios in Visual PROMETHEE you are first going to load another dataset.

In the **Main Menu**, click **File** and then **Open**. Find the TutorSites.vpg file (it should be located in the Visual PROMETHEE install folder) and open it.
This dataset corresponds to a location problem. An industrial company wants to build a new plant and hesitates between five different locations (Site 1 to Site 5).

Six criteria are considered relevant to compare the five locations:

- **Investment**: This is the investment cost in million Euros. It should be minimized.
- **Operations**: This is the annual operating cost. It is also expressed in million Euros and has to be minimized as well.
- **Employment**: This is the number of workers required to run the plant. Different locations correspond to different plant configuration or different technologies, so the choice has an impact on that number. As it is linked to salaries and to social costs, this criterion should be minimized.
- **Transportation**: This is a qualitative criterion that evaluates the site adequacy with respect to transportation. It encompasses factors such as the proximity to transportation networks, the distance to suppliers and to customers, etc. It is expressed on a 5-point scale (very bad to very good).
- **Environment**: This is a global evaluation of the environmental impact, on a 5 point impact scale: from very low (best) to very high (worst).
- **Social**: This is a global evaluation of the social impact, on the same 5 point impact scale: from very low (best) to very high (worst).
At the bottom of the spreadsheet, there are five tabs corresponding to five different scenarios. Each scenario represents the point of view of one stakeholder:

- **Industrial**: This is the point of view of the actual decision maker, of the company that wants to build the new plant.
- **Political**: This is the point of view of the regional political authority that has to allow the permit for building the plant.
- **Environmental**: This is the point of view of environmental associations within the region. They have some influence on the industrial decisions made in the region.
- **Social**: This is the point of view of the worker's unions. They also have some influence on industrial decisions as these are linked to the creation of jobs in the region.

Click on the tabs to switch from one scenario (point of view) to another. As you can see the preference parameters and even the criteria evaluations for more subjective criteria do change from one scenario to another.

The complete **Visual PROMETHEE** analysis is performed separately for each scenario. Here are the **PROMETHEE Diamonds** for scenarios **Industrial** (left) and **Social** (right):
For the **Industrial** scenario, **Site 3** is clearly the best choice, and **Site 1** is the worst one. There is a slight incomparability between **Site 5** and **Site 4**.

For the **Social** scenario, there is no incomparability and **Site 2** is the preferred choice. There is also a wider spread between the best and worst actions. That means that stronger preferences are expressed to differentiate actions in this scenario.

The "**All**" tab can be selected to perform the analysis on all the scenarios at the same time. In this case the weighing of the scenarios is taken into account to produce a consensus **PROMETHEE** ranking and several **GDSS** analyses. Here is the **PROMETHEE Diamond** for the consensus ranking:
Two actions appear clearly at the top of the ranking: **Site 2** and **Site 3**. They are incomparable in **PROMETHEE I**. That can be explained easily: **Site 2** is the best choice for scenarios **Environmental** and **Social** while **Site 3** is the best for scenarios **Industrial** and **Political**. It is thus very difficult to choose between these two actions. That is reflected in the **PROMETHEE I** partial ranking.

Besides the **PROMETHEE** rankings there are several **GDSS** extensions to the **GAIA** analysis that can be helpful to better understand the different points of view in a **GDSS** context. When the "All" scenarios tab is selected in the **Visual PROMETHEE** spreadsheet the following four "Multi-scenarios" options become available on the right side of the **GAIA** window:

- **Criteria**
  This is the regular **GAIA-Criteria** display where axes correspond to the criteria (or groups). In the GDSS context however this display will not show any evaluation differences between scenarios. Instead "average" evaluations will be shown. This can be misleading in case of subjective evaluations. Here is the **GAIA-Criteria** plane for the tutorial example:
There are not so many conflicts apparent as all criteria axes are oriented to the right. **Site 2** and **Site 3** also appear to be the best choices globally. But no information is available on the way each criterion has been evaluated by the different decision makers.

- **Scenarios**

  In this **GAIA-Scenarios** analysis axes correspond to the scenarios. They show the disagreements between the different scenarios. Here is the result for the tutorial example:
Two groups of decision makers appear: Industrial and Political are very close to each other and prefer Site 3 while Environmental and Social prefer Site 2. Globally there is no very strong conflict as all the axes are oriented to the right.

- **A: single action**
  
  *This analysis is not implement yet.*

- **C: singe criterion**
  
  In the GAIA-Unicriterion analysis a single criterion is compared over the different scenarios. This can be helpful to identify the sources of disagreement within a group of decision makers. Here are two very different examples. First the Investment criterion is selected.
This is an "objective" criterion for which the evaluations are the same in all the scenarios. The only differences can arise from the choice of the preference functions. In this case, all the actions are on a straight line as they are evaluated in the same way in all the scenarios.

For the second example the criterion Employment has been selected. The positions of the axes indicate that this criterion has been evaluated very differently in the four scenarios.
Site 4 is preferred by Political and Industrial. But not by Environmental and Social. Site 1 and Site 5 are preferred by Environmental but not at all by Political.

This shows that this criterion is evaluated very differently from one decision maker to another. Possibly because they do not understand the definition of the criterion in the same way. This can be a source of conflict and can make the decision making process more difficult. The GAIA-Unicriterion analysis can help to discover such situations and be a basis for establishing a better discussion basis: for instance the definition of the criterion could be modified or the criterion could be split into sub-criteria or the evaluation could be reviewed by the decision maker.

Several additional tools are also available in the GDSS context:

- Scenarios comparison
- Balance of Power

Advanced features

Visual PROMETHEE includes several more advanced or more specialized tools:

- Action Profiles: a disaggregated view of the strengths and weaknesses of an action. Multiple windows make it possible to compare up to five actions.
• **GAIA Webs**: an alternate profile view that relies on the GAIA analysis to draw spider-web charts that are easier to understand. Multiple windows make it possible to compare up to five actions.

• **PROMETHEE V Multiple Selection** under Constraints: Sometimes the problem is not to identify the "best" action but rather to select a "best" subset of actions according to additional constraints such as budget limits or diversification. This is sometimes known as portfolio analysis (in the context of R&D projects for instance)

• **PROMETHEE Sort**: can be used to sort the action into predefined classes. The classes can be either ordered or not. They can be defined by either boundary or central profiles.

• **Bank Adviser**;

• **Performance Analysis**: This is a DEA-like analysis where two clusters of criteria are compared: input criteria and output criteria. An efficiency measurement is derived from the PROMETHEE analysis of the two clusters of criteria. A graphical analysis (efficient frontier) is also available.

• **PROMap GIS Integration**: When the actions are geolocalized it is possible to set their position using a Google Maps interface from the Actions dialog and to display the PROMETHEE or GAIA results on the map with PROMap.

Besides there are several data management tools that can be useful:

• **Activation Center**: a central place to control easily the activation of actions, categories, criteria, groups, clusters, scenarios and coalitions.

• **Filters**: to automatically deactivate actions based on criteria minimum or maximum values.

• **Sort**: to change the display order of actions, categories, criteria, groups, clusters, scenarios or coalitions.

• **Snapshots**:
  - **Weight Presets**: to save up to five different criteria weighings for easy comparison.
  - **Layouts**: to save up to five different windows layouts for specific analyses.

There are also four assistants that can help you to set up your decision problem and to analyze it correctly:

- **Creation Assistant**
- **Hierarchy Assistant**
- **Weighing Assistant**
- **Analysis Assistant**

The **Preference Function Assistant** is also available from the Visual PROMETHEE spreadsheet (select "Help me..." in the Preference Function cell) to help you make the right choice of preference function and thresholds.

**Starting a new problem**

Let us go through the process of defining a new problem and analyzing it with Visual PROMETHEE.

1. **The problem**

Aouatif is a young Ph.D. student in biology. She wants to use the PROMETHEE-GAIA methodology for her research. She doesn't know which software to use and she decides to make a multicriteria evaluation of the available software.

The following software are available:

- **PromCalc**: a very old piece of software (last century tech) but yet very simple to use, provided you can still install it on a recent computer.
- **Decision Lab 2000**: more recent, but not supported anymore and a bit limited with respect to today's standards.
- **D-Sight**: this newer program is not very nice-looking and it is relatively expensive but is backed
by a "dream team" of young entrepreneurs driving (low end) BMW's... who knows where they will be next year?

- **Smart-Picker Pro**: that's the outsider. Nobody knows where it comes from... It looks OK even if a bit on the rough edge but... is it coming from the dark side of the PROMETHEE force?
- **Visual PROMETHEE**: the newest and most complete implementation of the PROMETHEE and GAIA methods, but still in a late beta stage.
- **DIY**: of course Aouatif could also develop her own software using MS Excel, MathLab or a programming language. (for non-English speakers: DIY = Do It Yourself)

2. **The model**

- **The actions**
  The actions of the problem are the different software available. There are thus six actions.

- **The criteria**
  What is important to keep in mind when comparing software? For Aouatif the following criteria should be considered:
  - **Price**: how much does it cost?
  - **Support**:
    - **Scientific**: is it backed by experts?
    - **Technical**: do they have a sufficient technical support level?
  - **Functions**:
    - **Data management**: how easy is it to import/export/manage data?
    - **Analysis**: what types of analyses are available?
  - **Interface**: is it easy to use?
  - **Installation**: Windows 8 compatible?
  - **Documentation**: is documentation available (manual/help/tutorials)?
  - **Localization**: is it available in my language?
  - **Evolution**: will they still be there next year?

- **Defining a new problem in Visual PROMETHEE**
  Let us define a new problem: click the menu item "File | New". A window appears where you should set the numbers of actions, criteria and scenarios.

There are six actions (the software to compare), ten criteria and a single scenario (Aouatif is the only one to decide). Adjust the fields as in the above screen-shot and click "OK". An empty spreadsheet appears (see below).
You should first change the names of the actions, criteria and scenario from their default values. To do that:

- for the actions, open the Actions dialog by either selecting from the menu "Model|Actions..." or clicking on an action name button ("action1", ...) in the spreadsheet.
- for the criteria, open the Criteria dialog by either selecting from the menu "Model|Criteria..." or clicking on a criterion name button ("criterion1", ...) in the spreadsheet.
- for the scenario, open the Scenarios dialog by either selecting from the menu "Model|Scenarios..." or clicking on the scenario name button ("Scenario1") in the spreadsheet.

Enter appropriate actions, criteria and scenario names. The resulting spreadsheet should look like the one below.
You still have to enter the evaluations. But...

- **The scales**
  
  Before we go further we have to think about scales.

  Some are obvious as the **Price** criterion: it is simply the price of the license expressed here in Euros (€). But most others here are qualitative scales and you have first to define them.

  For many qualitative criteria a 5-point scale (very good, good, average, bad, very bad) is appropriate. That is why it is predefined in **Visual PROMETHEE**.

  To define the scales of the criteria do the following. For each criterion open the **Criteria** dialog by either selecting from the menu "Model|Criteria..." or clicking on a criterion name button ("Price", ...) in the spreadsheet. Then select the right **Scale** type:

  - "currency" for the **Price** criterion,
  - "qualitative" for the other criteria, once "qualitative" is selected the qualitative scales drop-down list is activated just below the "Scale" field and you should select "5-point" from this list.
  - For the **Localization** criterion, it is more simple: it can be localized to your country/language or not, so you should select the "y/n" (yes/no) scale.

  Once the scales are properly defined, the evaluation table can be filled. According to the software characteristics, Aouatif has filled the table as it appears below:
Aouatif wants to visually identify the free software from the paid ones so she decides to create two categories of actions:

- **Free**: this category includes **PromCalc**, **Decision Lab 2000** (as both are discontinued) and **Visual PROMETHEE** (Academic Edition).
- **Paid**: this includes **D-Sight** and **Smart-Picker Pro**.
- The DIY solution is different as it involves development time. As such it will be left outside of the two categories.

To define categories:

- Open the **Action Categories** dialog using the menu item "**Model | Action Categories...**".
- Click "**New**" to create a new category and enter "**Free**" in the "**Name**" field.
- Choose a shape and a color to identify this category.
- Repeat the procedure for the "**Paid**" category.
- Click "**Close**" to close the dialog.

Now that the categories are created the next step is to assign actions to the categories:

- Click the "**PromCalc**" button to open the **Actions** dialog.
- In the **Category** drop-down list select "**Free**".
- Click "**Close**".
- Repeat the procedure for "**Decision Lab 2000**" and for "**Visual PROMETHEE**".
- Notice how the symbol and/or color change for these actions.
- Repeat the procedure for "**D-Sight**" and "**Smart-Picker Pro**" with the "**Paid**" category.

As there are many criteria and some are closely related to each other we are also going to define two groups of criteria:

- **Support**: Support includes scientific support (availability of scientific experts to
answer calls) as well as technical support (availability of computer scientists to answer technical calls).

- **Function**: Includes data management functions (import/export) as well as analysis capabilities.

**Visual PROMETHEE** allows for a three-level hierarchy of criteria with groups and clusters. For this case we only need a two-level hierarchy with some criteria grouped together. Here is how you should proceed in such a case:

- Open the **Clusters** dialog using the menu item "Model | Clusters...".
- Click "New" to create a new cluster and enter "Support" in the "Name" field.
- Choose a shape and a color to identify this cluster.
- Click "Clone" to automatically generate a criteria group with the same name.
- Repeat the procedure to create another cluster named "Function".
- Click "Close" to close the dialog.

Now that the clusters are created the next step is to assign criteria to the clusters:

- Click the "Scientific" button to open the **Criteria** dialog.
- In the **Group** drop-down list select "Support".
- Click "Close".
- Repeat the procedure for "Technical".
- Notice how the symbol and/or color change for these criteria.
- Repeat the procedure for "Data" and "Analysis" with the "Function" group.

What about preferences? Currently all criteria are set to be maximized. They have equal weights and the preference functions are all set to "Usual". Let us proceed now with preference modeling.

- **The preference parameters**
  
  For each criterion, you have to:

  - decide whether it has to be maximized or minimized,
  - choose a preference function and set the values of the corresponding thresholds.

  For this problem, it is obvious that **Price** should be minimized: indeed Aouatif prefers to pay less for the software and to save money. The other criteria use qualitative scales that were set up in such a way that they should be maximized. In the **Visual PROMETHEE** spreadsheet change the "Min/Max" field for criterion **Price** so that it reads "min" instead of "max".

  The choice of the preference functions is a more difficult step. For qualitative criteria including a small number of evaluation levels the **Usual** preference function is usually a good choice. But for the **Price** criterion small price differences should not be accounted for as much as larger ones. For such a criterion the **Linear** preference function is appropriate. Click on the "Preference Fn." cell for criterion **Price** and change the value from **Usual** to **Linear** in the drop-down list. You now have to change the default values for the indifference (Q) and preference (P) thresholds. Aouatif feels that a 10€ price difference is negligible (she doesn't mind to pay 10€ more) but a 50€ price difference is quite important with respect to the license price range of the software. So Q will be set to 10€ and P to 50€. Change the values accordingly in the spreadsheet (Hint: change P first as Visual PROMETHEE won't allow a Q value larger than the current P value).

  For the moment we will leave the weights to their initial values (1.00). All criteria thus have the same weight. We will change this later.

  The resulting dataset shown in the screenshot below is available as the "Aouatif" Visual PROMETHEE file that is installed together with the software.
3. **The analysis**

Let us now start the analysis.

- **GAIA**

  The GAIA analysis is usually a good starting point because it is descriptive and can help the decision-maker to better understand the decision problem. Here is the GAIA plane:
A first and important step is to verify the quality level of the **GAIA** plane. It is displayed at the bottom right of the **GAIA** window. In this case it is equal to 79.2% which is rather good.

In the **GAIA** plane, the six software are relatively far away from each other with the exception of the two **Paid** software (red diamonds) that are closer to each other. This indicates that most software are quite different from each other. Let us try to explain these differences.

Looking at the criteria, each criterion is represented by an axis. Three groups are detected:

- **Price**, **Scientific** and **Analysis**: it is interesting to note that the the **Free** software (green circles) are also the ones with the best **Scientific** support and **Analysis** capabilities.
- **Technical**, **Data**, **Installation**, **Localization** and **Evolution**: These criteria are oriented towards the right. They separate the older software (on the left side) from the newer (on the right side).
- **Interface** and **Documentation**: These two criteria are in the middle with respect to the two previous groups. Clearly the best documentation and interface are those of **Visual PROMETHEE**.

Finally we can have a look at the **Action Profiles** or **GAIA Webs** of the different actions:
- **PromCalc**: Cheap solution, with a very good scientific background and decent analysis capabilities but very old.

- **Decision Lab 2000**: Better interface and documentation than PromCalc but still very old.

- **D-Sight**: Expensive and not backed by the scientific expertise of the authors of the PROMETHEE methods. Technically a good solution (support, data interface and hardware compatibility) even if a bit rough on the interface and weak with respect to documentation. Besides who knows what these guys will do next year?

- **Smart-Picker Pro**: Similarly priced and scientifically backed as D-Sight it seems more limited with respect to functions. Besides nobody knows who manages the
company or where it is located...

- **Visual PROMETHEE**: Backed by the authors of the PROMETHEE methods, this one is the logical evolution of **PromCalc** and **Decision Lab 2000**. The interface is well polished, it includes several new developments, assistants, an extensive documentation, and it can be localized (currently available in five languages). It is also free for non-profit academic purposes.

- **DIY**: The **Do It Yourself** alternative is interesting because it can be tailor-made and it is easy to adapt to future needs. But it is a lot of work and there is no scientific background available to check the results.

Looking at the position of the decision axis and the orientation of the criteria axes, the current weight distribution seems consistent with the objectives of Aouatif. However, a weight sensitivity
analysis could be conducted to check the robustness of the PROMETHEE rankings.

- **PROMETHEE Rankings**
  The PROMETHEE I ranking shown below is rather clear. Three groups of software appear:
  
  - At the top, Visual PROMETHEE dominates the others.
  - In the middle, four software are very close to each other. There are no incomparabilities among them.
  - At the bottom, PromCalc is dominated by all the others.

- **Sensitivity Analysis**
  Let us now check how much the PROMETHEE rankings are affected by the weights of the criteria. What if for instance more weight is given to the Price criterion?

  The Visual Stability Intervals window can be used for this purpose. The screenshot below shows the display for criterion Price. It can be seen that Visual PROMETHEE is at the top of the PROMETHEE II ranking whatever the weight of the criterion is set to.
You can check that is the same for the following criteria: Scientific, Analysis, Interface, Installation, Documentation, Localization and Evolution.

For Technical, Visual PROMETHEE is a the top for weight values less than or equal to 67.86%. For larger weight values, D-Sight is first ranked and Visual PROMETHEE is second.

For Data, the weight has to be larger than 59% to see D-Sight and DIY at the top of the ranking.

Globally Visual PROMETHEE stays at the top of the ranking except for some very uneven weight distributions where most weight is allocated to Technical or to Data.

4. **The conclusion**

What do you think?

What software would you be using if you were Aouatif?
How to

This section contains more detailed explanations about how to manage activities with Visual PROMETHEE:

- Define a new problem
  - Define the actions
  - Define the criteria
  - Define the scenarios
  - Model preferences
  - Organize the criteria
  - Weigh the criteria
- Rank different actions
- Use the GAIA analysis
- Perform a sensitivity analysis
- Use weight presets
- Generate a report

Define a new problem

To define a new problem in Visual PROMETHEE, first use the "File | New..." command to generate a new empty spreadsheet. The Create a new problem dialog allows you to specify the number of actions, criteria and scenarios that should be included in the new problem. These can be adjusted later if necessary.

The following screenshot shows a newly created problem with five actions, three criteria and two scenarios. As it can be seen default names and data have been automatically generated.
The following steps should then be performed in order to properly model the problem:

1. **Define the actions**
2. **Define the criteria**
3. **Define the scenarios**
4. **Model preferences**
5. **Organize the criteria**
6. **Weigh the criteria**

**Define the actions**

Click on the name of an action or select "Model | Actions..." to open the **Actions** dialog and select the **action** you want to modify in the **Select** drop-down list. This dialog allows to change the properties of the actions.
The following information should be defined for each action in the decision problem:

- **Name**: the name of the action.
- **Shortname**: a shorter name that can be displayed to reduce the clutter on some graphics when there are many actions.
- **Active**: only active actions are considered in the computation of the results. Uncheck the box if the action should not be considered in the computation.
- **Description**: a text giving a more detailed description of the action.
- **Category**: each action belongs to a category (the default category is named **none**). This is useful to visually identify actions according to specific attributes (geographical location, nationality, technology, ...) as each category can be associated to a specific shape and specific colors. The action category can be selected in the drop-down list. New categories can be created using the "Model | Action Categories..." command (see the Action Categories dialog).
- **Location**: For geo-localized data, it is possible to associate a map location to each action. Click on the Location button to open the Location dialog and set the geographical coordinates of the action.

From this dialog you can also add a new action or delete the currently selected one.

**Define the criteria**

Click on the name of a criterion or select "Model | Criteria..." to open the Criteria dialog and select the criterion you want to modify in the Select drop-down list. This dialog allows to change the properties of the criteria.
The following information should be defined for each criterion in the decision problem:

- **Name**: the name of the criterion.
- **Shortname**: a shorter name that can be displayed to reduce the clutter on some graphics when there are many criteria.
- **Active**: only active criteria are considered in the computation of the results. Uncheck the box if the criterion should not be considered in the computation.
- **Description**: a text giving a more detailed description of the criterion.
- **Group**: each criterion belongs to a group (the default group is named none) and each group belongs to a cluster. This is useful to visually identify criteria that are linked to each other (such as for instance financial, technical, environmental or social criteria) within the Visual PROMETHEE criteria hierarchy with specific shapes and colors. The criterion group can be selected in the drop-down list. New groups can be created using the "Model | Criteria Groups..." command (see the Criteria Groups dialog).
- **Unit**: this is the name of the criterion unit.
- **Scale**: The drop-down list allows to select one of three possible scale type:
  - numerical: this is for quantitative criteria expressed on a numerical scale, evaluations will be displayed as numbers.
  - currency: this is for money! Evaluations will be displayed as the currency specified in the localization options,
  - qualitative: qualitative criteria can be evaluated on a qualitative scale, select the name of the scale in the drop-down list below. Qualitative scales can be defined using the Qualitative Scales dialog.
- **Decimals**: the number of decimal places displayed for the criterion.

From this dialog you can also add a new criterion.

**Define qualitative scales**

To define qualitative scales you can use the "Model | Qualitative Scales..." command and open the Qualitative Scales dialog.
From this window you can:

- Select one of the four predefined scales (yes/no, impact, 5-point or 9-point).
- Define a new qualitative scale:
  - Click the "New" button.
  - Give a name and a unit name to the new scale.
  - Set the number of levels (max. 10).
  - Define the levels and the associated values.
  - Define whether the scale values have to be minimized or maximized.

**Define the scenarios**

Visual PROMETHEE allows to define several scenarios for a given decision problem.

All the scenarios share:

- The set of actions, and action categories.
- The set of criteria, criteria groups and clusters.
- The qualitative scales.

The scenarios include specific values for:

- The evaluations of the actions.
- The criteria preference structures, including the preference functions and the weights.

Scenarios can be used to represent:

- Several points of view: each scenario corresponds to one stakeholder and incorporates his//her perceptions and preferences.
- Several hypotheses: such as for instance different forecasts for future or expected values.
- Several time periods.
- ...

Click on the name of the current scenario (at the top left of the spreadsheet) or select "Model | Scenarios..." to open the Scenarios dialog and select the scenario you want to modify in the Select dropdown list. This dialog allows to change the properties of the scenarios.
The following information should be defined for each scenario in the decision problem:

- **Name**: the name of the scenario.
- **Shortname**: a shorter name that can be displayed to reduce the clutter on some graphics when there are many scenarios.
- **Active**: only active scenarios are considered in the computation of the results. Uncheck the box if the scenario should not be considered in the computation.
- **Description**: a text giving a more detailed description of the scenario.
- **Weight**: relative weight of the scenario.
- **Coalition**: the coalition to which the scenario belongs.

From this dialog you can also add a new scenario or delete the currently selected one.

New scenarios can be added by:

- Clicking on the **New** button in the **Scenarios** dialog.
- Clicking the “Add scenario” button in the main window **toolbar**.
- Selecting “Edit | Duplicate Scenario” in the **Main Menu** to duplicate the current scenario.

**Model preferences**

Once the set of actions and the set of criteria have been defined it is important to model preferences.

This is done in two steps with **Visual PROMETHEE**:
1. A **preference function** has to be associated to each criterion.
2. The criteria have to be weighed according to the **decision-maker** priorities.

This has to be done separately for each scenario.

**Preference functions**

Six different types of **preference function** are available in **Visual PROMETHEE**.

Use the **Preference Function Assistant** to get advice on the best choice.

**Weights**
Weights have to be allocated to the criteria in order to reflect their relative importance for the decision maker.

When the number of criteria is large, it can be more difficult to allocate the weights. In such cases, however, criteria can often be organized hierarchically into clusters and groups. This makes it easier to allocate the weights and to ensure that no bias is induced by the number of criteria.

Use the Weighing Assistant to help you allocating weights.

Organize the criteria

Visual PROMETHEE allows to organize criteria into a three-level hierarchy. This is especially useful when the number of criteria is large. In such cases criteria can usually be grouped according to higher level objectives.

For instance in a context of sustainable development three higher objectives can be identified:

- Financial: criteria that measure the financial impact of the decisions.
- Environment: criteria that measure the environmental impacts of the decisions.
- Social: criteria that measure the social impacts of the decisions.

In Visual PROMETHEE these can be associated to clusters of criteria. This is the higher level of the hierarchy.

Within each cluster, several sub-groups of criteria can often be defined. For instance in the Environment cluster of criteria, the following criteria groups could be defined:

- Air: environmental impacts linked to the air quality.
- Water: environmental impacts linked to the water quality or availability.

This is the intermediate level of the hierarchy.

At the bottom level are the individual criteria:

- Each individual criterion belongs to one group.
- Each group belongs to one cluster.
In Visual PROMETHEE clusters and criteria groups are identified by colors:

- Each cluster is identified by a shape and background color.
- Each criteria group is identified by an outline color.

Clusters and criteria groups can also be analyzed as a whole using their **Grouped** property. This makes sensitivity analyses much easier.

The **Weighing Assistant** allows to allocate hierarchically the weights to the criteria.

**Weigh the criteria**

Weights have to be allocated to the criteria in order to reflect their relative importance for the decision maker. Use the **Weighing Assistant** to help you allocating weights.

**Rank different actions**

Once the actions and criteria have been defined and the preference parameters (preference functions and weights) have been set, it is possible to rank the actions using the PROMETHEE method.

**PROMETHEE Rankings**

Click “PROMETHEE-GAIA | PROMETHEE Rankings” to open the PROMETHEE Rankings window.

There are two tabs at the bottom of the window:

- **PROMETHEE I Partial Ranking**
- **PROMETHEE II Complete Ranking**

**PROMETHEE I Partial Ranking**

The **PROMETHEE I Partial Ranking** is based on the computation of two preference flows:

- **Phi+** (positive or leaving flow) is a measure of strength. It is represented on the left-side bar with the best (largest) values in green at the top of the bar and the worst in red at the bottom.
- **Phi-** (negative or entering flow) is a measure of weakness. It is represented on the right-side bar with the best (smallest) values in green at the top of the bar and the worst in red at the bottom.
Both $\Phi^+$ and $\Phi^-$ can be used to rank the actions. However they don't always provide exactly the same ranking. Indeed because of the conflicting aspect of a multicriteria problem it is not always easy to compare two actions: one can be much better on one subset of criteria and the other can be much better on another subset of criteria. In such cases and according to the preference parameters defined by the decision-maker different ways of evaluation (such as $\Phi^+$ and $\Phi^-$) can lead to different rankings.

PROMETHEE I tries to be prudent in such cases: it compares the two rankings induced by $\Phi^+$ and $\Phi^-$ and only includes preferences that are confirmed by both rankings. Consequently it is only a partial ranking: when the two flow rankings conflict with each other no comparison is made (incomparability). This can be useful as it shows the decision-maker what are the most difficult comparisons.

In Visual PROMETHEE the PROMETHEE I partial ranking is displayed by drawing a line for each action between its $\Phi^+$ score on the left vertical bar and its $\Phi^-$ score on the right vertical bar. When a line is on top of another it means that the action is preferred to the other. When two lines are crossing each other it means that the actions are incomparable in PROMETHEE I.

In the above example we see that Tourism B is preferred to all the other actions. The Sport car is incomparable with the Economic one. And Tourism B is incomparable with all the other actions (except Tourism B).

The way the display is organized the middle vertical bar actually shows to the $\Phi^+$ net flow scores of the actions and thus displays the PROMETHEE II Complete Ranking that is discussed in the next section.

PROMETHEE II Complete Ranking

The PROMETHEE II Complete Ranking is based on the $\Phi^+$ net flow which is the balance (difference) between $\Phi^+$ and $\Phi^-$. The $\Phi$ score can be negative: it is a number in the -1 to +1 range. The PROMETHEE Rankings window displays the $\Phi^+$ scores on a vertical bar.
In the above example, three groups of actions are easily identified:

- **Tourism B** at the top.
- **Luxury 1, Luxury 2** and **Tourism A** in the middle.
- **Sport** and **Economic** at the bottom.

It should be noted that as the PROMETHEE II Complete Ranking doesn't include any incomparabilities it is thus less prudent than the PROMETHEE I Partial Ranking.

**PROMETHEE Diamond**
The PROMETHEE Diamond is an alternate view of the PROMETHEE Rankings.
The 45°-angled square corresponds to the \((\Phi^+;\Phi^-)\) plane oriented in such a way that the vertical axis gives the \(\Phi\) score.

Each action is represented by a cone. The top of the cone is located at the \((\Phi^+;\Phi^-)\) coordinates of the action.

When a cone overlaps another one it corresponds to a preference. When two cones intersect each other there is an incomparability in the PROMETHEE II Partial Ranking.

In this example the three groups of actions are very easy to distinguish from each other.

**PROMETHEE Network**

Click "PROMETHEE-GAIA | PROMETHEE Network" to open this window.

The PROMETHEE Network representation of the PROMETHEE I Partial Ranking will feel familiar to the users of older PROMETHEE software such as PromCalc or Decision Lab. Actions are represented by nodes and arrows are drawn to indicate preferences. Incomparabilities are thus very easy to detect.
Visual PROMETHE uses an enhanced network representation: instead of drawing the nodes at arbitrary locations the relative positions of the actions in the PROMETHEE Diamond are used. The network representation is like a close-up of the Diamond view where preferences are indicated by arrows. This makes it very straightforward to appreciate the proximity between actions and thus the degrees of incomparability in the partial ranking.

**PROMETHEE Rainbow**
The PROMETHEE Rainbow is a disaggregated view of the PROMETHEE II Complete Ranking.
For each action a bar is drawn with as many slices as the number of criteria. Each slice corresponds to the contribution of the criterion to the Phi net flow score of the action taking into account the weight of the criterion. This way the sum of the positive slices minus the sum of the negative ones is equal to the Phi net flow score of the action.

In the above example it appears that:

- **Tourism B** has no negative contributions to its Phi score. It has no weaknesses compared to the other actions.
- While **Luxury 1**, **Tourism A** and **Luxury 2** have Phi scores that are very close to each other, the **Tourism A** car appears to be quite different from the two other ones: its bar is very short which means that it has a very average profile. The two other cars have larger bars with positive and negative slices: they are better on some criteria and worse on others.
- The **Economic** car has a very large bar: it is very good on some criteria (**Price** and **Consumption**) and very bad on others (**Habitability**, **Comfort** and **Power**).

**Use the GAIA analysis**

The **GAIA** analysis is a descriptive complement to the **PROMETHEE** rankings.

Click “**PROMETHEE-GAIA | GAIA Visual Analysis**” to open the **GAIA** window.
Perform a sensitivity analysis

It is important to keep mind that decision aid models such as the one used in the PROMETHEE and GAIA methods rely on different assumptions that make it possible to analyze the decision problem and to provide the decision-maker with sound advice.

In particular the PROMETHEE methodology rely on the definition of preference functions and weights to model the preferences and priorities of the decision-maker.

Visual PROMETHEE has been conceived to make this important modeling step as easy as possible:

- Most important data are centralized and can be modified directly in a spreadsheet-like table in the main window.
- The Preference Function Assistant is available to guide the choice of the preference functions.
- The Weighing Assistant and the Criteria Hierarchy Assistant can be used to organize the criteria and to allocate the weights.

While empirical studies have shown that the PROMETHEE method is rather robust with respect to the values of the preference function thresholds, the weights of the criteria usually have a strong impact on the results of the analysis, especially when there are strongly conflicting criteria.

Performing a weight sensitivity analysis is thus essential and Visual PROMETHEE includes several tools to facilitate this type of sensitivity analyses:

Detailed information about using GAIA can be found here.
- Actions, categories, criteria, groups, clusters, scenarios and coalitions can be temporarily deactivated using the Activation Center window to test or to compare easily different model configurations. Actions and Criteria can even be deactivated directly from the main window using intuitive checkboxes.

- The Walking Weights window can be used to interactively modify the weights. All the computations are continuously adjusted and the contents of the opened windows are updated as well.

- The Visual Stability Intervals window provides the user with a more exhaustive weight sensitivity analysis: it shows how the Phi score and the PROMETHEE II ranking vary as a function of the weight of a criterion and identifies the internal of stability of the top ranked actions.

- The Decision Maker Brain visualization in the GAIA window shows the degree of difficulty of the decision problem according to the robustness of the PROMETHEE II ranking to weight variations.

- The possibility to define multiple scenarios for a same decision problem can be used to compare different points of view in a group decision context (GDSS). It can also be useful to compare different hypotheses, for instance when the evaluation of some criteria relies on forecasts or is imprecise.

- The Balance of Power window is similar to the Walking Weights but allows for changing the weights of the scenarios.

**Use weight presets**

Weight Presets allow you to save up to five different sets of weights for easy comparison.

Indeed the weights allocated to the criteria are critical preference parameters: different weights can lead to quite different rankings especially when the criteria are conflicting.

Use the "Snapshots | Weight Presets" menu to open the Weight Presets window.

![Weight Presets window](image)

The window has two columns of buttons:

- The left column is used to switch from one weight preset to another. Just click the button to switch to a previously defined preset.
- The right column ("Update" buttons) is used to store presets: click on the "Update" button to store the current weights in the corresponding preset, a dialog opens to let you change the name of the preset and confirm:

![Update Preset dialog](image)

Click "Update" to save the preset with the current weights or click "Cancel" to cancel the change.

The Weight Presets are saved together with the problem data so that you can restore them later.
Generate a report

The data and the results of the analysis can be exported from Visual PROMETHEE in different ways to support reporting:

- Most windows include a local menu with a "Copy" item that can be used to copy the window's content to the clipboard. Most graphical output can thus be pasted directly into other applications such as word processors or presentation software.
- The "File | Export..." menu item can be used to export data and numerical results to a text file that can be imported in a spreadsheet software.
- The Report Generator ("File | Report...") produces a tailor-made report with multiple user-selectable sections. Reports can be generated in HTML, PDF or XLS(X) format.
User Interface

Visual PROMETHEE has a standard MS-Windows interface. Most controls are centralized in the main window (main menu and toolbars) and in local menus that are available in most windows:

- **Main Menu**
- **Toolbars**
- **Local Menus**

**Main Menu**

The Visual PROMETHEE Main Menu is organized as follows:

- **File**
  - **New**
  
  To start entering the data for a new problem. This opens the New dialog.
Problem Creation Assistant
This launches the Problem Creation Assistant.

Open
To open an existing Visual PROMETHEE file.

Recent files
Opens a sub-menu with the names of the five last opened files. Click on a file name to open the file.

Save
To save the current problem under its existing file name.

Save As
To save the current problem under a new file name.

Import
To import data from various formats of text files.

Export
To export data and results to a text file.

Report
To generate an HTML report.

PROMETHEE Certificate
To manage the PROMETHEE Certification of your files (this is NOT available in the current version).

Exit
To exit Visual PROMETHEE.

Edit
This is a standard Edit menu.

Cut
Copy
Paste
Select All
Duplicate action
To create a new action which is a copy of the currently selected action.

Duplicate criterion
To create a new criterion which is a copy of the currently selected criterion.

Duplicate scenario
To create a new scenario which is a copy of the current scenario.

Model
This is the menu that gives access to the different components of the current problem. From here you can edit most data.

Info
General information related to the current problem.

Qualitative Scales
Definition and management of the qualitative scales.

Actions
Definition and management of the actions.

Criteria
Definition and management of the criteria.

Scenarios
Definition and management of the scenarios.

Classes
Definition and management of the classes for sorting actions.

Hierarchy Assistant
Launches the Hierarchy Assistant.

Weighing Assistant
Launches the Weighing Assistant.

Action Categories
Definition and management of the action categories.
- **Criteria Groups**
  Definition and management of the criteria groups.
- **Clusters**
  Definition and management of the clusters.
- **Coalitions**
  Definition and management of the coalitions.

### Control
- **Activate**
  Opens the activity center.
- **Group**
  Opens the grouping window.
- **Filter**
  Allows to filter (deactivate) actions according to criteria values.
- **Sort**
  Allows to sort actions, criteria and other items according to various criteria.
- **Close all windows**
  Closes all opened windows.

### PROMETHEE-GAIA
This is the menu from where most analysis results can be accessed.
- **PROMETHEE Rankings**
  Separate visual representations of the PROMETHEE I Partial Ranking (line chart) and PROMETHEE II Complete Ranking (“thermometer”).
- **PROMETHEE Diamond**
  Combined visual representations of the PROMETHEE I and II Rankings.
- **PROMETHEE Network**
  Network representation of the PROMETHEE I Partial Ranking.
- **PROMETHEE Rainbow**
  Disaggregated view of the PROMETHEE II Complete Ranking.
- **PROMETHEE Table**
  Multicriteria leaving (Φ⁺), entering (Φ⁻) and net (Φ) flow values.
- **GAIA Visual Analysis**
  GAIA 2D and 3D displays.
- **Action Profiles**
  Up to five separate profile windows can be opened to compare the profiles of individual actions.
- **GAIA Webs**
  Up to five separate GAIA Web windows can be opened to compare the profiles of individual actions.
- **Walking Weights**
  Visual weight sensitivity analysis.
- **Visual Stability Intervals**
  Visual weight stability analysis.
- **PROMETHEE V Selection**
  Opens the PROMETHEE V window.
- **PROMETHEE Sort**
  Opens the PROMETHEE Sort window.
- **Bank Adviser**
  Reference set-based evaluation.
- **Performance Analysis**
  Opens the Performance Analysis sub-menu.
- **Preference Flows**
  Opens a window displaying the unicriterion net flow scores as well as the multicriteria flow scores.
• **GDSS**
  This is a specialized menu for Group Decision Support System (GDSS) features of Visual PROMETHEE.
  - **Scenarios Comparison**
    Side-by-side comparison of the scenarios net flow scores.
  - **Balance of Power**
    Allocate weights to the different scenarios.

• **GIS**
  This is a specialized menu for Geographical Information System (GIS) features of Visual PROMETHEE.
  - **PROMap**
    Integrate PROMETHEE-GAIA analyses with Google Maps.

• **Custom**
  This is the menu where the custom functions available in specialized versions of Visual PROMETHEE are located.

• **Assistants**
  - **Create**
    This assistant helps you step by step to setup a new decision problem from scratch.
  - **Hierarchize**
    This assistant helps you to organize the criteria in the Visual PROMETHEE three-level hierarchy.
  - **Weigh**
    This assistant helps you to allocate weights to the criteria within the three-level hierarchy.
  - **Analyze**
    This assistant helps you to better understand the results of the PROMETHEE-GAIA analysis.

• **Snapshots**
  - **Weight Presets**
    Allows you to save up to five different weight distributions for easy comparison.
  - **Layouts**
    Allows you to save up to five different windows layout for different types of analyses.

• **Options**

• **Help**
  - **Help**
    Opens the help/manual.
  - **www.promethee-gaia.net**
    Direct access to the PROMETHEE-GAIA web site (Internet connection required).
  - **The PROMETHEE Blog**
    Direct access to the PROMETHEE Blog web site (Internet connection required).
  - **The PROMETHEE FAQ**
    Direct access to the PROMETHEE FAQ web site (Internet connection required).
  - **Register...**
  - **About**
    Opens the "About" window where software version information can be found.

**Toolbars**

There are two toolbars in the main Visual PROMETHEE window.
The top row toolbar includes typical management options:

- New: Start a new problem.
- Open: Open an existing data file.
- Save: Save the current data.
- Cut: Cut to Clipboard.
- Copy: Copy to Clipboard.
- Paste: Paste from Clipboard.
- Add action: Add a new action to the current problem.
- Delete action: Delete the current action.
- Add criterion: Add a new criterion to the current problem.
- Delete criterion: Delete the current criterion.
- Add scenario: Add a new scenario to the current problem.
- Delete scenario: Delete the current scenario.
• **Creation Assistant**: Launch the Problem Creation Assistant.

• **Hierarchy Assistant**: Launch the Criteria Hierarchy Assistant

• **Weighing Assistant**: Launch the Criteria Weighing Assistant

• **Analysis Assistant**: Launch the Problem Analysis Assistant

• **Options**: Options.

• **Force Recalc**: Launch full computation update.

• **Activation Center**: Control the activity level of actions, criteria and scenarios.

• **Grouping**: Control the grouping of criteria and scenarios.

• **Filter**: Filter actions according to criteria values.

The **bottom row toolbar** includes most analysis options:

• **PROMETHEE Rankings**

• **PROMETHEE Diamond**

• **PROMETHEE Network**

• **PROMETHEE Rainbow**

• **PROMETHEE Table**

• **GAIA**

• **Action Profiles**

• **GAIA Webs**

• **Walking Weights**

• **Visual Stability Intervals**

• **PROMETHEE V Selection**

• **PROMETHEE Sort**

• **Bank Adviser**

• **Performance Analysis**

• **Efficient Frontier**

• **Preference Flows**

• **Scenario Comparison**

• **Balance of Power**

• **PROMMap**

• **Weight Presets**

• **Layouts**

**Local Menus**

Local menus are available in most **Visual PROMETHEE** windows.

The local menus usually include:

• Options to control the current display.

• Copy to clipboard function.

Right-click on the window to open the local menu.
Dialogs

Here is a list of all the dialogs available in Visual PROMETHEE.

- **New**
- **Import data**
- **Export data**
- **Report generator**
- **PROMETHEE Certificate**
- **Model**
  - Problem Info
  - Qualitative Scales
  - Actions
  - Criteria
  - Scenarios
  - Classes
  - Action Categories
  - Criteria Groups
  - Clusters
  - Coalitions
- **Options**

**New**

When you click "File | New", the following dialog opens:

![Create a new multicriteria ta...](image)

You can select the number of actions, the number of criteria and the number of scenarios.

When you press the "Ok" button an empty data set is created.

**Import data**

To access this dialog, click "File | Import...".

The "Import" dialog allows you to import data into a new problem. Data should be prepared in a CSV or TXT text file. This can be done easily from Excel for instance. Data will be imported into the current scenario.
From the "Import" dialog you can specify the data to import:

- Full: Evaluation table, including actions and criteria names as well as preference parameters (weights, preference functions and thresholds).
- Table: Evaluations with actions and criteria names.
- Evaluations: Evaluations only.
- Criterion: A single column of evaluations is imported. The corresponding criterion name has to be selected.

Examples of file formats are given in the Excel file provided with the Visual PROMETHEE install.

You can also specify the file format. This includes:

- The file type: either CSV or TXT.
- The delimiter in use: space, tab, semi-colon or comma.
- Whether quotes (") are used to delimitate strings or not.

Use the "Browse" button to locate the file you want to import.

Then press the "Import" button to import the data.

Click the "New..." button to create a new empty sheet before the import. Otherwise any existing data will be overwritten with the imported data.

Be sure that the import file is not open in Excel or any other program. Close it from Excel before you click "Import" otherwise Visual PROMETHEE will not be able to open the file and to import it.

**Export data**

To access this dialog, click "File | Export...".

You can export data to a text file for use in other software, such as for instance Excel or Word.
The "Data" section of the dialog allows you to specify what data you want to export:

- Evaluation table.
- Preference parameters (weights and preference functions).
- Unicriterion net flows.
- PROMETHEE rankings (multicriteria flows: Phi+, Phi- and Phi).
- You can also choose which scenario you want to export.

The "Format" section allows you to control the format of the export file:

- File type: either .csv or .txt or .prn
- Delimiter: choose the delimiter used in the export file.
- Quotes: choose whether to use quotes for strings in the export file.
- Click the "Browse" button to define the name and location of the export file.

Click the "Ok" button to export the data.

**Report Generator**

To access this dialog, click "File | Report...".

The Report Generator allows to generate HTML, PDF or XLS(X) reports.
The reports are organized into a number of sections and subsections that can be selected by the user. Use the checkboxes to select which sections or subsections you want to include in the report.

Two predefined reports are available:
- Basic report: only basic data and PROMETHEE and GAIA results are included.
- Full report: all data are included.

Click the appropriate button to select one of the two predefined reports.

Two options are available with respect to the scenarios included in the report:
- Current: current scenario only.
- All: all scenarios.

Two formats are available:
- HTML: an HTML file is produced.
- PDF: a PDF file is produced. Not fully implemented yet.
- XLS(X): a MS Excel file is produced.

At the bottom of the window are four buttons:
- Expand all: shows all the subsections.
- Contract all: hides all the subsections.
- Report: Start the report generation.
- Cancel: exit the dialog.

The display of the subsections can also be controlled individually using the buttons to the left of the section names.

Select your options and then click the "Report" button to generate the report. A dialog will open to let you specify the name and location of the report. A separate folder named after the report name with an "_Images" extension and containing the source files of the images contained in the report is also generated.

**PROMETHEE Certificate**
To access this dialog, click: "File | PROMETHEE Certificate...".

How can you tell that the analysis you made is correct?

How can you tell that the analysis you are shown by a third party is correct?

That will be possible with Visual PROMETHEE.

This feature is not implemented yet and will be available only in the Business Edition of Visual PROMETHEE.

Model

- Problem Info
- Qualitative Scales
- Actions
  - Location
- Criteria
- Scenarios
- Classes
- Action Categories
- Criteria Groups
- Clusters
- Coalitions

Problem Info

To access this dialog, click: "Model | Info...".

This dialog allows you to enter some general information related to the current problem.

You can specify:

- A description of the problem.
- The name of the author.
- Custom description of action (and plural): for instance in the example we are comparing car(s).
• Custom description of criterion (and plural): it could indicator(s) for instance.

Press the "Ok" button to confirm.

**Qualitative Scales**

To access this dialog, click: "Model | Qualitative scales...".

This is where you can define and manage qualitative scales.

There are four standard qualitative scales that are predefined when you create a new problem. These are:

- **y/n**: a simple 2-level scale.
- **impact**: this is a 5-level scale ranging from "very low" (best) to "very high" (worst); it is adequate for e.g. environmental or social impacts.
- **5-point**: this is the classical 5-level scale ranging from "very good" to "very bad".
- **9-point**: this extends the 5-point scale by adding intermediate levels.

To create a new scale, click the "New" button, set the number of levels and fill all the fields.

The maximum number of levels is set to 10. In practice you should try to keep the number of levels in a qualitative scale as low as possible (preferably no more than five) to ensure a consistent evaluation.

Each level is associated to a numerical value. When the number of levels is low, they are usually quite different from each other and you will probably use the usual preference function, so that actual values are not important. What is important is the order: from best to worst. Check that the "Orientation" is consistent with your choice.

You can also modify existing scales.

Scales are saved with the problem data and are thus problem-dependent. You can have different scales in different problems.

Click "Close" to exit.

**Actions**
To access this dialog, click: "Model | Actions...".

Here you can set the main properties of the actions.

- **Select**: Let you select one action.
- **Name**: To change the action name.
- **Shortname**: To change the action short name.
- **Active**: To activate/deactivate the action (deactivated actions are not taken into account in the computation).
- **Description**: Enter a description of the action.
- **Picture**: Click on the picture to change the picture linked to the action.
- **Category**: Select the category to which the action belongs.
- **Location**: Click to set the geo-localization of the action. This opens the Location dialog.

Click "New" to add a new action or "Delete" to delete the current action.

Click "Close" to close the window.

**Location**

To access this this dialog click the Location button in the Actions dialog.
This is a Google Maps window (Internet connection is required).

You can enter an address in the **Address** field and click on the **Locate** button to find it and center the map on the address.

You can also use the usual Google Maps controls and navigate to find the location on the map.

**Criteria**

To access this dialog, click: "**Model | Criteria...**".

Here you can set the main properties of the **criteria**.
Select: Let you select one criterion.
Name: To change the criterion name.
Shortname: To change the criterion short name.
Active: To activate/deactivate the criterion (deactivated criteria are not taken into account in the computation).
Description: Enter a description of the criterion.
Group: Select the criterion group to which the criterion belongs.
Unit: Set the unit of measurement of the criterion.
Scale: You can select the type of scale that will be use for the criterion. There are three possibilities:
  - numerical: numbers,
  - currency: evaluations will be displayed as a currency using the symbol and formats specified on the "Currency" row.
  - qualitative: qualitative scale, select the name of the scale in the drop-down list below.
Decimals: Set the number of decimal places to display for this criterion.

Click "New" to add a new criterion or "Delete" to delete the current criterion.
Click "Close" to close the window.

**Scenarios**
To access this dialog, click: "Model | Scenarios...".

Here you can set the main properties of the scenarios.
- Select: Let you select one scenario.
- Name: To change the scenario name.
- Shortname: To change the scenario short name.
- Active: To activate/deactivate the scenario (deactivated scenarios are not taken into account in the computation).
- Description: Enter a description of the scenario.
- Weight: Set the weight of the scenario.
- Coalition: To select the coalition this scenario belongs to.

Click "New" to add a new action or "Delete" to delete the current criterion.

Click "Close" to close the window.

**Classes**

To access this dialog, click: "Model | Classes...".

Here you can define and set the properties of the classes.
Select: Let you select one class.
Name: To change the class name.
Shortname: To change the class short name.
Description: Enter a description of the class.
Color: Color associated to the class.
Category: Select the action category that defines the class. That category should include either boundary or central profile(s) for the class.

Click "New" to add a new class or "Delete" to delete the current class.
Click "Close" to close the window.

**Action Categories**

To access this dialog, click "Model | Action categories...".

Visual PROMETHEE allows you to define action categories. Each action category is identified by a specific symbol and fill and outline colors. This can be useful to identify subsets of actions according to some characteristics such as e.g. localization, nationality, technology, etc.

Each action belongs to one category. There is a default category named "none". When you define a new action it is automatically assigned to the "none" category.

From this dialog you can edit existing categories or create new ones.

The "Action categories" list let you select one existing category.

- **Name**: Let you change the name of the selected category.
- **Shape**: Let you select the shape for the selected category.
- **Fill color**: Let you select the color that will fill the selected shape.
- **Outline color**: Let you select the outline color for the selected shape.
- **Active**: To activate/deactivate the category (deactivated categories are not taken into account in the computation).
• **Show**: To activate/deactivate the display of the actions within the category. *This feature is not implemented yet.*

• **Sort options**:
  - **Category to sort**: Determines whether the actions within the current category have to be considered in PROMETHEE Sort.
  - **Profile**: Shows whether the current category is a profile category for a class.

Click "**New**" to add a new category or "**Delete**" to delete the current category.

Click "**Close**" to close the window.

**Criteria Groups**

To access this dialog, click: "**Model | Criteria groups...**".

Visual PROMETHEE allows to organize criteria in a three-level hierarchy:

- at the bottom level are the individual criteria,
- each criterion belongs to a criteria group,
- each criterion group belongs to a cluster.

Each criterion belongs to one group. There is a default group named "none". When you define a new criterion it is automatically assigned to the "none" group.

The **Hierarchy Assistant** can be used to facilitate the setup of the criteria groups and clusters.

From this dialog you can edit existing criteria groups or create new ones.

The "Criteria Groups" list let you select one existing criteria group.

- **Name**: Let you change the name of the selected group.
- **Shortname**: Let you change the shortname of the selected group.
- **Cluster**: Let you select the cluster to which the selected group belongs.
- **Clusters button**: Let you manage clusters.
- Outline color: Let you select the outline color for the selected group.
- Active: To activate/deactivate the group (deactivated groups are not taken into account in the computation).
- Show: To activate/deactivate the display of the criteria within the group. This feature is not implemented yet.
- Grouped: When checked all the criteria within the group are considered and appear as a single dimension. The weights of the criteria within the group are always kept in the same relation even when the weight of the group is modified.

Click "New" to add a new group or "Delete" to delete the current group.

Click "Close" to close the window.

Clusters

To access this dialog, click: "Model | Clusters...".

Visual PROMETHEE allows to organize criteria in a three-level hierarchy:

- at the bottom level are the individual criteria,
- each criterion belongs to a criteria group,
- each criterion group belongs to a cluster.

Each criterion belongs to one group. There is a default group named "none". When you define a new criterion it is automatically assigned to the "none" group.

There is a default cluster named "none". The "none" group as well as any new defined group are automatically assigned to the "none" cluster.

The Hierarchy Assistant can be used to facilitate the setup of the criteria groups and clusters.

From this dialog you can edit existing clusters or create new ones.

The "Clusters" list let you select one existing cluster.

- Name: Let you change the name of the selected cluster.
- Shortname: Let you change the shortname of the selected cluster.
- Shape: Let you select the shape for the selected cluster.
- Fill color: Let you select the fill color for the selected shape.
- Active: To activate/deactivate the cluster (deactivated clusters are not taken into account in the computation).
- Show: To activate/deactivate the display of the criteria within the cluster. This feature is not implemented yet.
- Grouped: When checked all the criteria within the cluster are considered and appear as a single dimension. The weights of the criteria within the cluster are always kept in the same relation even when the weight of the cluster is modified.

Click "New" to add a new cluster or "Delete" to delete the current cluster.

Click "Clone" to automatically create a new criteria group with the same attributes as the current cluster. This is handy to quickly setup a simple two-level hierarchy and still benefit from all the color-coded features of the three-level hierarchy. The criteria group is allocated to the current cluster.

Click "Close" to close the window.

**Coalitions**

To access this dialog, click: "Model | Coalitions...".

Visual PROMETHEE allows to organize scenarios into different coalitions with specific shape, outline and fill color.

Each scenario belongs to one coalition. There is a default coalition named "none". When a new scenario is defined it is automatically assigned to the "none" coalition.

From this dialog you can edit existing coalitions or create new ones.

The "Coalitions" list let you select one existing coalition.

- Name: Let you change the name of the selected coalition.
• Shortname: Let you change the shortname of the selected coalition.
• Shape: Let you select the shape for the selected coalition.
• Fill color: Let you select the fill color for the selected shape.
• Outline color: Let you select the outline color for the selected shape.
• Active: To activate/deactivate the coalition (deactivated coalitions are not taken into account in the computation). This feature is not implemented yet
• Show: To activate/deactivate the display of the scenarios within the coalition. This feature is not implemented yet.
• Grouped: When checked all the scenarios within the coalition are considered and appear as a single dimension. The weights of the scenarios within the coalition are always kept in the same relation even when the weight of the coalition is modified. This feature is not implemented yet

Click "New" to add a new coalition or "Delete" to delete the current coalition.

Click "Close" to close the window.

**Options**

The Options dialog contains three tabs:

- **General**
- **Layout**
- **Advanced**

**General**

Currently the only operational options are for localization of the data.

Several countries are predefined including Belgium, México, United Kingdom and the United States. It is also possible to define custom locations. Depending on the selection, numbers and currency values will be displayed differently. The formats can be checked and modified by clicking the "Edit" button.
As seen on the above screenshot, it is possible to define the currency symbol, the currency format and number of decimal places. Thousand and decimal separators can also be modified.

**Layout**

From this tab you can control the behavior of **Visual PROMETHEE** when you start it.

The **Auto-Save** option is currently *not functional*.

The **Start with** radio button group determines which dataset is loaded when **Visual PROMETHEE** is started:

- **Cars demo**: the cars tutorial example is loaded.
- **Blank problem**: a blank problem is created with 2 actions, 1 criterion and 1 scenario.
- **Last problem**: the last opened dataset is reopened.

The **Default GAIA Stick** radio button group determines where the default position of the **Decision Stick** in the **GAIA** window.

**Advanced**

This tab contains options for advanced users. These should not be changed unless necessary.
Registration

This dialog is used to upgrade from the Demo Edition to the Business Edition.

To activate the license enter your license name and your serial key (5 groups of 4 digits) in the corresponding fields.

Press the Ok button to activate the Business Edition license.

No license or serial key are required for the Academic Edition.
Assistants

It is important to use tools the way they should be used. Otherwise you will end sorry. To avoid this Visual PROMETHEE includes several assistants to help you in the setup and analysis of your problem:

- **Problem Creation Assistant**
  This Assistant will lead you all the way from the problem definition to the analysis of the PROMETHEE and GAIA results. This is not yet fully implemented.
- **Preference Function Assistant**
  Choosing the right preference function for your criteria is essential to ensure a correct PROMETHEE analysis. This Assistant incorporates thirty years of experience to make sure you select the best type of preference function and assess the corresponding thresholds correctly.
- **Hierarchy Assistant**
  This Assistant will help you to organize your criteria into clusters and criteria groups.
- **Weighing Assistant**
  With this Assistant you will be able to assess the criteria weights visually, either directly or hierarchically to insure a proper weighing for clusters and criteria groups.
- **Analysis Assistant**
  This Assistant is under development.

Problem Creation

This is not yet fully implemented.

Preference Function

What is it?
The Preference Function Assistant is designed to help you to choose a preference function type and to set the corresponding thresholds values for a given criterion.

How to use it?
To start the Preference Function Assistant click on the Preference Fn. cell for the criterion you want to work with and select "Help me..." in the drop-down list. The Preference Function Assistant will open and display the first of five pages.

At the top of the window, five tabs are available to switch from one page to an other. At the bottom of the window are buttons to navigate from one page to the next or the previous one or to exit the Assistant.

The Preference Function Assistant

Page 1: Start

This first page contains a summary of the criterion information. From top to bottom:

- A first block of information is related to the distribution of the evaluations of the actions. It displays:
  - The type of scale of the criterion: numerical, currency or qualitative.
  - The minimum evaluation.
  - The maximum evaluation.
  - The range of the evaluations (maximum - minimum value).
  - The average evaluation.
  - The standard deviation of the evaluations.
  - Whether the criterion has to be maximized or minimized.

- A second block of information is related to the distributions of the pairwise differences between the evaluations of the actions. This is important as the preference function is a function of pairwise differences. This block displays:
  - The minimum (smallest) positive difference between the evaluations.
  - The maximum (largest) difference between the evaluations.
The average difference.
- The standard deviation of the differences.
- A diversity measure that is equal to 100% if all the evaluations are different from each other and decreases when the number of ties increases.

The inspection of these data can be helpful for the more experienced user.

Click the **Next >** button to proceed to Page 2 and select a preference function type.

**Page 2: Type selection**

At the top of the window is a question that you should answer. It is different for quantitative (as shown here) and for qualitative criteria. Depending on your answer a preference function type is suggested by the assistant ("Suggested type" at the left center of the window). Just below the suggestion you can see the currently selected type. In the screen shot, it appears in red as the currently selected type (V-shape) is different from the suggested type (Linear).

You now have several options:
- Click on the suggested type icon to select this preference function type.
- Click on any other icon to select an alternative preference function type.
- Click on the **Next >** button to proceed with the current selection.
- Click on the `< Previous` button to go back to Page 1.
- Click on the **Cancel** button to exit the Assistant.
Click the Next > button to proceed to Page 3 and assess the type of thresholds you will use.

**Page 3: Threshold type**
A single question has to be answered to determine whether you should use absolute or percentage thresholds. If you hesitate, leave the selection as it is.

Click the Next > button to proceed to Page 4 and assess the values of thresholds.

**Page 4: Threshold assessment**
Depending on the preference function type that has been selected up to two thresholds (Q, P or S) have to be assessed.
On the left side of the window are boxes for each threshold that has to be assessed depending on the type of preference function selected.

In each box you can see the selected value as well as the value suggested by the Assistant. You can enter a new value or click on the suggested value button to accept it.

On the right side of the window is a graphical representation of the currently selected preference function. Several pieces of information are displayed:

- The blue rectangle represents the distribution of the pairwise differences between evaluations, from the minimum to the maximum difference, the middle bar corresponds to the average difference.
- The green rectangles show the difference between the current and suggested values for the thresholds.

The two sliders are currently inactive.

Click the **Next >** button to proceed to Page 5 and validate your choice.

**Page 5: End**
This page displays your current selection.
Click the **Apply** button to proceed to validate your choice.

**Criteria Hierarchy**

**What is it?**
The **Criteria Hierarchy Assistant** is designed to help you to define the criteria hierarchy.

**How to use it?**
To start the Criteria Hierarchy Assistant select "**Assistants | Hierarchize...**" The Criteria Hierarchy Assistant will open and display the first of three pages. At the top of the window, three tabs are available to switch from one page to another. At the bottom of the window are buttons to navigate from one page to the next or the previous one or to exit the Assistant.

**The Criteria Hierarchy Assistant**

**Page 1: Clusters**
This first page is where you define the cluster.
Page 2: Criteria Groups
This second page is where you define the criteria groups and assign them to the cluster. Each criteria group belongs to one cluster.
Page 3: Hierarchy
This third page is where you assign the criteria to their respective criteria groups within the hierarchy. Each criterion belongs to one criteria group.

Weighing
What is it?
The Weighing Assistant is designed to help you to weigh the criteria within the criteria hierarchy.

How to use it?
To start the Weighing Assistant select "Assistants | Weigh..." The Weighing Assistant will open. At the bottom of the window are several buttons:
- Two radio buttons allow to switch between the Hierarchical and Absolute modes.
- The Set Equal button is used to set all weights equal.
- The Apply button saves the current weights to the spreadsheet.
- The Cancel button exits the Assistant.

The Weighing Assistant
The Assistant can be used in two modes:
- In the hierarchical mode, weights are assigned at the three levels of the hierarchy:
  - At the top level, clusters are assigned weights.
  - At the intermediate level, criteria groups are assigned relative weights within each cluster.
  - At the bottom level, individual criteria are assigned relative weights within each criteria group.
- In the absolute mode, weights are assigned directly to all the individual criteria, independently from their criteria groups and clusters.

The Assistant window contains four columns. From left to right:
- The name of the cluster, criteria group or criterion.
- A visual five-star rating for assessing the weight: click on the stars to define the weight.
- The corresponding weight value on 0 to 100 scale (one star is equal to 20).
- The bar in the rightmost column shows the resulting relative weight expressed in percent.

To the left are buttons that can be used to contract or expand the hierarchy display.

**Hierarchical mode**
When the Hierarchical mode is selected the following dialog is available.

Weights are input at all the hierarchy levels and the resulting absolute weights of the criteria are automatically computed.

**Absolute mode**
When the Absolute mode is selected the following dialog is available.
Weights are input at the individual criteria level only. The resulting weights of the criteria groups and clusters are automatically computed.

**Analysis**

This is not yet implemented.
Windows

Here is a list of all the windows available in Visual PROMETHEE.

For a description of the Visual PROMETHEE main window check the tutorial.

- **Activation Center**
- Filter
- Sort
- PROMETHEE Rankings
- PROMETHEE Diamond
- PROMETHEE Rainbow
- PROMETHEE Table
- GAIA
  - Decision Maker Brain
- Action Profiles
- GAIA Webs
- Walking Weights
- Visual Stability Intervals
- PROMETHEE V Selection
- PROMETHEE Sort
- Performance Analysis
- Preference Flows
- Scenarios Comparison
- Balance of Power
- PROMap
- Weight Presets
- Layouts

Activate

What is it?
The Activity Center enables you to quickly control which actions, criteria or scenarios are active or not.

Activation Center
There are three tabs: Actions, Criteria and Scenarios.
From each tab you can control which actions, criteria or scenarios are active or not (checkbox A).

It is also possible to control which categories of actions, groups of criteria, clusters or coalitions are active (checkbox A) or shown on the results displays (checkbox S) (the Show feature is not operational yet).

When a category, group or cluster is activated or deactivated, all the actions or criteria belonging to that item are automatically activated or deactivated.

Use the Expand and Contract buttons to respectively expand or contract the displayed hierarchical tree.

Use the Activate all button to activate all the items in the currently displayed tab.

**Group**

**What is it?**
The Grouping window enables you to quickly control which criteria or scenarios are grouped or not.

**Grouping**
There are two tabs: Criteria and Scenarios.
From each tab you can control which criteria or scenarios are grouped or not (checkbox Grp).

Use the Expand and Contract buttons to respectively expand or contract the displayed hierarchical tree.

Use the Ungroup all button to ungroup all the items in the currently displayed tab.

Filter

What is it?
The Filter allows to deactivate actions according to criteria values.

How to interact?
- The checkboxes in the leftmost column allow to active the filtering on each criterion separately.
- The "min" and "max" columns allow to introduce the filtering range for each criterion.
- The drop-down lists allow to select "<=", "<" or "n/a". In the last case, the corresponding range value is not considered.
- The "Check all" and "Uncheck all" buttons can be used to turn on or off all the criteria filtering.
- The "Filter" button applies the active filtering to the currently active actions.

Filter
There is one row for each criterion and the filtering range can be defined separately for each criterion.
In the above example, filtering is active for two criteria:

- **Price**: only cars in the 20,000€ to 30,000€ price range (limits included) will be selected.
- **Consumption**: only cars with a consumption lower than or equal to 8,5 will be selected.

Inactive range values are displayed in gray.

**Sort**

**What is it?**
This window allows to modify the sequence of actions, criteria or scenarios in the Visual PROMETHEE windows.

**How to interact?**
- Click on the tabs at the top of the window to select the type of items you want to sort.
- Use the "Sort options" buttons to sort the items according to predefined attributes.
- Use the arrow buttons to individually move a selected item within the list of items displayed on the left side.
- Click "Apply" to sort the items.
- Click "Close" to exit the dialog.

**Sort**
Various options are available.
They affect the sequence in which that actions, criteria or scenarios are presented in the Visual PROMETHEE windows.

There are seven tabs at the top of the window:

- **Actions**: can be sorted according to their name, shortname, category name, current net flow value or criterion value.
- **Categories**: can be sorted according to their name.
- **Criteria**: can be sorted according to their name, shortname, group name or current weight.
- **Groups**: can be sorted according to their name or cluster name.
- **Clusters**: can be sorted according to their name.
- **Scenarios**: can be sorted according to their name, shortname, coalition name or weight.
- **Coalitions**: can be sorted according to their name.

A manual sort is also possible using the arrow buttons. Select an item in the listbox and use the buttons to change its position in the list.

The sort can be done either by ascending or descending values.

**All sort options are not currently implemented.**

**PROMETHEE Rankings**

**What is it?**

The PROMETHEE Rankings window displays the PROMETHEE I and II rankings in two separate tabs.

**How to interact?**

There are two tabs at the bottom of the window. You can select the PROMETHEE I partial ranking or the PROMETHEE II complete ranking.

There is also a local menu. Right-click on the drawing to open it.

**Local Menu**

From the local menu the following options are available:
- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Shortnames: You can choose to display the actions full names or short-names.
- Locate: You can select an action that will be highlighted on the display. That makes it easier to locate a particular action, especially when the number of actions is larger.

**PROMETHEE I Partial Ranking**

The PROMETHEE I Partial Ranking is based on the comparison of the leaving flow (Phi+) and the entering flow (Phi-).

The left column corresponds to the Phi+ scores and the right column to the Phi- scores. They are oriented such that the best scores are upwards. This way the middle column corresponds to the net flow (Phi- scores).

On the left side you can see the ranking of the actions according to Phi+.
On the right side you can see the ranking of the actions according to Phi-.

For each action a line is drawn from its Phi+ score to its Phi- score.

When a line is completely on top of another one it means that the corresponding action is better on both Phi+ and Phi-. This action is thus preferred to the other in the PROMETHEE I Partial Ranking.

When two lines intersect the Phi+ and Phi- rankings are different and the two action are thus incomparable in the PROMETHEE I Partial Ranking.

For instance, in the Visual PROMETHEE example shown here, **Tourism B** is preferred to all the other actions. While **Sport** and **Economy** are incomparable actions.
PROMETHEE II Complete Ranking

The PROMETHEE II Complete Ranking is based on the net flow Phi.

The top half of the scale (in green) corresponds to positive Phi scores and the bottom half (in red) to negative scores.

In the example shown here, three groups of actions appear clearly:

- **Tourism B** is on top of all the other actions.
- **Luxury 1, Luxury 2 and Tourism A** are very close to each other in the middle of the ranking.
- **Sport** and **Economy** are at the bottom of the ranking.

PROMETHEE Diamond

What is it?

The PROMETHEE Diamond is an alternate display of the PROMETHEE I and II rankings. It shows both rankings in one 2-dimensional representation.

How to interact?

There is a local menu. Right-click on the drawing to open it.

Local Menu

From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Shortnames: You can choose to display the actions full names or short-names.
- Locate: You can select an action that will be highlighted on the display. That makes it easier to locate a
particular action, especially when the number of actions is larger.

**PROMETHEE Diamond**

In the **PROMETHEE Diamond** each action is represented as a point in the \((\Phi^+,\Phi^-)\) plane. The plane is angled 45° degrees so that the vertical dimension (green-red axis) corresponds to the \(\Phi\) net flow.

A cone is drawn for each action. When a cone is overlapping another one it means that the action is preferred to the other one in the **PROMETHEE I** Partial Ranking. Intersecting cones correspond to incomparable actions.

In the example, **Tourism B** is clearly preferred to all the other actions, while **Sport** and **Economic** are incomparable.

The vertical dimension corresponds to \(\Phi\), so it is possible to visualize both **PROMETHEE** rankings at the same time.

**PROMETHEE Network**

**What is it?**

The **PROMETHEE Network** is an alternate display of the **PROMETHEE I** ranking.

**How to interact?**

There is a local menu. Right-click on the drawing to open it.

**Local Menu**

From the local menu the following options are available:

- **Copy**: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Shortnames: You can choose to display the actions full names or short-names.
- Show flows: You can choose to display the Phi+ and Phi- values or not.
- Locate: You can select an action that will be highlighted on the display. That makes it easier to locate a particular action, especially when the number of actions is larger.

**PROMETHEE Network**

In the **PROMETHEE Network** display each action is represented as a node and preferences are represented by arrows. The nodes are located in relative positions corresponding to the **PROMETHEE Diamond** so that the proximities between flow values appear clearly.

![PROMETHEE Network Diagram]

In the example, **Tourism B** is clearly preferred to all the other actions, while **Sport** and **Economic** are incomparable but very close to each other.

**PROMETHEE Rainbow**

**What is it?**

The **PROMETHEE Rainbow** is a disaggregated view of the **PROMETHEE II** complete ranking. It shows the detail of the Phi net flow computation, emphasizing the good and weak features of each action.

**How to interact?**

There is a local menu. Right-click on the drawing to open it.

**Local Menu**

From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Show criteria: Control whether the names of the criteria are displayed or not.
- Shortnames: You can choose to display the actions and/or criteria full names or short-names.

**PROMETHEE Rainbow**

For each action, a bar is drawn. The different slices of each bar are colored according to the criteria. Each slice is proportional to the contribution of one criterion (flow value times the weight of the criterion) to the Phi net flow score of the action. Positive (upward) slices correspond to good features while negative (downward) slices correspond to weaknesses. This way, the balance between positive and negative slices is equal to the Phi score. Actions are ranked from left to right according to the PROMETHEE II Complete Ranking.

In the example, **Tourism B** shows no weaknesses. **Tourism A** seems very average. And **Economic** exhibits some very good features as well as some very weak features.

It is best to use various groups and/or clusters with contrasted colors to visually identify the slices.

**PROMETHEE Table**

**What is it?**

The PROMETHEE Table window displays the PROMETHEE preference flows in a tabular format.

**How to interact?**

There is a local menu. Right-click on the drawing to open it.

**Local Menu**

From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.

**PROMETHEE Table**

This is a table where actions are ranked according to the PROMETHEE II Complete Ranking. The Phi, Phi+ and Phi- scores are displayed.
GAIA

What is it?
The GAIA window displays the results of the GAIA analysis.

How to interact?
- There is a local menu. Right-click on the drawing to open it.

Local Menu
From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Shortnames: You can choose to display the actions and/or criteria full names or short-names.
- Zoom: You can zoom in or out to focus on some part of the GAIA plane.
- Show stick: You can select whether and where you want the 3D view of the Decision Stick displayed.
- Show axis: You can select a criterion to display the projections of the actions on its axis, in order to check the actions performance on that criterion.
- Locate: You can select an action that will be highlighted on the display. That makes it easier to locate a particular action, especially when the number of actions is larger.

GAIA
The GAIA window has a lot of options. On the right side you can find the following options:

- The top tool bar includes six buttons:
  - A: controls the display of the actions on the GAIA plane.
  - C: controls the display of the criteria on the GAIA plane.
  - PI: controls the display of the decision axis on the GAIA plane.
  - 3D: switches between 2D and 3D views.
  - Zoom in.
  - Zoom out.
- The u,v,w drop-down lists: control the displayed axes. (This is currently NOT operational)
- The 2D views check-boxes:
- The 3D controls can be used to change the orientation of the 3D display.
- The “Show DM Brain” check-box toggles the PROMETHEE VI display of the Decision-Maker Brain. The “Size” button is used to control the weight variations.
- The Multi-Scenarios buttons can be used to activate the GAIA GDSS features.

At the bottom right of the window, the percentage of information retained in the GAIA display is shown. A color code is used: green indicates a satisfying quality level while red corresponds to a too low level.
Decision Maker Brain

What is it?
The Decision Maker Brain window allows to control the freedom level of the criteria in the PROMETHEE VI analysis.

How to interact?
- The “+” and “−” buttons can be used to modify the freedom level separately for each criterion.
- The four buttons at the bottom of the window allow to set all the freedom levels to one of four preset values: 10%, 25%, 50% or 75%.

Decision Maker Brain
The Decision Maker Brain window is accessed by clicking on the "Size" button at the right side of the GAIA window. This button is active only when the Decision Maker Brain is displayed as in the following screenshot.
The window displays:

- The freedom level for each criterion, expressed as a percentage.
- The corresponding minimum, current and maximum percentage weights of the criteria in the PROMETHEE VI analysis.
**Action Profiles**

**What is it?**
The *Action Profile* window displays the profile of one action. Up to five separate *Action Profile* windows can be opened to compare profiles.

**How to interact?**
There is a drop-down list to select the action you want to see. The "Phi" checkbox controls whether the multicriteria net flow value is displayed or not.
There is also a local menu. Right-click on the drawing to open it.

**Local Menu**
From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.

**Action Profile**
The *Action Profile* window shows a graphical representation of the unicriterion net flow scores for the selected action.

![Action Profile Window](image)

Positive scores (upward bars) correspond to good features while negative scores (downward bars) correspond to bad ones.

In the example above, there are no bad features and *Consumption* is very good.

**GAIA Webs**

**What is it?**
The *GAIA Web* window displays an enhanced spiderweb display for one action. Up to five separate *GAIA Web* windows can be opened to compare different actions.

**How to interact?**
There is a drop-down list to select the action you want to see. The "Decision Axis" checkbox controls whether the decision axis and the multicriteria net flow value are displayed or not.
The "Rounded" checkbox can be used to generate a "rounded" version of the *GAIA Web*.
There is also a local menu. Right-click on the drawing to open it.

**Local Menu**
From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Name: Either full or short names or no names can be displayed.

**GAIA Web**
The GAIA Web window shows a graphical representation of the [unicriterion net flow](#) scores for the selected action.

In usual spiderweb displays the variables (criteria) are equally spaced around the center of the display. The shape of the spiderweb is thus highly dependent on the arbitrary order of the criteria. In a GAIA Web, criteria axes are oriented as in the GAIA plane. Thus criteria expressing similar preferences are located close to each other and the spiderweb shape is more meaningful. For each dimension (individual criterion or grouped criteria group or cluster), the radial distance corresponds to the net flow score (-1 at the center and +1 on the outer circle).
The "Rounded" option replaces the straight lines that are drawn between axes by curves, allowing for a smoother and more consistent shape. For instance, an action with equal scores on all dimensions would be represented as a circle instead of as a polygon.

The "Decision Axis" option shows the location of the Decision Axis as well as a dotted circle corresponding to the multicriteria net flow score of the actions (drawn in green if $\Phi$ is positive and in red if it is negative).

In the example above, there are no bad features and Consumption is very good. It is even clearer to see with the rounded option.

**Walking Weights**

**What is it?**
The Walking Weights let you easily change the weights of the criteria and check the impact on the analysis.

**How to interact?**
There is a drop-down list to select the criterion you want to control.
The padlock button is used to lock the percentage weight of the currently selected criterion.
The "Update" button is used to update the initial weights of the criteria with the current values.
The "Best to worst" button is used to rank the actions in the upper part of the window according to the PROMETHEE II Ranking.
The "Set equal" button is used to set all weights equal.
The "Reset" button is used to reset the weights to their initial values.
There is also a local menu. Right-click on the drawing to open it.

**Local Menu**
From the local menu the following options are available:

- **Copy**: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- **Shortnames**: To display full or short names for actions and/or criteria.

**Walking Weights**
The Walking Weights window contains two graphics:

- The upper part shows the PROMETHEE II Phi net flow scores for the active actions.
- The lower part shows the relative (percent) weights of the criteria (or grouped criteria groups or clusters).
Click on a criterion bar or use the bottom left drop-down list to select a criterion (or grouped group or cluster) and use the slider to change its weight. The change is reflected in the other opened windows.

Click on the padlock icon to lock the percentage weight of the selected criterion (a padlock icon is then displayed on top of the bar). Click again to unlock the weight. In the screenshot below, the weight of **Power** is locked to 20%.
**Visual Stability Intervals**

**What is it?**
The Visual Stability Intervals window let you easily change the weights of the criteria and check the impact on the analysis.

**How to interact?**
There is a drop-down list to select the criterion you want to visualize. The "Stability level" check box controls the display of the weight stability interval. The level can be adjusted from 1 to the total number of active actions.

There is also a local menu. Right-click on the drawing to open it.

**Local Menu**
From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Shortnames: To display full or short names for the actions.
- Locate: Select an action that will be highlighted on the display.

**Visual Stability Interval**
The Visual Stability Intervals window shows how the Phi multicriteria net flow scores change as a function of the weight of a criterion.
The horizontal dimension corresponds to the weight of the selected criterion. And the vertical dimension corresponds to the Phi net flow score. For each action a line is drawn that shows the net flow score as a function of the weight of the criterion. At the right edge of the display the weight of the criterion is equal to 100% and the actions are ranked according to that single criterion. At the left edge, the weight of the criterion is equal to 0%.

The position of the vertical green and red bar corresponds to the current weight of the criterion. The intersection of the action lines with the vertical bar gives the PROMETHEE II complete ranking.

On the example above, one can see that the scores of the Luxury 1 and 2 cars go down when the weight of the Price criterion increases (they are indeed expensive) while the score of the Economic car increases (it is the cheapest one).

When the "Stability level" check box is checked, two dotted vertical lines are drawn to show the weight interval within which the top of the PROMETHEE II complete ranking remains unchanged (WSI - weight stability interval). The number of actions taken into account (stability level) can be set from 1 (top ranked action only) to the number of active actions (full ranking).

**PROMETHEE V Selection**

**What is it?**
PROMETHEE V uses the net flow computation to optimize the selection of a subset of actions under constraints such as maximum budget, location, etc.

**How to interact?**
There are two tabs in this window:
- **Constraints:**
  To setup the selection constraints.
- **Solution:**
  To view the optimal selection and perform what-if analyses.

**PROMETHEE V**
The PROMETHEE V method is used to select a best subset of actions according to several user-defined
constraints. It is based on a 0-1 linear program where the objective function is to maximize the sum of the net flow (\(\Phi\)) scores of the selected actions.

**Constraints**
The top of the window includes two fields to set the minimum and maximum number of actions that should be selected. The two buttons allow to add or delete constraints in the bottom table.

For each constraint, it is possible to enter the coefficients, to specify the type of constraint (\(<=, = \text{ or } >=\)), to enter the right hand side, to specify the name and additional information (by clicking the button), and to activate or deactivate the constraint.

In the above example, one single "Budget" constraint has been added. Budget values (the prices of the cars, expressed in \(\text{k}\)\(\text{€}\)) have been entered for the different actions and the maximum budget is set to 55 \(\text{k}\)\(\text{€}\). The number of cars to select is set to 2.

**Solution**
When this tab is selected, a branch and bound algorithm is started to find the optimal solution of the 0-1 linear program.

The left table shows the optimal solution that was found. The actions are displayed in the PROMETHEE II rank from top to bottom. The "Optimal" column displays the optimal solution. The buttons in the "Compare" column can be used to change the selection for comparison and make what-if analyses. The "Total" rows shows the value of the objective function (i.e. the sum of the net flow scores of the selected actions) for both selections.

The right table shows the left and right hand sides of the constraints for both the optimal and the compared selections. Constraint violations appear in red.
In the above example, PROMETHEE V proposes to select the Tourism B (1st ranked in PROMETHEE II) and Tourism A (3rd ranked) cars for a total flow of 0.2707. It doesn't select the second best action (Luxury 1) as this would violate the "Budget" constraint. This can be checked in the "Compare" columns: the total flow is higher (0.3120) but the budget is too large (63.5 k€).

**PROMETHEE Sort**

**What is it?**
PROMETHEE Sort is an extension of PROMETHEE for sorting actions in predefined classes.

**How to interact?**
There are four tabs in this window:
- **Class Setup:** To setup the classes and the sorting parameters.
- **Actions Setup:** To select which actions have to be sorted.
- **Sort Result:** To view the class assignment.
- **Visual Sort:** To graphically visualize the sort result for ordered classes and boundary profiles.

**PROMETHEE Sort**
The PROMETHEE Sort method can be used in different contexts where the actions have to be allocated to a set of predefined classes:
- The classes can be ordered from the least preferred to the most preferred one (e.g. to represent different levels of risk from "very high" to "very low") or they can be unordered (e.g. to establish a taxonomy of consumers based on different consuming behaviors).
- Each class is identified by one or several reference profiles. In Visual PROMETHEE the profiles should belong to an action category that is linked to the class. The reference profiles can be either:
  - boundary profiles: this can be used only with ordered classes. In Visual PROMETHEE, each class has a upper boundary profile (the upper boundary profile of the most preferred class is not used).
  - central profiles: this is the only possible option for unordered classes.

**Class Setup**
The left part of the window displays the list of the existing classes. The right part contains several commands that can be used to control the sorting method.
The Classes radio buttons allow to choose either ordered or unordered classes.

The Profiles radio buttons allow to use either boundary (ordered classes only) or central profiles.

The Distance radio buttons allow to select the distance measurement used by the sort algorithm with central profiles.

The middle arrow buttons allow to change the order of the classes. In the case of ordered classes, the least preferred (worst) class should be at the top and the most preferred (best) class at the bottom of the list.

The Classes button opens the Classes dialog from which classes can added or edited.

The Sort button starts the computation and displays the results.

**Actions Setup**

The main part of the window displays two list boxes of action categories: to the left are the categories that have to be sorted, to the right those that don't have to be sorted (usually the profile categories). The arrow buttons can be used to move categories from one list to the other.
The Categories button opens the Categories dialog from which categories can be added or edited.

The Sort button starts the computation and displays the results.

The All actions button sets all the categories to be sorted, including the profile categories if the checkbox "Include profile actions" is checked.

Sort Result

Visual Sort

Visual Sort is available for ordered classes and boundary profiles only. It shows a PROMETHEE Diamond.
like view of an action compared to the class profiles.

**Bank Adviser**

**What is it?**
*Bank Adviser* is an extension of *PROMETHEE* designed for evaluating *actions* with respect to a *reference set*.

**How to interact?**
There is a drop-down list to select the action you want to evaluate. There is also a drop-down list to select the reference set of actions. There is also a local menu. Right-click on the drawing to open it.

**Bank Adviser**
The *Bank Adviser* analysis allows to evaluate an action with respect to a reference set of actions. The reference set can be for instance:

- a set of well-known actions,
- a subset of actions (for instance geographically defined),
- a set of reference points (fictive actions),
- a peer-group.
In **Visual PROMETHEE** the reference set has to be a *category* of *actions*.

The **Bank Adviser** window contains two areas:

- At the top is the action profile:
  This is the profile of the selected action compared only to the reference set actions. It is thus different from the **Action Profile** window where all actions are compared to each other.
- At the bottom is the ruler:
  The ruler shows the Phi scale (from -1.0 to + 1.0) and the positions of the selected action (wide cursor with the Phi value and the rank of the action indicated on top of it) and of the reference actions (thinner bars, with the closest reference actions indicated below the ruler).

**Performance Analysis**

**What is it?**
This section introduces an extension of the **PROMETHEE** method for the evaluation of the relative performance of a set of units, according to several input and output criteria.

It is still in a research development phase and is intended as an alternative to methods such as Data Envelopment Analysis (DEA).

The actions correspond to the units to evaluate and two clusters of criteria have to be defined: all input criteria should be in a single cluster, and all output criteria should be in another single cluster.

**Performance Analysis**
There are two types of analyses that are available:
- Aggregated score
I-O Efficiency

**Aggregated Score**
The table displays for each action:

- **Input**: The net flow computed for the input cluster of criteria.
- **Output**: The net flow computed for the output cluster of criteria.
- **O/I ratio**: A performance measurement computed as a ratio between normalized output and input flows.
- **Score**: A percentage score corresponding to the O/I ratio: the best performing action has a 100,00 score.

The example above is not very realistic and is just introduced for demonstration purpose: Economy (Price and Consumption) criteria are considered as the input and Luxury (Habitability and Comfort) criteria are considered as the output. (Power is thus not taken into account here.)

**I-O Efficiency**
This is a two-dimensional representation of the Input and Output flows.

An “efficiency” frontier is drawn in red.
In the example above, three actions are on the efficient frontier with quite different performance profiles:

- **Economic**: lower input use but lower output as well,
- **Luxury 1**: high input use but higher output as well,
- **Tourism B**: more average input and output levels.

It is difficult to compare those three actions with respect to I/O performance.

The other three actions lag behind the efficient frontier. Their performance could be improved comparatively to the "efficient" actions.

**Preference Flows**

**What is it?**
The Preference Flows window displays the PROMETHEE unicriterion and multicriteria preference flows in a tabular format.

**How to interact?**
There are two tabs in this window:
- Unicriterion: The unicriterion net flows are displayed.
- Multicriteria: The multicriteria positive, negative and net flows are displayed.
There is also a local menu. Right-click on the drawing to open it.

**Local Menu**
From the local menu the following options are available:
• Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.

**Preference Flows**

**Unicriterion**
The unicriterion net flows are displayed for each criterion (or grouped group or cluster).

```
<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th>Power</th>
<th>Consumption</th>
<th>Habitability</th>
<th>Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tourism B</td>
<td>0.2067</td>
<td>0.0800</td>
<td>0.7000</td>
<td>0.3000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Luxury 1</td>
<td>-0.5867</td>
<td>0.1600</td>
<td>-0.2000</td>
<td>0.3000</td>
<td>0.7000</td>
</tr>
<tr>
<td>Tourism A</td>
<td>0.1667</td>
<td>-0.2000</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Luxury 2</td>
<td>-0.4867</td>
<td>0.0800</td>
<td>-0.5000</td>
<td>0.5000</td>
<td>0.4000</td>
</tr>
<tr>
<td>Economic</td>
<td>0.8733</td>
<td>-0.9600</td>
<td>0.4000</td>
<td>-0.4000</td>
<td>-0.7000</td>
</tr>
<tr>
<td>Sport</td>
<td>-0.0733</td>
<td>0.3400</td>
<td>-0.5000</td>
<td>-0.7000</td>
<td>-0.4000</td>
</tr>
</tbody>
</table>
```

**Multicriteria**
The multicriteria positive (Phi+), negative (Phi-) and net (Phi) flows are displayed.

```
<table>
<thead>
<tr>
<th></th>
<th>Phi+</th>
<th>Phi-</th>
<th>Phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tourism B</td>
<td>0.3573</td>
<td>0.1000</td>
<td>0.2573</td>
</tr>
<tr>
<td>Luxury 1</td>
<td>0.2760</td>
<td>0.2213</td>
<td>0.0547</td>
</tr>
<tr>
<td>Tourism A</td>
<td>0.2060</td>
<td>0.1927</td>
<td>0.0133</td>
</tr>
<tr>
<td>Luxury 2</td>
<td>0.2560</td>
<td>0.2573</td>
<td>-0.0013</td>
</tr>
<tr>
<td>Economic</td>
<td>0.2647</td>
<td>0.4220</td>
<td>-0.1573</td>
</tr>
<tr>
<td>Sport</td>
<td>0.2280</td>
<td>0.3947</td>
<td>-0.1667</td>
</tr>
</tbody>
</table>
```

**Scenarios Comparison**

**What is it?**
The PROMETHEE Rankings window displays the PROMETHEE I and II rankings in two separate tabs.

**How to interact?**
There are two tabs at the bottom of the window:
• Pairwise: For comparing two scenarios side by side.
• All scenarios: To compare all the scenarios together.
There is also a local menu. Right-click on the drawing to open it.

**Local Menu**
From the local menu the following options are available:
- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application such as e.g. Word, Excel or PowerPoint.
- Locate: You can select an action that will be highlighted on the display. That makes it easier to locate a particular action, especially when the number of actions is larger.

**Scenario Comparison**

This window allows to compare the PROMETHEE II rankings obtained for several scenarios.

![Scenario Comparison Window](image)

The above example shows the "All scenarios" tab: the PROMETHEE II ranking for each scenario is displayed on a vertical green-red bars and a line is drawn for each active action.

In the "Pairwise" tab, only two scenarios are displayed. The two drop-down list boxes located at the top of the window are used to select the scenarios to compare.

**Balance of Power**

**What is it?**

The Balance of Power let you easily change the weights of the scenarios and check the impact on the analysis.

**How to interact?**

There is a drop-down list to select the scenario you want to control. The padlock button is used to lock the percentage weight of the currently selected criterion. not implemented yet

The "Update" button is used to update the initial weights of the scenarios with the current values. not implemented yet

The "Set equal" button is used to set all weights equal.

The "Reset" button is used to reset the weights to their initial values. not implemented yet

There is also a local menu. Right-click on the drawing to open it.

**Local Menu**

From the local menu the following options are available:

- Copy: Make a copy of the window to the clipboard. You will be able to paste it into another application
such as e.g. Word, Excel or PowerPoint.

- Shortnames: To display full or short names for the scenarios.

**Balance of Power**

The Balance of Power window contains the following information:

![Balance of Power window](image)

The bar chart shows the relative weights of the active scenarios.

Use the drop-down list or click on a bar to select a scenario. Then use the slider to change the weight of the selected scenario.

Click "Set equal" to set equal weights for all the active scenarios.

**PROMap**

**What is it?**

PROMap provides Visual PROMETHEE with GIS features.

**How to interact?**

There are several controls available in this window:

- To the left and top right of the window are the usual Google Maps controls you can used to explore the map.
- At the bottom of the window are several controls:
  - Locate: Click this button to center the map on the selected action.
  - Display: Select the type of information to be displayed on the map.
  - Copy: Copy the map to the clipboard.
- Clicking on an action marker opens an information window.

**PROMap**

The PROMap display provides the integration of the Visual PROMETHEE analysis with Google Maps. To use it an active Internet connection is required.

Each action can be associated to a geographical location on the map. This can be done in the Actions dialog.

The results of the PROMETHEE-GAIA analysis can then be displayed in Google Maps. There are four possible displays:

- **PROMETHEE**: Actions are represented by squares. Positive flow scores are displayed in green and negative scores in red. The size of the square is increasing with the absolute value of the score. So,
best ranked actions correspond to large green squares and worst actions to large red squares.

- **GAIA**: Miniature versions of the **GAIA Webs** are displayed with a green or red square outline according to whether the action's net flow score is positive or negative.
- **Picture**: The picture associated to the action is displayed.
- **None**: Standard Google Maps markers are displayed.

The size of the markers can be changed from S (small) to XL (extra-large) using the drop-down list box.

In the above example, **GAIA Webs** are displayed. Quite different profiles are visible.

In the second screen shot, the **PROMETHEE** ranking is represented by squares. The best action is located to the South while the worst one is located to the East.
Weight Presets

What is it?
Weight presets allow to save different sets of weights for easy comparison.

How to interact?
There are two columns of buttons in this small window:
- Clicking on a left column button loads the corresponding weight preset.
- Clicking on a right column button ("Update") allows to save the current weights to that preset and to change its name if necessary.

Weight Presets
Five different weight presets can be defined for a given data set. The presets are saved with the data.

When starting a new problem, the presets are automatically set to equal weights for all the criteria.
**Layouts**

**What is it?**
Layouts allow to save different windows configurations for different types of analyses and to switch easily from one layout to another.

**How to interact?**
There are two columns of buttons in this small window:
- Clicking on a left column button switches the windows positions to the corresponding layout.
- Clicking on a right column button ("Update") allows to save the current layout to that row and to change its name if necessary.

The two buttons at the bottom of the window allow to reset the position of all the windows and to close all the windows.

**Layouts**
Five different layouts can be defined. The layouts are saved within the software and can be used with any data set. Each layout stores the position and state (visible, hidden, maximized) of the different windows.
PROMETHEE and GAIA methods

This chapter describes the methodology behind Visual PROMETHEE. It is organized as follows:

- A general introduction to MCDA concepts.
- The preference model used in the PROMETHEE and GAIA methods (preference functions and weights).
- The way the PROMETHEE rankings are computed.
- The GAIA descriptive analysis.
- And more advanced topics:
  - Sensitivity analyses.
  - GDSS extensions.
  - PROMETHEE V selection under constraints.
  - PROMETHEE Sort.
  - Bank Adviser.
  - Performance analysis using PROMETHEE.

Here is a more detailed table of contents:

- **MCDA**
  - Multicriteria Table
  - Aggregation and Weighted Sum
  - Outranking Methods

- **PROMETHEE Preference Model**
  - Seven Requisites
  - Preference Functions
  - Criteria Weights
  - Pairwise Comparisons

- **PROMETHEE Rankings**
  - Preference Flows
  - PROMETHEE I Partial Ranking
  - PROMETHEE II Complete Ranking

- **GAIA**
  - Unicriterion Net Flows
  - GAIA Plane
  - GAIA 3D

- **Sensitivity Analysis**

- **GDSS PROMETHEE**
  - Multi-scenario Preference Flows
  - Consensus PROMETHEE Rankings
  - Multi-scenario GAIA

- **PROMETHEE V Selection**
- **PROMETHEE Sort**
- **Bank Adviser**
- **Performance Analysis**

**MCDA**

MCDA stands for MultiCriteria Decision Aid. It includes many approaches, models and methods to handle decision or evaluation problems where multiple evaluation criteria have to be taken into account.

Indeed most decisions we make are not easy because they involve multiple and conflicting objectives. For instance:
• **Procurement**: which is the best supplier?
• **Key Performance Indicators**: how to evaluate performance of business units?
• **Portfolio Management**: how to compose the best R&D projects or financial assets portfolio?
• **Location**: what is the best place to build a new facility (plant, warehouse, hypermarket, ...)?
• **Health Care**: what is the best therapeutic choice to treat a patient?
• **Sustainable Development**: what is the best way to achieve sustainable development?

In each case, one or several persons (decision-makers or stakeholders) have to compare different solutions (actions) with several objectives in mind. For instance:

• **Procurement**: minimize the price paid, maximize the quality of the product purchased, maximize the quality of service supplied, ...
• **Key Performance Indicators**: minimize costs, maximize profit, maximize efficiency, ...
• **Portfolio Management**: minimize risk, maximize expected return, ...
• **Location**: minimize investment cost, maximize expected return, minimize environmental impacts, maximize safety, ...
• **Health Care**: maximize efficiency, minimize side effects, reduce costs, ...
• **Sustainable Development**: reduce environmental impacts, reduce social impacts, improve wealth.

The degree of achievement of these objectives can be measured by defining appropriate quantitative or qualitative evaluation criteria such as for instance:

• the price of an equipment (in € or in $ or...),
• a qualitative measurement of social impact (on a scale such as: very low, low, moderate, high or very high),
• GHG emissions, ...

These criteria are usually conflicting with each other:

• Usually higher quality equipment is more expensive.
• Taking care of environmental issues can have a negative impact on profit.
• Building a new hypermarket closer to a big city will cost more money but will bring a higher level of expected return.
• ...

That's why most of our decisions are difficult to make. So what's best?

It depends. On your priorities. On your preferences.

**MCDA** methods are designed to assist decision-makers in such a context.

The **PROMETHEE** and **GAIA** methods can help you to answer the following questions and many others as well:

• "What is the best choice?"
  The **PROMETHEE Rankings** will show you the best compromise solutions according to the evaluation criteria, your preferences and priorities.
• "Is this a good customer?"
  The **PROMETHEE Sort** procedure will help you to allocate an item to a predefined class (such as for instance: good customers, average customers or bad customers).
• "Why is this not a good solution?"
  The **GAIA** visual analysis will help you to understand better the decision problem, to see what is possible and what is not, to justify your choices or to acknowledge that some choices cannot be
justified. It will also help you to explain to other persons why some decisions are better.

- "Which projects should we support?"

PROMETHEE V will assist you in selecting different options according to constraints such as budget limit, incompatibilities, diversification, etc.

- "Why can't we agree on a common decision?"

The GDSS extensions of PROMETHEE and GAIA are available to help a group of persons to make a decision together.

The next sections of this chapter introduces basic concepts about multicriteria decision aid in the context of the use of the PROMETHEE and GAIA methods and of the Visual PROMETHEE software.

- Multicriteria Table
- Aggregation and Weighted Sum
- Outranking Methods

**Multicriteria Table**

The PROMETHEE methods are designed to analyze data within a multicriteria table including:

- a number of actions,
- several criteria.

In mathematical terms the problem is the following:

$$\max \left\{ f_1(a), f_2(a), \ldots, f_j(a), \ldots, f_k(a) \right\} | a \in A$$

where \( A \) is a finite set of \( n \) actions and \( f_1 \) to \( f_k \) are \( k \) criteria. \( f(a) \) is the evaluation of action \( a \) on criterion \( f \).

There is no objection to consider some criteria to be maximized and others to be minimized but for the sake of simplicity we will suppose here that all criteria have to be maximized.

The evaluations of the actions on the criteria form a two-way multicriteria table:

<table>
<thead>
<tr>
<th></th>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( \ldots )</th>
<th>( f_j )</th>
<th>( \ldots )</th>
<th>( f_k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>( f_1(a_1) )</td>
<td>( f_2(a_1) )</td>
<td>( \ldots )</td>
<td>( f_j(a_1) )</td>
<td>( \ldots )</td>
<td>( f_k(a_1) )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( f_1(a_2) )</td>
<td>( f_2(a_2) )</td>
<td>( \ldots )</td>
<td>( f_j(a_2) )</td>
<td>( \ldots )</td>
<td>( f_k(a_2) )</td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
</tr>
<tr>
<td>( a_i )</td>
<td>( f_1(a_i) )</td>
<td>( f_2(a_i) )</td>
<td>( \ldots )</td>
<td>( f_j(a_i) )</td>
<td>( \ldots )</td>
<td>( f_k(a_i) )</td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
</tr>
<tr>
<td>( a_n )</td>
<td>( f_1(a_n) )</td>
<td>( f_2(a_n) )</td>
<td>( \ldots )</td>
<td>( f_j(a_n) )</td>
<td>( \ldots )</td>
<td>( f_k(a_n) )</td>
</tr>
</tbody>
</table>

The expectation of the decision-maker is to identify an action that is the best (optimal) on all the criteria at the same time.

That is usually impossible as the criteria are more or less conflicting with each other. The objective of MCDA is thus to identify the best compromise decisions.

In order to achieve this objective, it is essential to have some information about the preferences and the priorities of the decision-maker. This information is not contained in the multicriteria table. And different decision-makers will have different preferences and priorities.

Gathering information about the decision-maker preferences and priorities can be done in many different ways. In the next chapters we compare two common ways and we emphasize their qualities and their limits.
The Visual PROMETHEE demo is about a person who wants to purchase a new car. There are six cars to compare. These are the actions. And there five criteria to compare them. The multicriteria table is displayed in the Visual PROMETHEE spreadsheet when you start the program.

Aggregation and Weighted Sum

One very common way to try to solve multicriteria decision problem is to aggregate all the criteria into a single summary score.

That can be done in several ways.

The simplest and most often used way is to compute a weighted sum (or weighted average) of the evaluations:

$$V(a) = \sum_{j} w_j \times f_j(a)$$

where:

- $w_j > 0$ is the weight allocated to criterion $f_j$ (the more important $f_j$ the larger $w_j$),
- $V(a)$ is the resulting score of action $a$.

The actions can then be ranked according to their $V$ score, from the largest to the smallest value.

This approach has several limits and can be dangerous for the following reasons:

- It is a completely compensatory approach which means that a very bad evaluation on one criterion can always be compensated for by better values on other criteria. For instance it could recommend to purchase a Rolls-Royce because this car is so powerful, so comfortable, so safe, so luxurious, so well made, ... never mind the price!
- The weights of the criteria are linked to the scales of measurement of the criteria in a way that is difficult to manage. It is like adding apples and pears.
- Reducing an action to a single score means that a lot of information get lost about the conflicts among the criteria that have to be solved to make a decision. That's a very important piece of information that is understated.

The aggregation of criteria can be done in more sophisticated ways. This is the purpose of MAUT (multi-attribute utility theory) which is rather popular in the USA and in UK.

However MAUT still suffers the same limits and dangers as the simpler weighted sum approach.

Using MAUT approaches (such as in the Macbeth or D-Sight software) you risk to end up with unbalanced decisions.

A much better solution to get more balanced compromise solutions as a decision-maker would want it is to use another type of methods: outranking methods.

Outranking Methods

Outranking methods are based on a more familiar way of thinking. Instead of trying to define what is good and what is bad, which can be very difficult especially when you are facing a new problem for which you have very few reference points, it is usually much easier to compare one solution to another. That is the underlying principle of outranking methods:
Outranking methods model the way the decision-maker compares two actions. Outranking methods do not require the decision-maker to define what is good or what is bad. Outranking methods do use the results of the pairwise comparison of the actions to build a relative ranking of the actions from the best one to the worst one.

That can obviously be done in many ways.

The first outranking methods were the ELECTRE methods developed in the 1970's by Professor Bernard Roy at the University of Paris-Dauphine in France. ELECTRE I focused on selecting the best action while ELECTRE II was one of the first ranking methods. In 1979 ELECTRE III introduced the notion of indifference and preference thresholds that can be found in PROMETHEE.

Other outranking methods have been developed such as for instance the ORESTE method.

The PROMETHEE methods were first introduced in 1982 and have been constantly improved since that time. They elaborate on the strengths of the ELECTRE methods and bring newer dimensions such as the GAIA graphical descriptive method. They are described in the next chapters.

**PROMETHEE Preference Model**

The PROMETHEE methods are among the most widely used outranking methods. This chapter describes the main elements of the preference modeling in the PROMETHEE methods. It is the basis to the PROMETHEE rankings and to the GAIA graphical descriptive analysis.

- **Seven Requisites**
- **Preference Functions**
- **Criteria Weights**
- **Pairwise Comparisons**

**Seven Requisites**

When facing a multicriteria table few information is available on the decision-maker preferences: criteria are to be maximized or minimized. With so few information the analysis of the multicriteria table is limited to checking the dominance relation and identifying efficient actions. To go further and provide the decision-maker with more interesting conclusions more information is necessary.

**Dominance relation and efficiency (Pareto-optimality)**

The dominance relation is based on a unanimity rule. An action \( a \) dominates an action \( b \) if it is at least as good as \( b \) on all criteria and better than \( b \) on at least one criterion.

An action is said to be efficient (or Pareto-optimal) if it is not dominated by any other action.

A possible approach to the analysis of a multicriteria table could be to identify the efficient actions as good solutions and to reject the dominated actions.

The problem with dominance is that there are usually very few dominances in a multicriteria table because of the conflicting character of many criteria: when one action is better on one criterion it is often worse on other conflicting criteria. The consequence is that the number of efficient actions is usually very large. Besides dominance doesn't take into account the amplitude of the deviation between the evaluations. It makes no difference between "strong" or "weaker" dominance.

Dominance and efficiency are thus inadequate for the analysis of multicriteria tables.

In the next section seven requisites are introduced that should be included in a better multicriteria approach.
Seven requisites

For a good multicriteria method at least seven requisites are important:

- **Requisite 1**: The amplitude of the deviations between the evaluations of the actions for each criterion should be taken into account (to pay 10€ more is not the same as to pay 1000€ more). This is not the case with dominance and efficiency analysis.

- **Requisite 2**: As each criterion usually has specific scale and measurement unit, scaling effects should be avoided: it is not acceptable to obtain conclusions depending on the scales in which the evaluations are expressed (changing the currency from euros to dollars should not affect the results of the analysis). Unfortunately not all multicriteria procedures are respecting this requisite.

- **Requisite 3**: When considering the pairwise comparison of two actions \( a \) and \( b \), the three following situations appear naturally:
  - \( a \) is preferred to \( b \).
  - \( a \) and \( b \) are indifferent.
  - \( a \) and \( b \) are incomparable because they are very different from each other: \( a \) is much better than \( b \) on some criteria and \( b \) is much better than \( a \) on other criteria.

  Of course the purpose of a MCDA method is to reduce as much as possible the number of incomparabilities, provided it is not dangerous. Systematically withdrawing incomparabilities such as in aggregation methods is more disputable.

- **Requisite 4**: Different multicriteria methods request different additional information and operate different calculation procedures so that the solutions they propose can be different. It is therefore important to develop methods being understandable by the decision-maker. “Black box” effect should be avoided.

- **Requisite 5**: A good multicriteria method should not include technical parameters with no significance for the decision-maker. Such parameters would indeed induce a “black box” effect.

- **Requisite 6**: A good multicriteria method should provide information on the existing conflicts between the criteria.

- **Requisite 7**: Most multicriteria methods are using weights to define the relative importance of the criteria. It is usually not easy to define values for the weights. The decision-maker can hesitate. Actually these weights can also be seen as degrees of freedom for the decision-maker to explore possible solutions. A good multicriteria method should therefore include appropriate sensitivity analysis tools.

These seven requisites have been taken into account in the development of the PROMETHEE methods:

- Requisites 1, 2 and 5 are addressed by the introduction of preference functions.
- Requisite 3 is taken care of in the PROMETHEE I and II rankings.
- Requisite 4 is achieved by trying to keep the PROMETHEE methods as simple as possible.
- Requisite 6 is addressed by the GAIA method.
- Requisite 7 is addressed by the various sensitivity analysis tools that have been developed for PROMETHEE including the PROMETHEE VI procedure (decision-maker's brain).

Preference Functions

What is a preference function

Contrarily to aggregation methods (MAUT, Macbeth, D-Sight, ...), PROMETHEE makes no assumption as to what is good and what is bad. That can be dangerous when this information is not reliable: suppose you are moving to a foreign country and you are looking for a new house. You have no idea about what is cheap and what is expensive. But it is much easier for you to compare two different prices and to decide whether the price difference is important for you or not. That is the way outranking methods and PROMETHEE are working.

PROMETHEE is based on the pairwise comparison of the actions. It means that the deviation between the evaluations of two actions on a particular criterion has first to be modeled. For small deviations, there will probably be either a weak preference or no preference at all for the best action as the decision-maker will consider this deviation as small or negligible. For larger deviations, larger preference levels are expected.
With PROMETHEE preference levels are measured on a scale going from 0 to 1: 0 means no preference at all while 1 means a full preference. The deviation has to be translated to such a preference degree between 0 and 1. That is the purpose of the preference function.

PROMETHEE requires to associate a preference function to each criterion in order to model the way the decision-maker perceives the measurement scale of the criterion.

There are six different types of preference function available in the PROMETHEE methods.

**Six different types of preference function**

From the beginning the PROMETHEE methods have included six types of preference function.

In practice they are sufficient to address most cases but some types are more used than others. Namely:

- **Type I**, the Usual preference function, is a good choice for qualitative criteria including a small number of evaluation levels (like the often used 5-point scale ranging from very bad to very good).
- **Type IV**, the Level preference function, is a good choice for qualitative criteria with a larger number of levels.
- **Type V**, the Linear preference function, (and Type III, V-shape, as a special case) is the best choice for most quantitative criteria.

**Type I: Usual preference function**

The Usual preference function is very simple. Actually it corresponds to optimization: the larger the value the better. It doesn't include any threshold.

It can be the right choice for a criterion with a few very different evaluations. That is often the case for qualitative criteria. For example, this choice would be appropriate for a 5-level qualitative scales with the following levels: very bad, bad, average, good, very good. Provided that you feel that a one-level difference is already very important. In other words, you feel that "very good" is much preferred to "good" and "average" is much preferred to "bad" and so on.

Using the Usual preference function with a quantitative criterion such as a price would mean that you consider equivalent a price difference of 1€ and a price difference of 1,000€. This would of course be not appropriate.

**Type II: U-shape preference function**

The U-shape preference function introduces the notion of an indifference threshold.

**Type III: V-shape preference function**

The V-shape preference function is a special case of the Linear preference function where the Q indifference threshold is equal to 0. It is thus well suited to quantitative criteria when even small deviations should be
accounted for.

**Type IV: Level preference function**

The Level preference function is better suited to qualitative criteria when the decision-maker wants to modulate the preference degree according to the deviation between evaluation levels.

**Type V: Linear preference function**

The Linear preference is the best choice for quantitative criteria when a Q indifference threshold is wished.

**Type VI: Gaussian preference function**

The Gaussian preference function is an alternative to the Linear one. It has a smoother shape but it is more difficult to set up because it relies to a single S threshold that is between the Q and P thresholds and has a less obvious interpretation. It is seldom used.

**Q, P and S thresholds**

Depending on the type of preference function that has been selected up to two thresholds have to be assessed. These are:

- Q - the indifference threshold
- P - the preference threshold
- S - the Gaussian threshold

**Q: Indifference threshold**

The Q indifference threshold is the largest deviation that is considered as negligible by the decision-maker.

To determine the value of Q one should start with a very small deviation (for instance a few euros) and increase it progressively until it is not felt to be negligible anymore. This means that Q is just below that first significant value.

**P: Preference threshold**

The P preference threshold is the smallest deviation that is considered as sufficient to generate a full preference.

To determine the value of P one should start with a very large deviation (for instance several thousands euros) and progressively reduce it until some hesitation arises. This means that P is slightly above this last value.

**S: Gaussian threshold**
The S Gaussian threshold correspond to the inflection point of the Gaussian curve (similarly to the standard deviation in statistics). It is thus a deviation for which the preference degree is equal to 0.39 so it is in between a Q and a P value. It is also more difficult to assess. A rule of thumb could be to determine a Q and a P value and to set S equal to their average (S = (Q+P) / 2).

Criteria Weights
The weights of the criteria are essential parameters to reflect the priorities of the decision-maker.

The weights are non-negative (> 0) numbers representing the relative importance of the criteria. In PROMETHEE they are defined independently from the scale of measurement of the criteria. More important criteria have larger weights while less important ones have smaller weights.

We suppose here that the weights are normalized in such a way that their sum is equal to 1 (100%). This normalization is done automatically in Visual PROMETHEE.

Assessing weights to the criteria is not straightforward. It involves the priorities and perceptions of the decision-maker. The weights also represent his/her space of freedom. Visual PROMETHEE includes several sensitivity analysis tools to help the decision-maker in that task.

Pairwise Comparisons
PROMETHEE is an outranking method. It is based on the principle of pairwise comparison of the actions.

A first step in the PROMETHEE modeling is thus to compare each action with each other.

This is done by computing a multicriteria preference index in the following way:

$$\pi(a,b) = \sum_{j=1}^{k} w_j \times P_j(a,b)$$

where:

- \( w_j > 0 \) is the normalized weight allocated to criterion \( f_j \) (the more important \( f_j \) the larger \( w_j \)),
- \( P_j(a,b) \) is the value of the preference function for criterion \( f_j \) when action \( a \) is compared to action \( b \).

With normalized weights, \( \pi(a,b) \) is a number between 0 and 1. It expresses how much \( a \) is preferred to \( b \) taking into account all the criteria and their weights. For instance:

- if \( \pi(a,b) = 0 \) : All the \( P_j(a,b) \) values are equal to 0 which means that \( a \) is never even slightly preferred to \( b \) on any criterion.
- if \( \pi(a,b) = 1 \) : All the \( P_j(a,b) \) values are equal to 1 which means that \( a \) is strongly preferred to \( b \) on all the criteria.

So that:

- \( \pi(a,b) \approx 0 \) means that there is a weak preference for \( a \) over \( b \).
- \( \pi(a,b) \approx 1 \) means that there is a strong preference for \( a \) over \( b \).

The following properties hold:

$$\begin{cases} 
\pi(a,a) = 0 \\
0 \leq \pi(a,b) \leq 1 \\
0 \leq \pi(a,b) + \pi(b,a) \leq 1 
\end{cases}$$
Missing values

Missing values can arise in the multicriteria table for various reasons, e.g.:

- Because the information is simply not available for some actions. That can be due to the lack of access to the data, to budget or time constraints for instance.
- Because a criterion can be pertinent for only some of the actions.

This problem can be addressed in different ways.

Replacing missing values by arbitrary values

As most MCDA methods rely on the availability of all the evaluations in the multicriteria table, the generally used approach is to replace the missing values by some replacement values. The replacement value can be:

- A fixed value, such as for instance 0. This is obviously completely arbitrary and can introduce unwanted biases in the analysis. For instance replacing a missing cost value by 0€ is really dangerous.
- A value computed from the distribution of the available evaluations on the corresponding criterion (for instance the arithmetic average). This will reduce the biases but it is still arbitrary to assume that the missing value is central.
- An estimate of the missing value, provided that it is possible to do so.

Excluding actions or criteria with missing values

A second possibility is to remove from the analysis any action or criterion for which there are missing data.

This raises two problems:

- In the case of a single missing value, should the action or the criterion be removed?
- When the number of missing value is small, such a procedure can lead to the removal of interesting actions or important criteria for which interesting information is actually available.

That approach can however make sense when there are many missing values that are concentrated on one or a few number of actions or criteria. Indeed, if one only has a very limited knowledge about some action or some criterion, it could be wise to exclude this action or this criterion from the analysis.

Handling missing values at the pairwise comparison level

One advantage of PROMETHEE being a pairwise comparisons method is that it is possible to handle missing at that level.

When two actions $a$ and $b$ are compared, the multicriteria preference index is computed:

$$\pi(a, b) = \sum_{j=1}^{\mathcal{J}} w_j \times P_j(a, b)$$

It involves the values taken by the preference functions associated to the criteria and not directly the evaluations of the actions themselves. If for criterion $f_j$, either $f_j(a)$ or $f_j(b)$ is missing, a value has to be defined for $P_j(a, b)$. The more neutral value in such case is 0 : this way no assumption is made about any preference between $a$ and $b$. This is quite different from the replacement approach where $a$ is preferred to some actions and some actions are preferred to $a$ depending on the replacement value. In this case, no preference is generated. Actually, if all the evaluations of an action are missing, this action will have a net flow score equal to 0.

This procedure is implemented in Visual PROMETHEE.
PROMETHEE Rankings

There are two PROMETHEE rankings. They are based on the computation of preference flows.

- Preference Flows
- PROMETHEE I Partial Ranking
- PROMETHEE II Complete Ranking

Preference Flows

The preference flows are computed to consolidate the results of the pairwise comparisons of the actions and to rank all the actions from the best to the worst one.

Three different preference flows are computed:

- \( \phi^+ \): the positive (or leaving) flow
- \( \phi^- \): the negative (or entering) flow
- \( \phi \): the net flow

\( \phi^+ \): positive (leaving) flow

\[
\phi^+(a) = \frac{1}{n-1} \sum_{b \neq a} x(a, b)
\]

The positive preference flow \( \phi^+(a) \) measures how much an action \( a \) is preferred to the other \( n-1 \) ones. It is a global measurement of the strengths of action \( a \). The larger \( \phi^+(a) \) the better the action.

\( \phi^- \): negative (entering) flow

\[
\phi^-(a) = \frac{1}{n-1} \sum_{b \neq a} x(b, a)
\]

The negative preference flow \( \phi^-(a) \) measures how much the other \( n-1 \) actions are preferred to action \( a \). It is a global measurement of the weaknesses of action \( a \). The smaller \( \phi^-(a) \) the better the action.

\( \phi \): net flow

The net preference flow \( \phi(a) \) is the balance between the positive and negative preference flows:

\[
\phi(a) = \phi^+(a) - \phi^-(a)
\]

It thus takes into account and aggregates both the strengths and the weaknesses of the action into a single score.

\( \phi(a) \) can be positive or negative. The larger \( \phi(a) \) the better the action.

PROMETHEE I Partial Ranking

The PROMETHEE I ranking is a partial ranking. This means that all the actions are not necessarily compared and that the ranking can include incomparabilities.

The ranking is based on the two following preference flows:
- \( \Phi^+ (\phi) \): the positive (or leaving) flow,
- \( \Phi^- (\phi) \): the negative (or entering) flow.

As the two preference flows are consolidating the \textit{pairwise comparisons} of the actions according to opposite points of view, they usually induce two different rankings on the set of actions. The \textbf{PROMETHEE I partial ranking} is the intersection of these two rankings. So action \( a \) is preferred to action \( b \) in the \textbf{PROMETHEE I ranking} if and only if it is preferred to \( b \) according to both preference flows. That is:

\[ a \text{P}^I b \text{ if and only if } \phi^+ (a) \geq \phi^+ (b) \text{ and } \phi^- (a) \leq \phi^- (b) \]

where \( \text{P}^I \) stands for "is preferred to in the PROMETHEE I ranking" and at least one of the two inequalities should be strict (otherwise the two actions are indifferent (in a tie)).

Whenever the two preference flows give opposite rankings of the actions the actions become \textit{incomparable}.

The \textbf{PROMETHEE I partial ranking} can be represented in several ways. While older software like PromCalc and Decision Lab used a network representation, Visual PROMETHEE introduces more visually appealing and informative representations:

- The \textbf{PROMETHEE Rankings} window makes it easy to compare the rankings corresponding to the two preference flows.
- The \textbf{PROMETHEE Diamond} display is a two-dimensional alternative representation that is useful to detect the proximities of the actions.
- The \textbf{PROMETHEE Table} window gives access to the flow scores for an easy export to Excel for instance.

**PROMETHEE II Complete Ranking**

The \textbf{PROMETHEE II ranking} is a complete ranking. This means that all the \textit{actions} are compared and that the ranking includes no \textit{incomparabilities} even when comparison is difficult. The resulting ranking can thus be more disputable, especially in the presence of strongly conflicting criteria.

The ranking is based on the \textit{net preference flow}. It combines the two other preference flows in a single summary score. So action \( a \) is preferred to action \( b \) in the \textbf{PROMETHEE II ranking} if and only if it is preferred to \( b \) according to the net preference flow. That is:

\[ a \text{P}^{II} b \text{ if and only if } \phi(a) > \phi(b) \]

where \( \text{P}^{II} \) stands for "is preferred to in the PROMETHEE II ranking".

The \textbf{PROMETHEE II complete ranking} can be represented in several ways. While older software like PromCalc and Decision Lab used a network representation, Visual PROMETHEE introduces more visually appealing and informative representations:

- The \textbf{PROMETHEE Rankings} window makes it easy to compare the rankings corresponding to the two preference flows.
- The \textbf{PROMETHEE Table} window gives access to the flow scores for an easy export to Excel for instance.
- The \textbf{PROMETHEE Rainbow} window provides a disaggregated view of the ranking.
- The \textbf{Walking Weights} window presents the ranking under a bar chart form.

**Rank reversal**

Rank reversal refers to the fact that the relative positions of two \textit{actions} in a ranking can change when another action is added to or deleted from the set of actions.
This phenomenon is inherent to pairwise-comparisons-based multicriteria decision aid methods such as for instance PROMETHEE, ELECTRE, AHP or Macbeth. Indeed in such methods the scores (preference flows in PROMETHEE) used to rank the actions are built from the pairwise comparisons of all the actions. Different sets of actions thus provide different scores and rank reversal can occur.

In the case of the PROMETHEE methods rank reversal is limited. It can be proved for instance that:

- The PROMETHEE rankings are consistent with the dominance relation. In other words if an action is dominated by another one it will never be preferred to that other one in the PROMETHEE rankings.
- Rank reversal can only happen when the flow values of the actions are relatively close to each other. Which means that rank reversal mostly occurs between actions that are very close to each other in the PROMETHEE rankings. It is also important to keep in mind that a poor choice of preference function (for instance using the Usual preference function with continuous numerical criteria) can increase the occurrence of rank reversals. The visual representations used in Visual PROMETHEE make it easy to detect such cases.

**GAIA**

GAIA is the descriptive companion method to PROMETHEE.

- **Unicriterion Net Flows**
- **GAIA Plane**
- **GAIA 3D**
- **PROMETHEE VI Brain**

**Unicriterion Net Flows**

The net preference flow can be computed for each criterion separately. The unicriterion net flow for criterion \( f_j \) is then defined as:

\[
\phi_j(a) = \frac{1}{n-1} \sum_{b \neq a} \left[ P_j(a, b) - P_j(b, a) \right]
\]

And we have the following property:

\[
\phi(a) = \sum_{j=1}^{k} \sum_{j=1}^{k} \phi_j(a)
\]

The unicriterion net flow values are always numbers between -1 (worst possible value) and +1 (best possible value).

This decomposition (or disaggregation) is interesting for at least two reasons:

- It is possible to evaluate the relative performance of an action on any criterion, taking into account the preference function defined by the decision-maker. That information is used to draw the action profiles and the GAIA Webs.
- Using the unicriterion net flows the multicriteria table can be represented in a \( k \)-dimensional space taking into account the scales of the criteria with the preference functions defined by the decision-maker. That is the basis of GAIA.

**GAIA Plane**

The objective of GAIA is to describe the major features of the decision problems graphically:

- How much are actions different or similar to each other? Are there clusters of similar actions?
• Which criteria are conflicting with each other? Are there strong conflicts to solve? Are there groups of criteria expressing similar preferences?
• What is the impact of the weighing of the criteria on the PROMETHEE rankings?

The GAIA analysis starts from the unicriterion net flow table:

<table>
<thead>
<tr>
<th></th>
<th>( \phi_1 )</th>
<th>( \phi_2 )</th>
<th>( \ldots )</th>
<th>( \phi_j )</th>
<th>( \ldots )</th>
<th>( \phi_k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>( \phi_1(a_1) )</td>
<td>( \phi_2(a_1) )</td>
<td>( \ldots )</td>
<td>( \phi_j(a_1) )</td>
<td>( \ldots )</td>
<td>( \phi_k(a_1) )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( \phi_1(a_2) )</td>
<td>( \phi_2(a_2) )</td>
<td>( \ldots )</td>
<td>( \phi_j(a_2) )</td>
<td>( \ldots )</td>
<td>( \phi_k(a_2) )</td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
</tr>
<tr>
<td>( a_i )</td>
<td>( \phi_1(a_i) )</td>
<td>( \phi_2(a_i) )</td>
<td>( \ldots )</td>
<td>( \phi_j(a_i) )</td>
<td>( \ldots )</td>
<td>( \phi_k(a_i) )</td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
</tr>
<tr>
<td>( a_n )</td>
<td>( \phi_1(a_n) )</td>
<td>( \phi_2(a_n) )</td>
<td>( \ldots )</td>
<td>( \phi_j(a_n) )</td>
<td>( \ldots )</td>
<td>( \phi_k(a_n) )</td>
</tr>
</tbody>
</table>

This table is similar to but contains more information than the original multicriteria table because the preference functions defined by the decision-maker are taken into account. It also means that each criterion is expressed on the same normalized net flow scale (scores between -1 and +1). Each action is thus associated to a \( k \)-dimensional profile and can be seen as a point in the \( k \)-dimensional space.

Similar actions are expected to be close to each other and their location in the \( k \)-dimensional space indicates what are their strengths and what are their weaknesses. The relative positions of the actions also reveals the links and the possible conflicts between the criteria. It is however difficult to use this information when there are more than two or possibly three criteria because the \( k \)-dimensional space cannot be visualized.

GAIA uses a dimension-reduction technique that is borrowed from statistical data analysis. This technique is called the principal components analysis (PCA).

PCA allows to define a series of orthogonal dimensions (principal components) that keep as much information as possible on the relative positions of the actions in the \( k \)-dimensional space.

In the original GAIA method the two first principal components (named U and V) are computed and displayed in the GAIA plane.

The GAIA plane is the best two-dimensional representation of the multicriteria problem. It retains the maximum possible quantity of information from the \( k \)-dimensional representation. This quantity of information can be measured and is usually called \( \Delta \). In Visual PROMETHEE it appears under the name "Quality" in the GAIA window.

Three different pieces of information appear in the GAIA plane:

• Actions are represented by points.
• Criteria are represented by axes.
• The weights of the criteria are represented by the decision axis.

The following figure shows the GAIA plane for the Visual PROMETHEE demo. In this case the quantity of information contained in the plane is equal to 89,9% (as shown in the GAIA window in Visual PROMETHEE).
Actions

Actions are represented by points. We have the following properties:

- Actions that are similar to each other appear close to each other in the **GAIA** plane. In the above picture, it is the case of the two **Luxury** cars.
- Actions that are very different from each other appear far away from each other in the **GAIA** plane. It is the case for the **Economic** and the **Sport** cars.

Subsets of similar actions can thus be identified.

In the example, four subsets of actions are identified:

- Luxury cars (**Luxury 1** and **Luxury 2**),
- Tourism cars (**Tourism A** and **Tourism B**),
- **Economic**,
- **Sport**.

Criteria

Criteria are represented by axes drawn from the center of the plane. We have the following properties:

- Criteria expressing similar preferences are represented by axes oriented in similar directions. That is the
case for example of Habitability and Comfort.

- Criteria expressing conflicting (opposite) preferences are represented by axes oriented in opposite directions. That is the case for example of Power and Consumption.
- The length of a criterion axis is representative of its relative discriminating power: the longer the axis the more discriminating the criterion.

Subsets of criteria expressing similar preferences can thus be identified and the relative discriminating power of the criteria can be assessed.

In the example, three subsets can be identified:

- Luxury criteria (Habitability and Comfort) in the North-East direction,
- Economy criteria (Price and Consumption) in the West direction,
- Power on its own in the South-East direction.

The identification of subsets of criteria make it easier to understand the conflicts that have to be solved in making a decision. In this example, it appears that the decision-maker has to compromise between three conflicting objectives: luxury, economy and power.

**Actions and criteria**

The position of the actions with respect to the criteria axes indicate how well actions are performing on the different criteria.

Let us consider the criterion Price in the example. What is important is the direction of the corresponding axis: in this case the Price axis is oriented to the left. This means that the more an action is located to the left of the GAIA plane the better it is with respect to criterion Price.

Visual PROMETHEE allows you to check this by selecting a criterion in the "Show axis..." local menu. Choosing Price as the criterion to display gives the following graphic. The red line extends the direction of the criterion axis. It is oriented. In this case the 'best' values are on the left and the 'worst' are on the right side according to the criterion axis orientation.

Each action is projected orthogonally on the criterion direction. The projections show the relative performance of the actions on the selected criterion. The distance to the criterion is meaningful. What matters is the place where the action projects on the criterion. In the example we see that:

- Economic is clearly the best (the cheapest car),
- Tourism A and B are the second best (cheapest) cars and have very similar prices,
- Sport is more expensive,
- Luxury 1 and 2 are the most expensive cars/

This information is of course limited by the quality of the GAIA plane.
Decision Axis

The **Decision Axis** is a visual representation of the weighing of the criteria in the **GAIA** plane. As weights are allocated to the criteria the best actions in the **PROMETHEE** rankings are more or less influenced by the different criteria.

The **Decision Axis** is similar to a weighted average of the criteria axes. It indicates the direction of the **PROMETHEE II** ranking and thus show which criteria are in agreement with the **PROMETHEE II** ranking and which are not. This can be helpful to detect under- or over-weighed criteria. In the above example one can see that with the current weights of the criteria **PROMETHEE** will probably propose actions that are good on **Habitability**, **Comfort** and **Consumption** but probably worse on **Price** and **Power**. If the decision-maker feels that this is not appropriate according to his/her priorities, he/she should increase the weights of **Price** or **Power**.

When the weights of the criteria are modified, the position of the **Decision Axis** changes. This can be checked interactively in **Visual PROMETHEE** using the **Walking Weights** window.

The length of the **Decision Axis** is important to take into account when analyzing the **GAIA** plane. Indeed if the **Decision Axis** is short that means that it is at a large angle from the **GAIA** plane and that it is not well represented. The orientation of the **Decision Axis** is then much less informative. Actually the **Decision Axis** is the projection of the weight vector (**Decision Stick**) on the **GAIA** plane. A 3D view of the **Decision Stick** can be displayed in the **GAIA** window to emphasize the angle between the stick and the **GAIA** plane.
Action Profiles

The positions of the actions in the GAIA plane are directly related to the profiles of the actions. However the GAIA plane has a limited quality level and there can be some distortions. It is thus interesting to look at the exact action profiles to complement the GAIA information. The Action Profile window is available for this purpose in Visual PROMETHEE. In this display unicriterion net flow scores are displayed in a bar chart.

GAIA Webs

GAIA Webs are an alternative display to Action Profiles.

Spiderweb graphs such as for instance in the D-Sight software are nice-looking but can be misleading. The problem is that they are strongly dependent on the arbitrary ordering of the criteria in the multicriteria table. When the ordering of the criteria is changed quite different shapes can be observed and it is thus very difficult to understand what is displayed. Spiderwebs are very poor graphical representations.

The GAIA Web is a smarter alternative web display. Instead of displaying the different criteria at arbitrary angles, the positions of the criteria axes in the GAIA plane are used as a reference. In that way criteria that are strongly correlated are close to each other in the GAIA Web and the web shape is easier to understand.

Unicriterion net flow scores are represented on the web: -1 values are drawn at the center of the web while +1 values are drawn on the outer circle. A polygon is then drawn connecting the different criteria.

Below are two examples of typical GAIA Webs. On the left side is the GAIA Web for action Luxury 1. On the right side is the GAIA Web for action Economic. The two shapes are very different from each other. For Luxury 1 the criteria Habitability and Comfort are very good while Price is a concern. For Economic the criteria Price and Consumption are very good. These are clearly two opposite profiles.
GAIA Webs can be drawn in two ways. Either showing a polygon with straight lines between criteria or as a "rounded" shape. In the latter case, a curve is drawn instead of a straight line from one criterion to the next one. The curve is drawn in such a way that its distance from the center of the web goes progressively from one unicriterion net flow value to the next. This provides smoother and better balanced webs. As an example let us look at the Tourism A car. It is a very average action with unicriterion net flow scores close to 0 on all criteria. Below are its "straight" and "rounded" GAIA Webs. The 'rounded' web better shows the uniformly average character of the action. In the 'straight' version this is less obvious as the straight lines can come closer to the center between criteria (as for instance between Price and Power) and give a false impression of weakness.
GAIA 3D

The classical GAIA analysis is limited to the two first principal components (U and V in Visual PROMETHEE) yielding a two-dimensional representation of the decision problem: the GAIA plane.

When the quality (\(\lambda\)) of the GAIA plane is low (let us say as a rule of thumb less than 70%) the analysis can be misleading as it excludes a potentially part of information contained in the multicriteria problem.

There are several possible workarounds:

- Partial analyses can be undertaken. Indeed the quality of the GAIA plane usually increases when the number of criteria or the number of actions is reduced. For instance:
  - GAIA planes can be computed for subsets of criteria (such as for instance individual clusters in Visual PROMETHEE) thus giving several higher quality views instead of one single lower quality view.
  - For a global view of the decision problem, subsets of criteria (criteria groups or clusters in Visual PROMETHEE) can be aggregated before performing the GAIA computation (using the "Grouped" property in Visual PROMETHEE). In this case each subset will appear as a single dimension in the GAIA plane. Of course the relations between the criteria within a same subset cannot be analyzed in this way.
  - GAIA planes can also be computed for separate subsets of actions (action categories in Visual PROMETHEE).

In any cases these solutions provide with partial views of the decision problem.

- Additional principal components can be computed. This results in a higher dimension representation of the decision problem. In practice more than three principal components are difficult to visualize as we are used to live in a three-dimensional world. Another solution to improve the quality of the GAIA analysis while maintaining a global view of the decision problem is thus to compute a third principal component (W in Visual PROMETHEE). This has however some limits:
  - Visualizing three-dimensional data on a computer screen can be tricky as perspective is difficult to render. A workaround is to look at separate two-dimensional views (U-V, U-W or V-W). This
is possible in Visual PROMETHEE.

- The quality improvement can be limited: often when the two-dimensional representation quality is insufficient the third dimension only brings a marginal improvement as the decision problem typically involves many conflicting criteria that are impossible to represent accurately in a low dimension space.

Most GAIA plane features can be extended to the 3D representation.

In the Visual PROMETHEE demo problem the U-V plane has a very high quality level close to 90% (actually 89.9%). The third axis thus brings only a more limited quality improvement. As can be seen on the GAIA window, the 3D representation quality level is equal to 98%. When analyzing the U-W (quality level: 70%) or W-V (quality level: 37%) planes it should be remembered that the third axis is responsible for 8% within the total quality level.

A simple calculation shows the respective quantities of information (rounded to integer values) for U (70% - 8% = 62%), V (37% - 8% = 29%) and W (8%). The U axis is thus by far the most informative axis. A look at the U-V plane can explain this: except for the Sport car all the other actions are spread over the U axis with smaller vertical differences. Thus most important differences between these five other cars can be explained by a single axis.

This is confirmed if the Sport car is deactivated (in the next screenshot): the U-V plane quality level is now equal to 97% and the 3D quality level is 100%. The corresponding axes quantities of information are the following: 83% (86% - 3%) for U, 12% (15% - 3%) for V and only 3% for W.
PROMETHEE VI Brain

Allocating weights to the criteria can be a difficult step in the decision process and the decision-maker can hesitate to give a precise weight to each criterion. Typically some order of magnitude is known (such criterion is felt much more important than an other, two criteria are felt equally important, etc) but precise values are difficult to define.

Even when the decision-maker feels comfortable with a set of weights it is interesting to examine what happens to the PROMETHEE rankings when the weights are slightly changed. Are they stable or very sensitive? This is a weight sensitivity analysis.

PROMETHEE and GAIA provide the decision-maker with several possibilities with respect to weight sensitivity analysis.

PROMETHEE VI goes beyond the simple weight sensitivity analysis as it enables the decision-maker to explore his/her space of freedom by defining upper and lower limits for the weights of the criteria. Within these limits many different weighings and PROMETHEE rankings are possible. For each such weighing the Decision Axis has a corresponding position in the GAIA plane. The area determined by the tip of the Decision Axis in the GAIA plane when all the possible weighing are considered is drawn on the GAIA plane. It is usually called the Decision-Maker Brain (Brain).

The red ellipse in the following screenshot is the outline of the Brain when the weights of the criteria are allowed to vary from 16% to 24% (i.e. 20% +/- 4%). It is interesting to notice that the Brain is located entirely in the upper part of the GAIA plane. Thus the Decision Axis is always close to the Consumption, Habitability and Comfort criteria and the Sport car will never be at the top of the PROMETHEE ranking with weights within these limits.
Actually there are two possible situations:

1. When the Brain is entirely located on one side of the GAIA plane the Decision Axis is always oriented in the same direction and the PROMETHEE rankings are expected to be stable. The preferred actions are easy to identify.

2. When the Brain overlaps the center of the GAIA plane it means that the Decision Axis can be oriented in any direction. The PROMETHEE rankings can thus be very different depending on the values of the weights within the limits set by the decision-maker. The problem is thus much harder to solve.

**Sensitivity Analysis**

Sensitivity analysis is essential to multicriteria decision aid. Indeed many parameters have to be set up in a multicriteria model. With the PROMETHEE and GAIA methods these include:

- The choice of the preference functions and of the related thresholds.
- The choice of the weights allocated to the criteria.

The results of the PROMETHEE and GAIA analysis are of course dependent from these parameters. It is thus important to check that slight variations of the parameters don't have to large influence on the analysis
An interesting property of the PROMETHEE methods is that the preference flows are linear functions of the weights of the criteria. This makes it easy to perform sensitivity analyses.

In Visual PROMETHEE several tools are available for weight sensitivity analysis:

- The Walking Weights analysis.
- The Visual Stability Intervals.
- The Decision Maker Brain in the GAIA window.
- The Balance of Power window for multiple scenarios.

GDSS PROMETHEE

Most multicriteria decision aid methods have been designed in the context of a single decision-maker. With PROMETHEE and GAIA this means that a single person expresses his/her preferences by defining the criteria and their associated preference functions and allocating weights to the criteria.

In many decision problems however several persons are usually involved. They can be actual decision-makers such as:

- family members who have to agree on their new car, or their new home;
- directors in a company board who have to agree on an investment strategy;
- country leaders at UN;

or they can be stakeholders involved in the decision process. For instance in the demo TutorSites plant location problem available with Visual PROMETHEE four stakeholders are involved:

- **Industrial**: this is the actual decision-maker, the company that wants to build a new plant.
- **Political**: this is the political (regional) authority that has to agree on the project and to deliver a permit for building the plant. They are not an actual decision-maker but they have a strong impact on the decision process.
- **Environmental**: here are the environmental protection groups that are concerned about the project. They have their own objectives and have some power on the decision process.
- **Social**: worker's unions can also influence the decision process. They have their own objectives.

Every stakeholder can have different objectives, different priorities or even different evaluations on subjective criteria that are measured on qualitative scales. What is then the best consensus solution?

The GDSS extension of PROMETHEE allows to take into account such situations.

This is achieved by defining several scenarios for the decision problem.

All the scenarios share the same lists of actions and criteria. Everything else can be different from one scenario to another:

- Different evaluations.
- Different preference functions (min/max, preference function type, thresholds).
- Different criteria weights.

Each scenario can be analyzed separately using PROMETHEE and GAIA. Individual (single scenario) rankings and GAIA planes are thus easily obtained.

However, it is possible to make more interesting multi-scenario analyses. This is the purpose of GDSS PROMETHEE.
In a first step multi-scenario preference flows are computed to aggregate the preferences from the different scenarios. Consensus (multi-scenario) PROMETHEE I and II rankings can then be computed. Finally, the properties of the preference flows allow for several multi-scenario extensions of the GAIA analysis.

**GDSS PROMETHEE** is explained in the next pages:

- Multi-scenario preference flows
- Consensus PROMETHEE rankings
- Multi-scenario GAIA analysis
  - GAIA-Criteria
  - GAIA-Scenarios
  - GAIA-Action
  - GAIA-Unicriterion

### Multi-scenario Preference Flows

Let us generalize the **multicriteria table** to the case where \( S \) scenarios are defined.

For each scenario \( s \) (\( s=1,...,S \)) we have the following multicriteria table:

<table>
<thead>
<tr>
<th></th>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( \ldots )</th>
<th>( f_j )</th>
<th>( \ldots )</th>
<th>( f_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>( f_1^s(a_1) )</td>
<td>( f_2^s(a_1) )</td>
<td>( \ldots )</td>
<td>( f_j^s(a_1) )</td>
<td>( \ldots )</td>
<td>( f_i^s(a_1) )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( f_1^s(a_2) )</td>
<td>( f_2^s(a_2) )</td>
<td>( \ldots )</td>
<td>( f_j^s(a_2) )</td>
<td>( \ldots )</td>
<td>( f_i^s(a_2) )</td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
</tr>
<tr>
<td>( a_i )</td>
<td>( f_1^s(a_i) )</td>
<td>( f_2^s(a_i) )</td>
<td>( \ldots )</td>
<td>( f_j^s(a_i) )</td>
<td>( \ldots )</td>
<td>( f_i^s(a_i) )</td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
<td>( \ldots )</td>
<td>( \vdots )</td>
</tr>
<tr>
<td>( a_n )</td>
<td>( f_1^s(a_n) )</td>
<td>( f_2^s(a_n) )</td>
<td>( \ldots )</td>
<td>( f_j^s(a_n) )</td>
<td>( \ldots )</td>
<td>( f_i^s(a_n) )</td>
</tr>
</tbody>
</table>

where \( f_i^s(a) \) is the evaluation of action \( a \) on criterion \( f_j \) for scenario \( s \).

Based on these \( S \) single scenario multicriteria tables, the three PROMETHEE **preference flows** can be computed separately for each scenario \( s \):

\[
\phi_{+s}^s(a) = \frac{1}{n-1} \sum_{b=1}^{n} \pi_s(b,a)
\]

\[
\phi_{-s}^s(a) = \frac{1}{n-1} \sum_{b=1}^{n} \pi_s(b,a)
\]

\[
\phi_s(a) = \phi_{+s}^s(a) - \phi_{-s}^s(a)
\]

where \( \pi \) is the multicriteria preference index computed for scenario \( s \).

Multi-scenario preference flows are then computed as the weighted sum of the single scenario flows:

\[
\phi_{+s}(a) = \sum_{s=1}^{S} W_s \cdot \phi_{+s}^s(a)
\]

\[
\phi_{-s}(a) = \sum_{s=1}^{S} W_s \cdot \phi_{-s}^s(a)
\]
where $W_s$ is the normalized weight allocated to scenario $s$.

This computation is the same as if all the single scenario multicriteria tables where all set side to side in a larger multicriteria table and the weights of the criteria were adjusted taking into account the weights of the scenarios. The multi-scenario preference flows can thus be used to produce PROMETHEE rankings taking into account all the scenarios and their relative importance.

The unicriterion net flows can also be computed separately for each scenario:

$$\phi^s_j(a) = \frac{1}{n-1} \sum_{b \neq a} \left[ P^i_j(a, b) - P^i_j(b, a) \right]$$

where $P^i_j$ is the preference function for criterion $f_j$ in scenario $s$.

According to the previous definitions the following properties hold:

$$\phi^s(a) = \sum_{j=1}^5 w^s_j \phi^s_j(a)$$

where:

$$\phi^s_j(a) = \sum_{j=1}^5 W^s_j \cdot \phi^s_j(a)$$

These are used in the GDSS GAIA extensions.

**Consensus PROMETHEE Rankings**

The PROMETHEE I and II rankings can be computed for each scenario base on the single scenario preference flows.

Consensus (multi-scenario) rankings can also be computed from the multi-scenario preference flows. They are rankings that encompass the preference information from all the scenarios. They are thus proposing good consensus solutions.
Multi-scenario GAIA

Four different GAIA extensions are available in a multi-scenario context:

- **GAIA-Criteria**
- **GAIA-Scenarios**
- **GAIA-Action**
- **GAIA-Unicriterion**

The TutorSites demo problem is used to illustrate this section.

**GAIA-Criteria**

In the **GAIA-Criteria** analysis the multi-scenario unicriterion net flows are displayed. There is one axis for each criterion or grouped group or cluster.

This view is interesting when the criteria are rather objective and similar evaluations are observed in the different scenarios. In such cases the **GAIA-Criterion** display will be very similar to the single scenario GAIA views. On the other hand when some criteria are evaluated quite differently from one scenario to another these differences will not appear in **GAIA-Criteria** as the multi-scenario unicriterion flows are weighted averages of the single scenario flows. The **GAIA-Unicriterion** analysis can be used to analyze these differences and the **GAIA-Scenarios** analysis can be useful to better understand the differences between the scenarios.

In the above screenshot it is obvious that two sites (*Site 3* and *Site 2*) are globally preferred but there is no way to detect different evaluations in criteria such as for instance *Employment* or *Environment.*
In the **GAIA-Scenarios** analysis the single scenario multicriteria net flows are displayed. There is one axis for each **scenario** or grouped **coalition**.

![Graph showing multicriteria preferences for scenarios]

In this view, the multicriteria preferences for all the scenarios are compared. It is possible to identify groups of scenarios with similar points of view and to detect conflicts among scenarios.

In our example there are two groups of scenarios:

- **Industrial** and **Political** for which **Site 3** seems to be the best choice.
- **Social** and **Environmental** for which **Site 2** seems to be the best choice.

These two groups of scenarios are oriented in different but not completely opposite directions. This means that the conflict between the two groups is not so important. Indeed, all scenarios agree that **Site 3** and **Site 2** are much better solutions than the other three sites. The **GDSS** situation could have been much more conflicting.

Beyond the **GAIA-Scenarios** analysis it is interesting to be able to identify the origin of the conflicts between the scenarios. There are several possibilities:

- Conflicts can arise from quite different preferences (**preference functions**) or priorities (**weights**). In such cases it is usually difficult to make changes and it can be quite hard to reach a consensus solution.
- Conflicts can also arise from different perceptions of a single **criterion** or **action**. Indeed the definition of a criterion can be unclear for some decision-maker and lead to different evaluations. In the same way, information related to a specific action can be different for some decision-makers. To identify such situations and try to establish a more common and more objective evaluation basis for all the decision-makers (scenarios) the **GAIA-Unicriterion** and **GAIA-Action** analyses can be used.
**GAIA-Action**

In the *GAIA-Action* analysis a single selectable action is displayed as it is evaluated in the different scenarios or grouped coalitions. There is one axis for each criterion or grouped group or cluster.

This feature is not implemented yet.

**GAIA-Unicriterion**

In the *GAIA-Unicriterion* analysis a single selectable criterion is displayed as it is evaluated in the different scenarios or grouped coalitions. There is one axis for each scenario or grouped coalition.

The two following screenshots from the demo problem show two typical and quite different situations.
The first screenshot is for the criterion **Investment**. This criterion is computed in an objective way and thus the evaluations are the same in all the scenarios. Accordingly all the sites are aligned on the U axis. In this case the V and W axes are meaningless. There is a perfect agreement on the evaluation of the sites on this criterion.

The second screenshot is for the criterion **Employment**. In this case the scenario axes are strongly conflicting. Indeed **Industrial** and **Environmental** want to minimize this criterion while **Political** and **Social** want to maximize it. Moreover the evaluations themselves are different from one scenario to another. This indicates that the definition of this criterion is not the same for all the decision-makers. A more precise definition of the criterion or splitting the criterion into two or more sub-criteria could be helpful to establish a better common basis for evaluation and to reduce the sources of conflict between the decision-makers.

**PROMETHEE V Selection**

Many multicriteria problems are about selecting one action among a set of possible actions. It is the case in the two **Visual PROMETHEE** examples:

- In **TutorCars** somebody wants to buy one new car.
- In **TutorSites** a company wants to build one new plant.

In other cases decision-makers can be interested in selecting a subset of actions according to their multicriteria evaluation and to additional constraints. That type of decision problem is also known as **portfolio management**. Here are some examples:

- **R&D projects**: Given a set of project proposals which ones should be selected? The best ones of course according to criteria such as expected return or risk level. But there is usually a total budget constraint. There can be incompatibilities between some projects that cannot be selected at the same time. Or a wish to balance the number of selected projects among departments or types of activities.
- **Financial investment**: What is the best portfolio of investment? Taking into account individual asset evaluation (such as return or risk) as well as for instance diversification constraints.

- **Networking**: A company in the distribution sector want to establish a network of shops in a new area. What is the best selection given budget limits, competitors, customers location, etc?

- **Marketing**: To launch a new product several marketing actions are available (Internet, TV, newspapers, billboards, ...). What is the best mix?

Without additional constraints it would seem logical to select the actions that are ranked at the top of the PROMETHEE ranking. But the first ranked action could for instance be a very expensive option and could exhaust most of the available budget. A better solution could then be not to select the first action but rather several others that are individually less appealing but that globally provide a better performance.

PROMETHEE V is designed to solve such problems. It works in two steps:

1. **A PROMETHEE II analysis** of the data is made. The multicriteria net flow \( \phi_i \) provides with a global evaluation of the actions taking into account all the criteria.

2. A **0-1 linear program** is then defined as follows in order to solve the multiple selection problem:

   - A binary (0-1) variable \( x_i \) is associated to each action \( a_i \) : \( x_i = 1 \) means that action \( a_i \) is selected while \( x_i = 0 \) means it is not.

   - The objective is to select actions in such a way that the sum of the \( \phi_i \) values of the selected actions is as large as possible:

     \[
     \max \sum_{i=1}^{n} \phi_i x_i
     \]

     Without additional constraints all actions with a positive net flow (Phi) value will be selected as this makes for the largest positive sum of flows.

   - Additional linear constraints can be added according to the requirements of the decision-maker. For instance:
     - Number of actions to select: if exactly \( m \) actions have to be selected, the following constraint will be added to the linear program:
       \[
       \sum_{i=1}^{n} x_i = m
       \]
     - Maximum total budget: if the maximum budget available is \( B \) and each action \( a_i \) has a corresponding cost equal to \( b_i \) then this constraint can be added:
       \[
       \sum_{i=1}^{n} b_i x_i \leq B
       \]
     - Incompatibility between two actions: if actions \( a_i \) and \( a_j \) cannot be selected at the same time, the following constraint can be used:
       \[
       x_i + x_j \leq 1
       \]
     - Many other types of constraints can be added to the linear program such as for instance geographical or sectoral diversification.

The 0-1 linear program is solved in **Visual PROMETHEE** using a branch and bound algorithm. The
PROMETHEE V window displays the optimal solution and allows for what-if analyses.

PROMETHEE Sort

Sorting vs ranking

Many MCDA methods are designed to solve ranking problems, i.e. to rank actions from the best to the worst one according to several criteria and to the preferences (preference functions) and priorities (weights) of the decision-maker. It is the case of PROMETHEE I and II. It is perfectly appropriate whenever one has to make a decision among a set of possible actions and to identify the best possible action.

There are however other decision-making situations. Sometimes the decision-maker has some reference points about what to expect from the actions and is able to define different classes of actions such as for instance:

- "good" and "bad" actions,
- "good", "average" and "bad" customers,
- different consumer behaviors,
- different types of companies, ...

The problem is then to associate each action to one class. It is a sorting problem.

Ranking is relative while sorting is absolute. In the PROMETHEE II ranking there is always a best (first ranked) and a worst (last ranked) action but that doesn't mean that the the best action is a "good" one or that the last one is a "bad" one. Indeed all actions could be "good" or could be "bad". In a sorting problem all the actions could be "bad" or all the actions could be "good".

The next step in a sorting problem is to characterize the different classes. What is a "good" action? What is a "bad" action? Clearly some additional information is required.

In PROMETHEE Sort as in most MCDA sorting methods this is done by defining reference actions or profiles. The profiles can be either actual actions or fictive ones.

Different sort problems

Sorting problems can be subdivided into different categories according to at least two factors:

- **Classes**: can be ordered according to the preferences of the decision-maker (e.g. "good", "average" or "bad" customers) or unordered (e.g. different consumer behaviors).
- **Profiles**: can be used to identify the boundaries between ordered classes or be typical (central) actions.

PROMETHEE Sort provides the decision-maker with appropriate analyses in each possible case.

PROMETHEE Sort - Ordered classes

Let us consider a multicriteria table as defined previously.

We suppose that the preferences are modeled as in the PROMETHEE I and II methods.

We suppose that $C$ ordered classes have been defined by the decision-maker: $C_{l_1}, C_{l_2}, \ldots, C_{l_C}$ where $C_{l_1}$ is the least preferred class and $C_{l_C}$ is the most preferred one. To each class one or several profiles are attached. Let us note $b_{p}^{c}$ (for $p = 1, 2, \ldots, P_{c}$) the $P_{c}$ profiles attached to the class $C_{l_c}$. These profiles can be either boundary or central profiles.

Boundary profiles

In the case of boundary profiles, we suppose that the boundary profiles associated with one class correspond to the upper boundary of that class. The boundary profiles for the most preferred class ($C_{l_C}$) are
thus ignored.

With boundary profiles, some additional consistency is required: indeed as the classes are ordered so are their boundaries. A requirement is thus that the profiles for class \( Cl_i \) should dominate the profiles for class \( Cl_j \) when \( i > j \) (\( Cl_i \) is preferred to \( Cl_j \)).

In order to assign an action \( a \) to a class \( Cl_i \), PROMETHEE Sort compares the action to all the profiles. The PROMETHEE ranking method is used for this purpose: action \( a \) is compared to all the profiles and the preference flows are computed.

**Central profiles**

In the case of central profiles, the profiles associated with one class correspond to typical actions belonging to that class.

PROMETHEE Sort then computes a distance from the action to sort to the different classes. The action is assigned to the closest class.

**PROMETHEE Sort - Unordered classes**

When the classes are unordered, boundary profiles do not make any sense. The PROMETHEE Sort analysis is thus limited to central profiles and is similar to that for ordered profiles.

**Bank Adviser**

Bank Adviser allows to evaluate actions with respect to a reference set of actions. The reference set can be for instance:

- a set of well-known actions,
- a subset of actions (for instance geographically defined),
- a set of reference points (fictive actions),
- a peer-group.

While the PROMETHEE Rankings are based on the pairwise comparison of all the actions and thus provide the decision-maker with a relative evaluation of the actions, Bank Adviser compares each action to a reference set.

This means that the action is compared to the reference actions only. The resulting Phi score is thus a measurement of how well the action compares to the reference set. It is independent from the other actions evaluations.
Performance Analysis

The PROMETHEE Performance Analysis extension has been developed for cases where two sets of criteria have to be compared and a notion of performance is important. This is similar to the Input/Output model used in Data Envelopment Analysis (DEA).

This work is still ongoing research.

When measuring the efficiency of operational units (or DMU's - decision-making units - in the language of DEA), it is common to compare input criteria (different resources allocated to the units) to output criteria (results generated by the activity of the units) and to look for some kind of "best" output/input ratio. The PROMETHEE Performance Analysis extension provides decision-makers with two tools that can be used in such a context:

- **Performance Aggregated Score**: a global output/input ratio score.
- **I-O Efficiency**: a graphical view of input vs output criteria emphasizing a notion of efficiency.

To use these two tools in Visual PROMETHEE two clusters of criteria have to be defined: one cluster should contain all the input criteria and the other should contain all the output criteria.

**Performance Aggregated Score**
The Performance Aggregated Score is computed as a ratio of normalized output and input net flow scores as follows:
I-O Efficiency

The I-O Efficiency frontier is drawn in the plane corresponding to the input and output net flow scores. Actions located on the efficiency frontier (red line) have input and output net flow scores that are not dominated by any other action.
Additional examples and exercises

Here are four additional examples that are described and analyzed and for which some practical exercises are proposed.

The corresponding data files are automatically installed with Visual PROMETHEE.

- **Powerplants**: A powerplant location problem.
- **Hypermarkets**: A distribution network management problem including a PROMETHEE V application.
- **Cars**: Another approach to the car selection problem with an emphasis on the Decision-maker Brain in GAIA.
- **CUV**: An actual 2012 car selection problem involving CUV’s (Compact Utility Vehicles). Guess what car Bertrand Mareschal is driving today!

## Powerplants

### The context

Given the ever increasing demand for electricity in Europe, the European political authority has decided to build a new large hydro-electrical power plant. Six national projects (sites) have been proposed by six European countries, and six evaluation criteria have been defined by the European authority in order to select the best project:

### The actions

Six national sites:

- \( a_1 \): Italy
- \( a_2 \): Belgium
- \( a_3 \): Germany
- \( a_4 \): Sweden
- \( a_5 \): Austria
- \( a_6 \): France

### The criteria

- \( f_1 \): Manpower
- \( f_2 \): Power
- \( f_3 \): Construction cost
- \( f_4 \): Operation cost
- \( f_5 \): Number of villages to evacuate
- \( f_6 \): Safety level

### The model

Some criteria are to maximize, others are to minimize. Preference functions and weights have been associated to the criteria. In a first step, without well established priorities, all the weights have been set to equal values (\( w_j = 1, j = 1,2,\ldots,6 \)).

All the data are given in the following table.
The analysis

The two next figures show the PROMETHEE rankings as networks (arrows indicate preferences):
Use Visual PROMETHEE to confirm these two rankings. Check the incomparability between \( a_1 \) (Italy) and \( a_2 \) (Belgium) by comparing their profiles: these are very opposite to each other.

When the weights of the criteria are modified, the resulting rankings can be quite different. For instance if a weight of 50 (50\%) is allocated to criterion Power and weights of 10 (10\%) are allocated to each other criterion, France becomes the best location. If a larger weight is allocated to the Villages criterion (55\%, with 9\% for each other criterion), Belgium becomes the best choice. Check this using Visual PROMETHEE.

The GAIA plane shows three conflicting groups of criteria. Can you identify them? What about the reliability (quality level) of the two-dimensional representation?

Belgium seems to be a very good solution for the criteria Villages and Construction, but it is very bad on Power and Operation. It is the opposite for Italy and France. Check this in Visual PROMETHEE by looking at the action profiles or the GAIA Webs. What are the main advantages of Sweden? And what are its main weaknesses?

The position of Austria in the GAIA plane is more central. It is also the top ranked action in the PROMETHEE rankings. How do you explain that?
Exercises

Exercise P1
What is the PROMETHEE II ranking for the following weights:

\[ w_{\text{Power}} = 50 \quad w_{\text{Manpower}} = w_{\text{Construction}} = w_{\text{Operation}} = w_{\text{Villages}} = w_{\text{Safety}} = 10 \]

Exercise P2
What is the PROMETHEE II ranking for the following weights:

\[ w_{\text{Villages}} = 5.5 \quad w_{\text{Manpower}} = w_{\text{Power}} = w_{\text{Construction}} = w_{\text{Operation}} = w_{\text{Safety}} = 1 \]

Exercise P3
What is the PROMETHEE II ranking for the following weights:

\[ w_{\text{Power}} = w_{\text{Safety}} = 5 \quad w_{\text{Operation}} = 4 \quad w_{\text{Manpower}} = w_{\text{Construction}} = w_{\text{Villages}} = 1 \]
Exercise P4
Set all preference functions to the “Usual” type and compare the PROMETHEE I and II rankings (with equal weights).

Exercise P5
Starting from the initial data, change $f_2(a_2)$ to 100, $f_4(a_2)$ to 2 and $f_6(a_2)$ to 8. What is the new PROMETHEE II ranking? Does it conform to your prediction?

Exercise P6
Using the Walking Weights display, progressively increase the weight of the Power criterion ($f_3$) up to 7. Look at the decision axis in the GAIA plane. What is finally the best action?

Exercise P7
Use the following weight distribution to build a new PROMETHEE II ranking:

\[ w_{Manpower} = 1 \quad w_{Power} = 5 \quad w_{Construction} = 1 \quad w_{Operation} = 4 \quad w_{Villages} = 1 \quad w_{Safety} = 5 \]

Exercise P8
Move the decision axis in order to rank Germany as the best choice. (It is not easy!)

Hypermarkets

The context
A large US distribution company wants to develop a network of hypermarkets in Belgium. 12 potential locations are considered: 2 in the region of Antwerp, 3 in the region of Bruges, 4 in the region of Brussels and 3 in the region of Namur.

Antwerp and Brussels are large cities, where construction costs are high, space is scarce, but many potential customers are available. On the contrary, Bruges and Namur are smaller cities, with more space available and lower construction costs.

Five evaluation criteria are considered: construction cost expressed in millions of Euros, potential customers (thousands), number of parking places available, access to the road network (qualitative 1 to 6 scale), and the number of close competitors.

The actions
Twelve locations:
- $a_1$: Antwerp1
- $a_2$: Antwerp2
- $a_3$: Bruges1
- $a_4$: Bruges2
- $a_5$: Bruges3
- $a_6$: Brussels1
- $a_7$: Brussels2
- $a_8$: Brussels3
- $a_9$: Brussels4
- $a_{10}$: Namur1
- $a_{11}$: Namur2
- $a_{12}$: Namur3

The criteria
- $f_1$: Construction cost
- $f_2$: Population
- $f_3$: Parking
The model

Some criteria are to maximize, others are to minimize. Preference functions and weights have been associated to the criteria.

All the data are given in the next table.
The analysis

The PROMETHEE I partial ranking doesn't include any particularly important incomparabilities. The PROMETHEE II ranking is more interesting:

```
+---+---+---+---+---+---+
| a3 | a11| a10| a9 | a8 | a2 |
+---+---+---+---+---+---+
| a4 | a5 | a12| a2 | a1 | a6 |
```

**PROMETHEE II Complete Ranking**

The twelve locations are almost perfectly ranked by city: the three Bruges sites (a4, a5 and a3) are ranked first, followed by the ones in Namur (a11 and a12), finally we find the ones in Antwerp and in Brussels. This can be explained by the specific geographical characteristics of each city.

![PROMMap Display](image)

**PROMMap Display**

The GAIA plane retains 86% of the information. It is thus particularly reliable. Criterion \(f_2\) (Population) shows a large discriminating power (longer axis) and is strongly conflicting with most other criteria. On the other hand, Construction (\(f_1\)), Parking (\(f_3\)) and road Access (\(f_4\)) are expressing similar preferences. The geographical characteristics of the cities are confirmed. Indeed the actions appear to be geographically grouped in four clusters:

- **Bruges** on the right side of the plane: these are good solutions for Construction, Access and Parking.
- **Namur** closer to the center of the plane: these are more "medium" solutions.
- **Antwerp** at the top left of the plane: these are good solutions for Competitors and Population.
- **Brussels** at the bottom left of the plane: these are good solutions for Population (Brussels is the
largest city, but it is quite expensive, crowded and there are a lot of competitors there).

If the company were to select a single location, it should of course select it in the region of Bruges.

Actually the problem is not a single selection problem: the company wants to develop a nationwide network including several locations. It would be therefore absurd two make the selection on the sole basis of the PROMETHEE II ranking. Indeed the first six sites would be competing with each others in the Bruges and Namur regions while the Brussels and Antwerp regions wouldn't be covered.

A better solution is provided by PROMETHEE V taking into account additional selection constraints:

- The company wants to select between 5 and 9 sites. These values are entered in the PROMETHEE V constraints window as the Minimum and Maximum number of actions to select.
- Eight more constraints are introduced in the PROMETHEE V spreadsheet:
  - Global return: The management aims at a global expected annual return of at least 4000 k€ (individual annual returns are estimates in k€)
  - Total manpower: The total manpower should be at least 500.
Antwerp=1: Exactly one of the selected sites should be in Antwerp.
Bruges<=2: Maximum two sites are allowed to be selected in Bruges.
Brussels>=2: At least to sites should be selected in Brussels as it is the largest city in the country.
Namur>=1: At least one site should be selected in Namur.
ExclBrussels: The sites Brussels2 and Brussels4 are located very close to each other. They cannot be selected together as they would directly compete with each other. However the management wants the company to be present in that area: one of the two sites should be selected.
ExclNamur: A similar constraint is expressed for Namur2 and Namur3.

According to these constraints the PROMETHEE V selection is given below. It includes the seven following sites:

Antwerp2, Bruges2, Bruges3, Brussels1, Brussels2, Namur1 and Namur3

for a total net flow value equal to 0.1260

Notice that the PROMETHEE V selection doesn't correspond to the top of the PROMETHEE II ranking.

Exercises
Exercise H1
What is the PROMETHEE I ranking for this problem?

Exercise H2
If the preference function associated to $f_4$ is changed to the Level type with $q = 1.5$ and $p = 2.5$, is the PROMETHEE II ranking modified?

Exercise H3
What is the PROMETHEE II first ranked location when the weight of criterion $f_2$ is increased from 1 to 10? Is this what you were expecting?

Exercise H4
Progressively increase the weight of the Population criterion ($f_2$). What is the minimum weight required to put a Brussels location at the top of the PROMETHEE II ranking?

Exercise H5
Starting from the initial weight distribution, increase now the weight of the Competitors criterion ($f_5$). For a value of $w_5 = 5$, is Antwerp leading the ranking?

Exercise H6
Find a weight distribution such that the decision axis is almost orthogonal to the GAIA plane.

Exercise H7
Use the PROMETHEE V "Compare" function to compare the optimal selection to:
1. the selection of the seven PROMETHEE II top-ranked sites,
2. the selection of the PROMETHEE II best-ranked sites in each city (one in Antwerp, two in Bruges, two in Brussels and two in Namur).

Cars
The context
A decision aid professor wants to purchase a new car. He hesitates between six models and has identified six criteria in order to compare these models. Most are technical criteria but they of course include the Price of the car as well as Prestige criterion.

The actions
Six models:
- $a_1$: Small 1
- $a_2$: BMW 700
- $a_3$: Audi A4
- $a_4$: Volvo
- $a_5$: VW Golf
- $a_6$: Small 2

The criteria
- $f_1$: T1 - a technical criterion
- $f_2$: Price
- $f_3$: T2 - a technical criterion
- $f_4$: T3 - a technical criterion
- $f_5$: Prestige
- $f_6$: T4 - a technical criterion

The model
Some criteria are to maximize, others are to minimize. Preference functions and weights have been associated to the criteria.
All the data are given in the next table.

The analysis

Much weight has been given to the **Price** criterion and the **Small** cars that are much cheaper than the others are clearly at the top of the **PROMETHEE** rankings.
PROMETHEE I Partial Ranking
**Exercises**

**Exercise C1**
Analyze the **GAIA** plane.

**Exercise C2**
Lower progressively the weight of the **Price** criterion and observe the changes in the **PROMETHEE** rankings.

**Exercise C3**
Increase progressively the weight of the **Prestige** criterion and observe the changes in the **PROMETHEE** rankings.

**CUV**

**The context**
Another decision aid professor wants to purchase a new car: a compact utility vehicle (CUV) to replace his Mazda RX8. It is a big change and he hesitates between different models available on the Belgian market. He has identified six criteria in order to compare theses models. Contrarily to the previous examples these are actual data from 2012 and the problem is also an actual one.

**The actions**
24 CUV models available on the Belgian market at the time of the Brussels **Salon de l’Auto** in January 2012.

**The criteria**
- $f_1$: **Price**, in € (professors are no rich people).
- $f_2$: **Power**, in kW (power welcome).
- $f_3$: **Gas efficiency**, in L/100km (gas is money).
- $f_1$: CO$_2$ emission, in g/km (green... OK, if it is British Racing Green...)
- $f_2$: Length, in centimeters (I prefer larger cars).
- $f_3$: Trunk size, in dm$^3$ (need space to move).

**The model**

Some criteria are to maximize, others are to minimize. [Preference functions](#) and [weights](#) have been associated to the [criteria](#).

All the data are given in the next table.
The analysis
The **GAIA** plane inspection shows that there are four groups of criteria:

- **Power** and **Length** are oriented to the left. The more powerful cars are also the larger ones.
- **Gas efficiency** and **CO$_2$ emission** are oriented to the top. A better gas efficiency means less CO$_2$ emissions.
- **Price** is on its own and more or less opposite to all the criteria. If you want a large, powerful and gas efficient car, you will have to pay for it.
- **Trunk** has a very short axis. Indeed with the exception of one car that has a very large trunk (755 dm$^3$), all the other are in the 360 dm$^3$ to 564 dm$^3$. Given that the preference threshold ($\rho$) for this criterion has been set equal to 150 dm$^3$ and that there is an indifference threshold ($q$) equal to 50 dm$^3$ this criterion is much less discriminating than the other ones.

Four action categories have been defined to better identify the cars according to their regional origin:

- German cars are represented in red.
- French cars are represented in blue.
- Asian cars are represented in yellow.
- Other cars are represented in green.

Regional groupings can be observed in the **GAIA** plane:

- German cars are more powerful and more expensive.
- French cars are grouped in the lower-left part of the plane, with the exception of the **Dacia Duster** that has a very special profile (low price and good gas efficiency).
- Asian cars are usually cheaper (the **Mazda CX5** is the full-options version) but show a wider spread over the plane thus providing the buyer with more diversified profiles.
The PROMETHEE Diamond shows the domination of a few Asian cars and of the Dacia Duster (it is much cheaper than the others). The PROMETHEE I incomparabilities emphasize the many different profiles provided by Asian manufacturers. The German cars are handicapped by higher prices and lag in the middle of the PROMETHEE II ranking. Overall the Mazda CX5 is at the top.
Exercises

Exercise U1
Given that the **Trunk** criterion is not much discriminant, deactivate it and compare the **PROMETHEE II** with the original one. Are there many changes? Check the position of the car with the largest trunk. Is it what you were expecting?

Exercise U2
In what range can you change the weight of the **Trunk** criterion without changing the **PROMETHEE II** top-ranked car? Hint: Use the **Visual Stability Intervals** window and adjust the stability level to 1.

Exercise U3
Guess which car I am driving now!
Useful links

You can find additional information at:

- **www.promethee-gaia.net**
  This is the official PROMETHEE-GAIA web site. Here you can find and exchange information related to the methods and their implementation:
  - blog.promethee-gaia.net
    The PROMETHEE Blog with information about events related to the methods and the software.
  - forum.promethee-gaia.net
    The PROMETHEE-GAIA Forum where people can exchange information and experience related to the methods, the software and their applications.
  - faq.promethee-gaia.net
    The PROMETHEE-GAIA FAQ with questions and answers related to the methods and the software.
  - biblio.promethee-gaia.net
    The Bibliographical Database with over 400 scientific references related to the PROMETHEE methods.

- **www.decision-drive.com**
  This is the site dedicated to the business applications of the PROMETHEE methods.

- **www.sustainable-decisions.com**
  This site is dedicated to the use of multicriteria methods in the context of sustainable development.

- The LinkedIn PROMETHEE Decision Aid Methods group
- Twitter at @bmaresc
- and more coming soon...