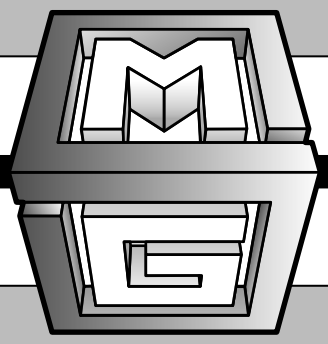

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CoDE-SMG – Technical Report Series

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Abstract

PROMETHEE and GAIA belong to the family of multi-criteria outranking methods. A key aspect of their successful application to real problems relies on the existence of user-friendly software implementing these approaches. Following PROMCALC and DECISION LAB 2000, D-Sight is the third generation of PROMETHEE and GAIA based applications. It offers multiple interactive and visual tools that help the decision maker to better understand and manage his multi-criteria problem. The aim of this paper is to provide a description of D-Sight by presenting its main characteristics. An illustrative case study about the outsourcing of IT infrastructure and application development is detailed.

D-Sight: a new decision support system to address multi-criteria problems

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Abstract

PROMETHEE and GAIA belong to the family of multi-criteria outranking methods. A key aspect of their successful application to real problems relies on the existence of user-friendly software implementing these approaches. Following PROMCALC and DECISION LAB 2000, D-Sight is the third generation of PROMETHEE and GAIA based applications. It offers multiple interactive and visual tools that help the decision maker to better understand and manage his multi-criteria problem. The aim of this paper is to provide a description of D-Sight by presenting its main characteristics. An illustrative case study about the outsourcing of IT infrastructure and application development is detailed.

Keywords : Multi-criteria decision aid, decision making software, PROMETHEE, GAIA, Project Portfolio Management

I. Introduction

Multi-criteria decision aid (MCDA) addresses problems where choices, alternatives, items, etc. are evaluated on several conflicting criteria. The aim is to help a decision maker to structure and to better understand his problem by providing him valuable information about the consequences of his choices, the synergies and redundancies between criteria, the influence of parameters, the comparison of action profiles, … The approaches developed in the MCDA community can be divided in three major categories: interactive, multi-attribute and outranking methods [14].

PROMETHEE (**P**reference **R**anking **O**rganization **METH**od for **E**nrichment **E**valuations) [3] and GAIA (**G**eometrical **A**nalysis for **I**nteractive **A**id) [11] belong to the family of outranking methods. Since the original presentation of the PROMETHEE I and II rankings by Jean-Pierre Brans [2] in 1982, a number of extensions have been proposed such as a complementary geometrical analysis approach called GAIA [11], tools for sensitivity analysis [12] or a procedure for group decision support [9]. We refer the interested reader to [5] for a state of the art of these developments.

Recently, M. Bezhadian et al. [1] have realized a comprehensive literature review of the applications of PROMETHEE to various fields such as finance, health care, logistics and transportation, chemistry, environmental management, … (they listed more than 200 papers published in 100 journals). From our point of view, a key factor of this success relies on the existence of efficient and user-friendly software. Following PROMCALC [4] and DECISION LAB 2000, D-Sight constitutes the third generation of PROMETHEE based applications. It has been developed by Quantin Hayez at the CoDE-SMG laboratory under a grand of the Walloon Region supervised by Prof. Yves De Smet. Prof. B. Mareschal

acted as scientific adviser. The main intention underlying this project was to develop an application based on interactive visual tools. Now that the resulting product has reached a certain level of maturity[1], the aim of this paper is to offer a complete description of the software.

D-Sight implements classic functionalities such as the PROMETHEE I and II rankings, the GAIA visualization tool, sensitivity analysis (including for instance the walking weights or the decision maker's brain) and a Group Decision Support System (GDSS). Compared to previous software, several functional improvements have been proposed in addition to a modern user interface: a new visualization format for the PROMETHEE I ranking called the "Diamond", a plugin system allowing the customization of the software, a module for automatic updates, the explicit projections in the GAIA plane, new GAIA visualization options [8, 13], a multiple levels hierarchy of criteria, a functionality dedicated to the elicitation of weights,… D-Sight is available since February 2010. Up to now, it is regularly used by several universities and research centers all over the world for teaching and research purposes [6, 10]. In addition, D-Sight is used in private companies as well. Some of those collaborations led to the publication of different case studies [7].

The paper is organized as follows: a brief description of PROMETHEE and GAIA is provided in section II. Then, the main characteristics, the architecture of D-Sight and the plugin system are presented in section III. Finally an illustrative case study is detailed in section IV in order to highlight the added value of using D-Sight. Therefore, we will consider the case of a production company that is looking to outsource both IT infrastructure and application development.

II. Model

In this section, we provide a brief description of PROMETHEE and GAIA. As already stressed, we invite the interested reader to consult [5] for a detailed presentation of the methods and their extensions.

Let $A = \{a_1, .., a_n\}$ be a set of n alternatives and $F = \{f_1, .., f_q\}$ be a set of q criteria. Without loss of generality we will assume that these criteria have to be maximized. In what follows, we will also use the terms: actions, alternatives, items, projects … to describe the object of the decision.

At first, we will focus on the PROMETHEE prescriptive approach. Basically, this one can be divided in four main steps:

Step 1: Pair-wise comparisons of alternatives for every criterion.

For every couple of alternatives (a_i, a_j) we compute the evaluation difference for every criterion f_k:

$$d_k(a_i, a_j) = \mathrm{f_k}(a_i) - \mathrm{f_k}(a_j) \qquad (1)$$

When $d_k(a_i, a_j)$ is positive we may state that "a_i has better evaluation than a_j on criterion k". Moreover, this difference allows us to quantify the intensity of this assertion. Nevertheless, $d_k(a_i, a_j)$ still depends on the units of criterion k and does not take into account the intra-criterion preference information of the decision maker.

Step 2: Computation of unicriterion preference degree

[1] At date, D-Sight is now available in version 3.3.1

When comparing two actions for a given criterion, any difference is not always meaningful. On the one hand, one may for instance accept that below a certain threshold, it is considered as negligible. On the other hand, when the difference exceeds a certain limit the decision maker can conclude to a situation of strict preference (no matter if the difference increases even more). These examples illustrate the role of intracriterion preference parameters. They allow the decision maker to express how differences should be interpreted. The computation of preference degrees, denoted $P_k(a_i, a_j)$, is performed as a mapping of $d_k(a_i, a_j)$ into $[0,1]$;

$$P_k: \mathfrak{R} \to [0,1]: d_k(a_i, a_j) \to P_k[d_k(a_i, a_j)] \triangleq P_k(a_i, a_j) \qquad (2)$$

Where P_k is a positive non-decreasing function such that $P_k(x) = 0, \forall x < 0$. Usually, six different types of preference functions are considered in the literature. They are represented in Figure 1 - PROMETHEE preference functions.

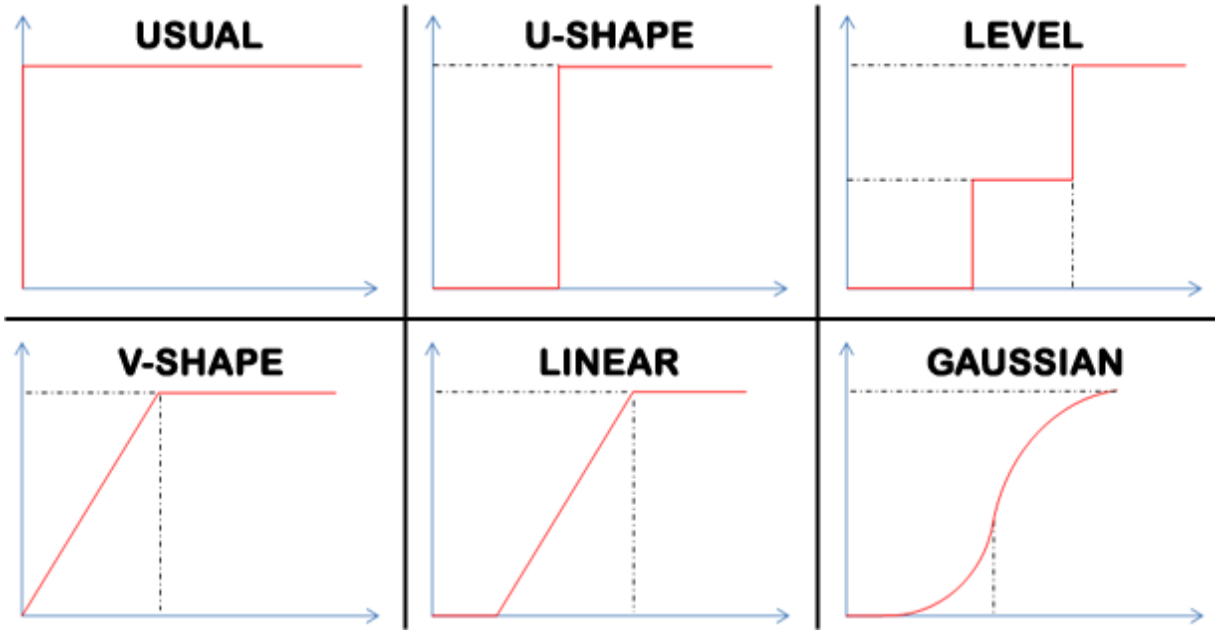


Figure 1 - PROMETHEE preference functions

Step 3: Computation of preference degrees

Once the pair-wise comparisons of actions have been made for every criterion, one may aggregate these values in order to obtain global preference degree of a_i over a_j. This is done using a weighted sum.

$$\pi(a_i, a_j) = \sum_{k=1}^{q} w_k . P_k(a_i, a_j) \qquad (3)$$

Where w_k denotes the relative importance of criterion f_k. We further assume that $w_k \geq 0$ and $\sum_{k=1}^{q} w_k = 1$.

Step 4: Computation of positive, negative and net flow scores

The global preference degrees allow the decision maker to compare any pair of alternative by taking into account all the criteria. In order to be able to rank the alternatives, we will compute positive Φ^+, negative Φ^- and net flow Φ scores as follows:

$$\Phi^+(a_i) = \frac{1}{n-1} \sum_{a_j \in A} \pi(a_i, a_j) \qquad (4)$$

$$\Phi^{-}(a_i) = \frac{1}{n-1}\sum_{a_j \in A} \pi(a_j, a_i) \qquad (5)$$

$$\Phi(a_i) = \Phi^{+}(a_i) - \Phi^{-}(a_i) \qquad (6)$$

The PROMETHEE I partial ranking is based on the positive and negative flow scores. An alternative a_i will be ranked before a_j if $\Phi^{+}(a_i) \geq \Phi^{+}(a_j)$ and $\Phi^{-}(a_i) \leq \Phi^{-}(a_j)$ with one of these inequalities being strict. An alternative a_i will have the same rank as a_j if $\Phi^{+}(a_i) = \Phi^{+}(a_j)$ and $\Phi^{-}(a_i) = \Phi^{-}(a_j)$. In the other cases, the alternatives will be considered to be incomparable.

The PROMETHEE II complete ranking is such that an alternative a_i is ranked before a_j if $\Phi(a_i) > \Phi(a_j)$. The two alternatives have an equal rank if $\Phi(a_i) = \Phi(a_j)$. Obviously, $\phi(a_i) \in [-1,1]$.

Let us further note that:

$$\Phi(a_i) = \sum_{k=1}^{q} w_k . \left[\frac{1}{n-1}\sum_{a_j \epsilon A} P_k(a_i, a_j) - P_k(a_j, a_i)\right] \triangleq \sum_{k=1}^{q} w_k . \Phi_k(\mathrm{a_i}) \qquad (7)$$

The unicriterion net flow score, denoted ϕ_k, has the same interpretation as the net flow score but is limited to a unique criterion. Similarly, $\phi_k \in [-1,1]$. This transformation shows that the net flow (global score) is the weighted sum of the unicriterion scores.

The PROMETHEE prescriptive method can be complemented by a descriptive procedure called GAIA. Any alternative a_i can be represented in two different spaces. In the evaluation space, its coordinates are $[f_1(a_i), f_2(a_i)..,f_q(a_i)]$. In the unicriterion net flow space, they become $[\phi_1(a_i), \phi_2(a_i)..,\phi_q(a_i)]$. In the later, the coordinates do not depend any more from the units. Additionally, the unicriterion preferences of the decision maker are taken into account. The GAIA plane is nothing else than the result of a Principal Component Analysis (PCA) applied on that space. By doing so, the decision maker can visualize a two dimensional representation of his problem and therefore identify groups of actions, synergies and redundancies between criteria, the best and the worst alternatives for every objective and the most desirable compromise solution(s). We refer the interested reader to [11] for a detailed description of GAIA.

III. D-Sight

a. Introduction

As stated in the introduction, D-Sight has been developed at the Université Libre de Bruxelles (ULB). More particularly, this project was conducted in the CoDE-SMG laboratory of the Engineering Faculty. Its development was made possible thanks to a grant of the Walloon region.

The D-Sight software is distributed by the D-Sight company which is a spin-off from the University and was founded in 2010. The company, which is still strongly connected to the University, continues developing the software by adding new features or new algorithms. All the users' experiences are used to orient the development of the software in the best way to make it more efficient and user friendly.

b. Main Characteristics

The aim of D-Sight is to help decision makers who are facing decision problems in which they have to compare various alternatives while considering multiple criteria. It gives them a standard framework

that allows them to conduct a deep analysis process. With the software, they can easily find the best compromise solution, justify their decisions and, as a consequence, save time.

c. Architecture

D-Sight is programmed in Java. Even though D-Sight is currently only available for Windows platforms, the use of Java allows an easy portage of the application to different platforms (MacOS, Linux …). Its structure has been designed following the best practices in programming to ensure easy maintenance and evolution. The data layer is clearly defined allowing easy access for external applications. The software has already been integrated with other systems. For example, databases interactions have already been successfully realized to allow decision makers to automatically retrieve all their data to directly perform the analysis.

Integration and external access have been made easier thanks to the plugin system presented in the next section. It is based on the **Open Services Gateway initiative (**OSGi) framework. This technology is the dynamic module system for Java. It allows remotely installing, starting, stopping, updating and uninstalling applications or components, without rebooting.

Different options were available to use the framework. The chosen one was to load it above D-Sight and to register a service in the framework to allow the bundles (plugins) to get access to the application. This is represented in the figure hereunder.

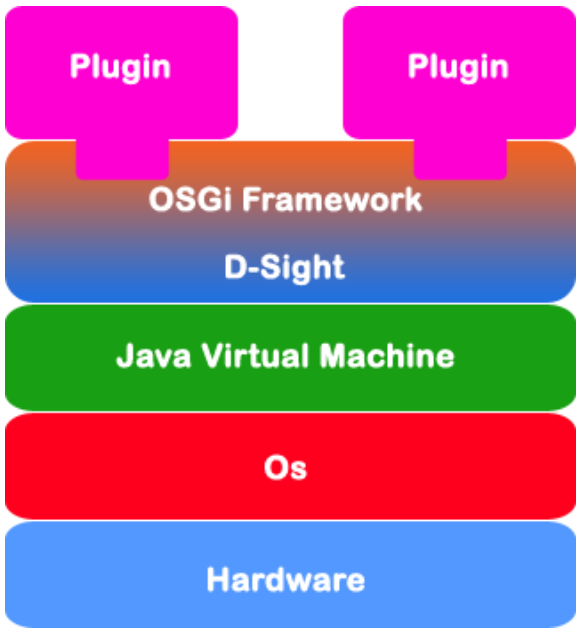


Figure 2 - OSGi integration in D-Sight

d. Plugin System

D-Sight integrates a plugin system that allows the user to extend the functionalities of the software. The user can access a plugin store while using D-Sight in which he gets access to the different available extensions. A plugin can be installed in one click and be used without restarting the software. The additional module is fully integrated with the rest of the application making it totally transparent for the user.

At the moment, there are 6 different plugins available:

- The “maps” plugin offers a complete maps system that allows the user to position his alternatives anywhere on maps. The maps results can also interact with the sensitivity analysis tools.
- The “multi-actors” (multi-scenarios) plugin allows taking into account different stakeholders (scenarios) in the decision process. Each of them can have his own set of data or parameters or both. The results are then computed for each of the participant. Furthermore, a global view of the problem is offered in order to analyze the aggregated results and find which solutions represents a consensus or are conflictual. This plugin is illustrated in the application section.
- The “subset optimization” plugin: this plugin is based on the PROMETHEE V method and gives the opportunity to the decision maker to find the best subset of alternatives (according to scores) while taking different types of constraints into account. This plugin is also illustrated in the application section.
- The “GAIA Criterion” plugin offers an extension of the GAIA plane but using any criterion as the first principal component in the PCA. Even if this choice decreases the quality of the global projection, it enhances the information related to the selected criterion.
- The “GAIA Stick” plugin offers an extension of the GAIA plane but using the decision stick as the first component of the PCA. As a consequence, the projections of the alternatives on the stick perfectly represent the PROMETHEE II ranking.
- The “How to Improve” plugin helps the decision maker to assess the improvement needed on a specific criterion to increase the relative position of a given alternative in the PROMETHEE II ranking.

IV. Application

a. Introduction

We are now going to illustrate the use of D-Sight in a particular real-life situation. While the structure of the problem is taken from an existing case, the data have been modified in order to ensure confidentiality. This will however give another example where multi-criteria analysis can be conducted and will highlight how D-Sight can be used in this context.

b. Context

IT outsourcing is a growing industry. It allows industries to focus on their core business while letting specialized companies manage their IT infrastructure, operations and application development. This strategy has been deployed with success in a number of organizations around the world allowing both sides of the partnership to grow. IT is thus deployed as a service.

When discussing about IT outsourcing, the main distinction is whether infrastructure and / or applications are outsourced. In the remaining part of the article, infrastructure outsourcing will be referred to as IO while application outsourcing will be referred to as AO.

- IO focuses on the IT components of the organization: from network backbone (routers, switches, firewall ...) to end-users workstations without forgetting servers (mail, web, ERP, …) or support. In addition of the daily operations of maintenance / upgrade / etc..., IO might as well include the implementation of new projects.

- AO on the other side takes care of the applications development and ensures that it supports the business in the daily work of the end-users (whether they are manufacturing employees, clerks, salesperson, etc...).

In the example that we consider, we analyze a case of a production company (Production Inc.) that outsources both infrastructure and application development to an external IT partner (IT Inc.). IT Inc. is therefore responsible of all operations and application development for Production Inc in a full IO and AO deal. In addition, IT Inc. is a key advisor of Production Inc. and, due to its deep knowledge of all IT operations, is in a good position to suggest potential improvements and new projects to implement the required changes. On a yearly basis, IT Inc. gathers inputs from all its employees in order to suggest to Production Inc. the best projects that will support its operations and growth. Furthermore, the executive team of Production Inc. also has a list of projects that they would like to conduct and therefore need to select which projects are more worth their investment.

c. Structure

In this context, Production Inc. needs to combine its own projects and the different projects submitted by IT Inc. and will need to evaluate which are the best. This evaluation cannot be only based on the sole costs (whether implementation, maintenance, training ...), thus making usually the selection of projects a complex task. In this particular scenario, Production Inc. has identified a number of criteria that they wish to consider before taking a decision on the projects to implement. Those criteria have been divided into two main categories: price and quality, each category being subdivided as shown below:

1. **Costs**
    - **Project**: those criteria reflect the direct costs visible to Production Inc.
        - **Initial Investment**: this is the cost of additional components that need to be added to the infrastructure (for instance new servers, new network routers ...). It is expressed in Euros.
        - **Implementation cost**: this is the cost of labor necessary to implement the project (installation, configuration, integration ...). It is expressed in Euros.
    - **Operational**: this reflects the costs once the project has been completed and that it is fully functional (i.e. put in production)
        - **Daily operations**: this is the difference of costs between daily operations before the implementation of the project and once it is completed. If the system is less expensive to work with on a daily basis, it can therefore contain negative values. It is expressed in Euros.
        - **Knowledge transfer**: this is the price of transferring the knowledge from the people who realized the project to the people who will maintain the solution in place. It is expressed in Euros.
2. **Quality**
    - **Logistic**: this subcategory reflects the planning of the project in terms of required efforts and length
        - **Length**: this is the expected length of the project, from the planning phase until it is deployed into the production environment. It is expressed in days.
        - **Man days**: this is the required effort and it highlights how much time the different resources working on the project are going to spend. This is expressed in Man Days

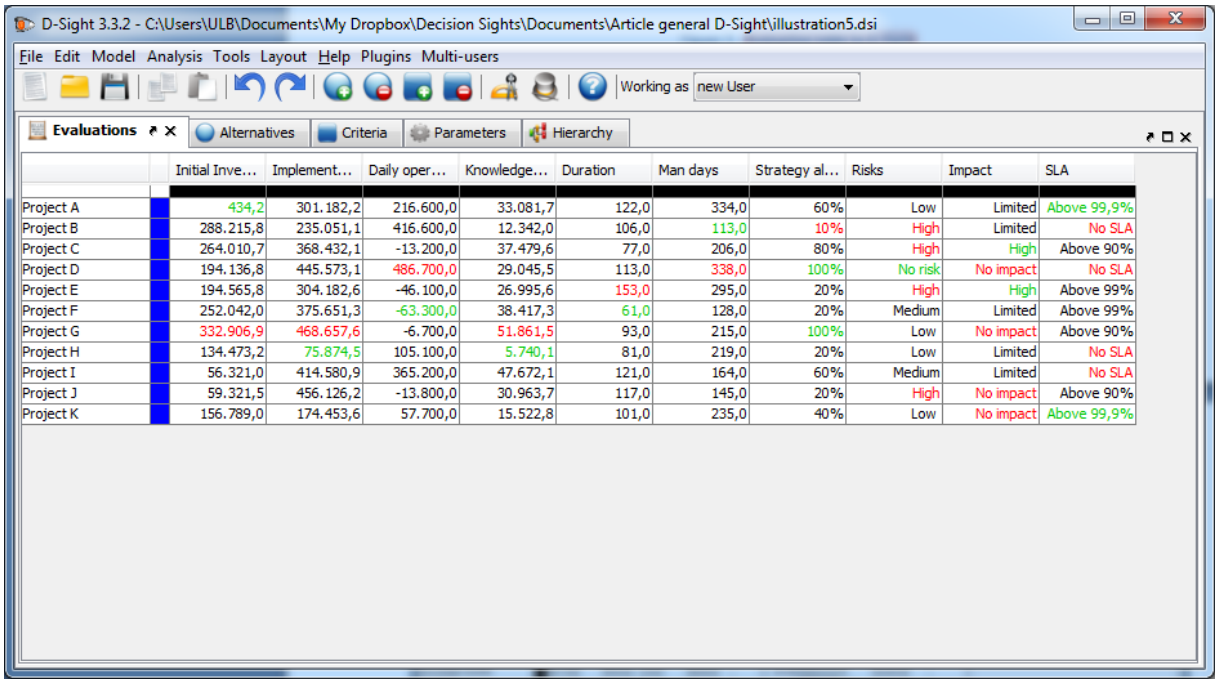
(MD) where 1 MD is the time spent by one resource during one day (8h). This criterion is not directly related to the length of the project as it depends of the time repartition.

- **Strategy**: this subcategory assesses how the projects align with the strategy defined by the executive team of Production Inc and what are the risks involved with the implementation of the project.
  - **Strategy alignment**: this criterion measures against a qualitative scale how the project is aligned with the predefined strategy of Production Inc. The scale is [10%; 20%; 40%; 60%; 80%; 100%].
  - **Risks**: the risks associated with this project is expressed against a qualitative scale [no risk; low; medium; high] defined internally by Production Inc.
- **Service**: this subcategory highlights how the projects are going to impact the level of service provided by IT Inc.
  - **Impact**: the impact is measured against a qualitative scale [no impact; limited impact; high impact] and shows how the projects are going to impact the daily operations. This does not only include technical reasons (expected downtime, data unavailability…) but also the learning phase for the employees (new functionality, new product ...).
  - **Service Level Agreement (SLA)**: finally, Production Inc will assess whether a SLA will need to be put in place in order to ensure that the new service / system implemented complies with their expectations. The scale is [no SLA; above 90%; above 99%; above 99.9%].

d. Analysis with D-Sight

i. Inputs

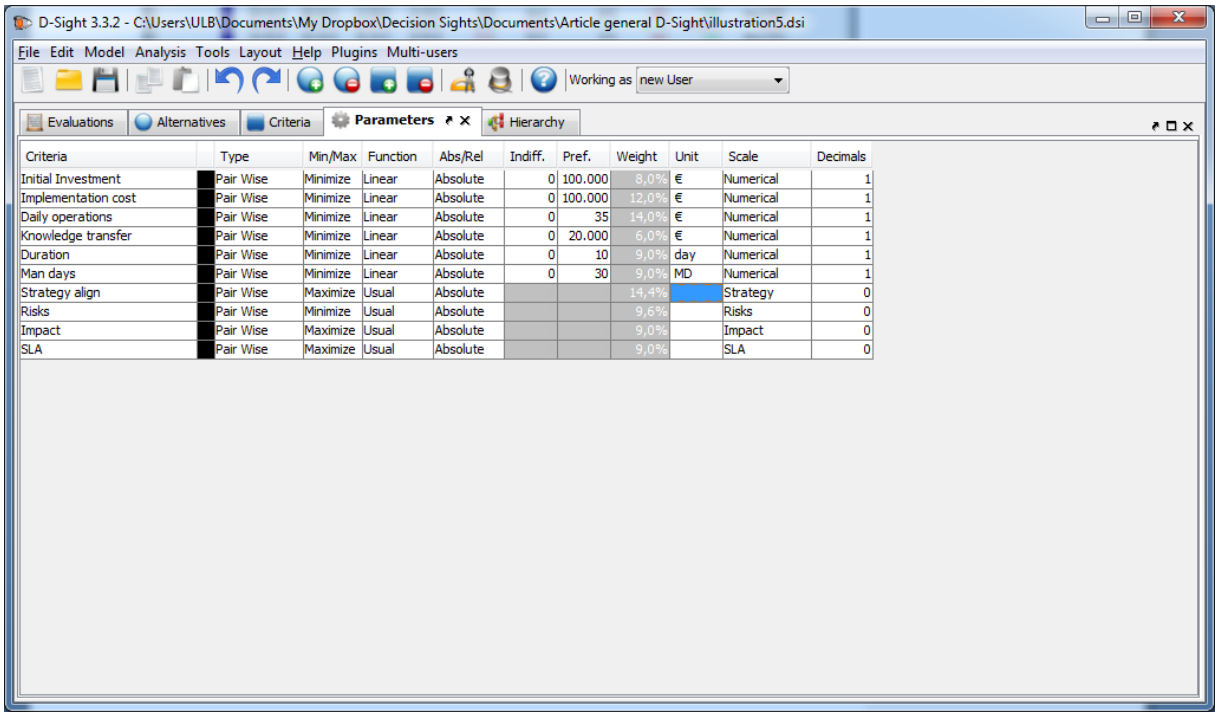
D-Sight is launched by default with the five main inputs panels. The first one is the Evaluations panel gathering all the alternatives (Project A, Project B …) and all the criteria. They are respectively represented in each row and in each column. As represented in Figure 3, the evaluations can be numerical or based on qualitative scales.



	Initial Inve...	Implement...	Daily oper...	Knowledge...	Duration	Man days	Strategy al...	Risks	Impact	SLA
Project A	434,2	301.182,2	216.600,0	33.081,7	122,0	334,0	60%	Low	Limited	Above 99,9%
Project B	288.215,8	235.051,1	416.600,0	12.342,0	106,0	113,0	10%	High	Limited	No SLA
Project C	264.010,7	368.432,1	-13.200,0	37.479,6	77,0	206,0	80%	High	High	Above 90%
Project D	194.136,8	445.573,1	486.700,0	29.045,5	113,0	338,0	100%	No risk	No impact	No SLA
Project E	194.565,8	304.182,6	-46.100,0	26.995,6	153,0	295,0	20%	High	High	Above 99%
Project F	252.042,0	375.651,3	-63.300,0	38.417,3	61,0	128,0	20%	Medium	Limited	Above 99%
Project G	332.906,9	468.657,6	-6.700,0	51.861,5	93,0	215,0	100%	Low	No impact	Above 90%
Project H	134.473,2	75.874,5	105.100,0	5.740,1	81,0	219,0	20%	Low	Limited	No SLA
Project I	56.321,0	414.580,9	365.200,0	47.672,1	121,0	164,0	60%	Medium	Limited	No SLA
Project J	59.321,5	456.126,2	-13.800,0	30.963,7	117,0	145,0	20%	High	No impact	Above 90%
Project K	156.789,0	174.453,6	57.700,0	15.522,8	101,0	235,0	40%	Low	No impact	Above 99,9%

Figure 3 - Evaluation table in D-Sight

The two following panels allow the decision maker to list the alternatives and criteria. Names and short names can also be assigned to all these elements. The fourth panel is meant to introduce the evaluation parameters and is represented in Figure 4 that allows the interested reader to consult the parameters used in this case.



Criteria	Type	Min/Max	Function	Abs/Rel	Indiff.	Pref.	Weight	Unit	Scale	Decimals
Initial Investment	Pair Wise	Minimize	Linear	Absolute	0	100.000	8,0%	€	Numerical	1
Implementation cost	Pair Wise	Minimize	Linear	Absolute	0	100.000	12,0%	€	Numerical	1
Daily operations	Pair Wise	Minimize	Linear	Absolute	0	35	14,0%	€	Numerical	1
Knowledge transfer	Pair Wise	Minimize	Linear	Absolute	0	20.000	6,0%	€	Numerical	1
Duration	Pair Wise	Minimize	Linear	Absolute	0	10	9,0%	day	Numerical	1
Man days	Pair Wise	Minimize	Linear	Absolute	0	30	9,0%	MD	Numerical	1
Strategy align	Pair Wise	Maximize	Usual	Absolute			14,4%		Strategy	0
Risks	Pair Wise	Minimize	Usual	Absolute			9,6%		Risks	0
Impact	Pair Wise	Maximize	Usual	Absolute			9,0%		Impact	0
SLA	Pair Wise	Maximize	Usual	Absolute			9,0%		SLA	0

Figure 4 - Parameters Table

The last of the five panels allows structuring the criteria into a hierarchy tree. Categories can be defined in order to gather criteria or other categories or both. These tree can easily be constructed by drag and dropping its elements. The categories are defined in that panel. As represented in Figure

5, each category has also a name, a short name and a color. They have two additional interesting properties. The first one is that they can be disabled as the criteria or alternatives. The exception in that case is that when a category is enabled / disabled, all its content is automatically enabled / disabled. The last property of a category is that it can be grouped or ungrouped. This will be illustrated later on.

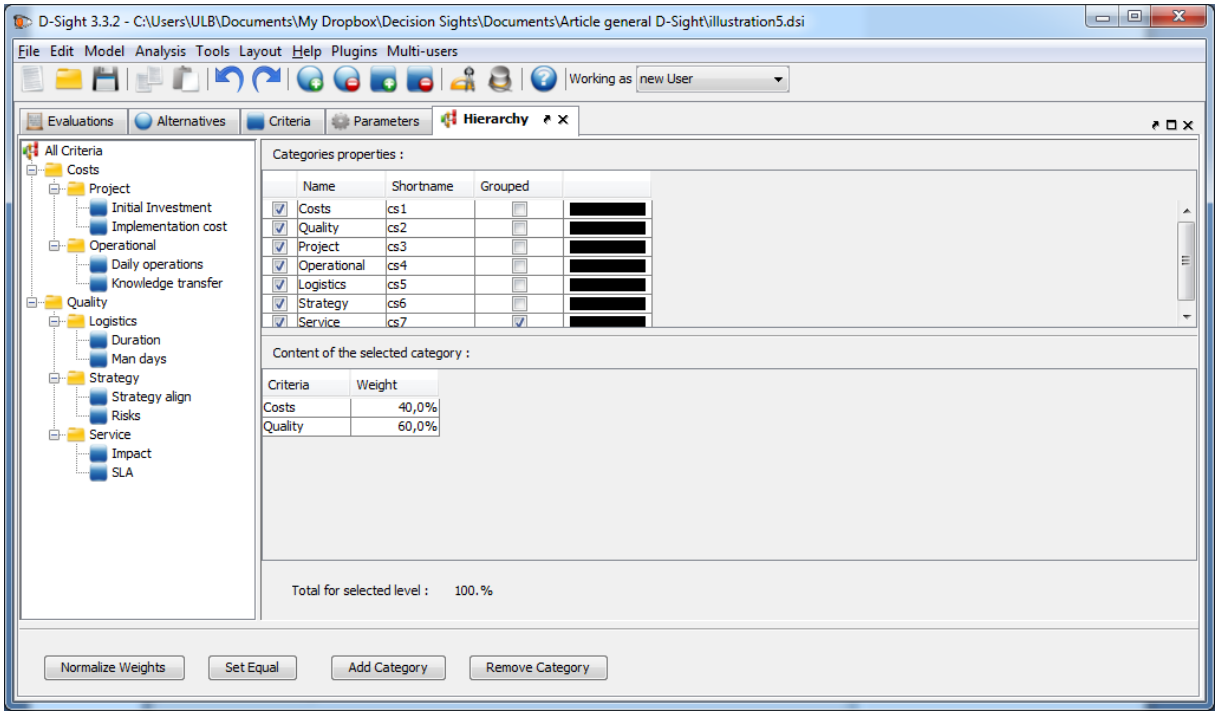


Figure 5 - Hierarchy Definition

ii. GAIA analysis

The Global Visual Analysis offers a complete representation of the problem. As shown in Figure 6, the alternatives are represented by the blue points and the criteria are represented by the different axes. Let us note that the criteria are not represented “as is” but according to the decision maker’s preferences (e.g. the preferences functions). The computation of this chart depends on two things:

- the alternatives and their gross criteria evaluations;
- the intracriterion parameters expressing the way the decision maker wants to evaluate those alternatives for the different criteria.

As the decision maker has here defined a hierarchy, he can choose what he wants to see in the GAIA plane by grouping or ungrouping the categories. In Figure 6, the Costs category is ungrouped as the Quality. Their respective category children are represented as they are grouped. Thanks to this plane and the “grouping” functionality, the alternatives can be easily compared on different level of details.

Let us remind the reader that different types of observations can now be done [11]:

- **Relative positions of the alternatives**: if two projects are close in the plane, as J and B in Figure 6, it means that they should be similar with respect to the different criteria.
- **Alternatives and criteria**: an axis indicates the direction of the area in which the alternatives are good for the associated criterion. In Figure 7, the decision maker can directly see that F is the best alternative on the global Logistics (e.g. F goes the further on the *Logistics* axis).

- **Relative positions of the criteria**: if two criteria axes are in the same direction, that means that they are similar (e.g. globally, the projects which are good for the first criterion are also good for the second). If two criteria axes are in opposite directions, that means that they are conflicting (e.g. globally, the projects which are good for the first criterion are not good for the second). In Figure 76, one can observe that in average, the projects having interesting Strategy scores are not good on the Operational aspects (e.g. Strategy goes on the left while Operational is oriented to the right).

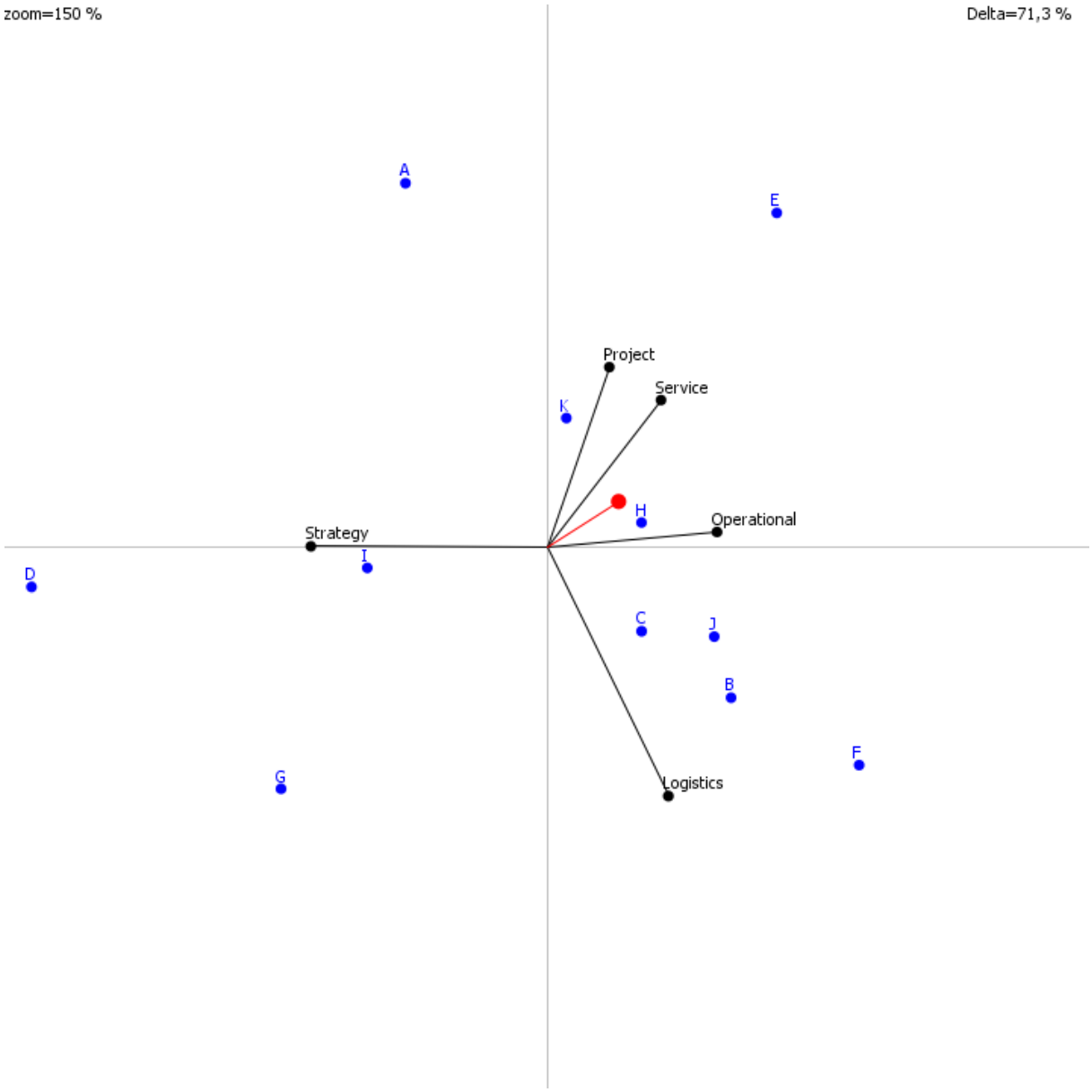


Figure 6 - GAIA representation

The red axis (the one without label) of the GAIA plane is called the decision axis. It is obtained by using the weights of the criteria given by the decision maker. It represents the compromise he wants to make between the criteria. By projecting the projects on this axis, the global ranking can be visualized as shown in Figure 8.

We would like to emphasize that the ranking inferred visually by projecting the alternatives on the criteria axes or on the decision axis may not be completely correct. This is due to the fact that a two-dimensional representation of a *k*-dimensional problem is used. This issued has already been addressed in [8].

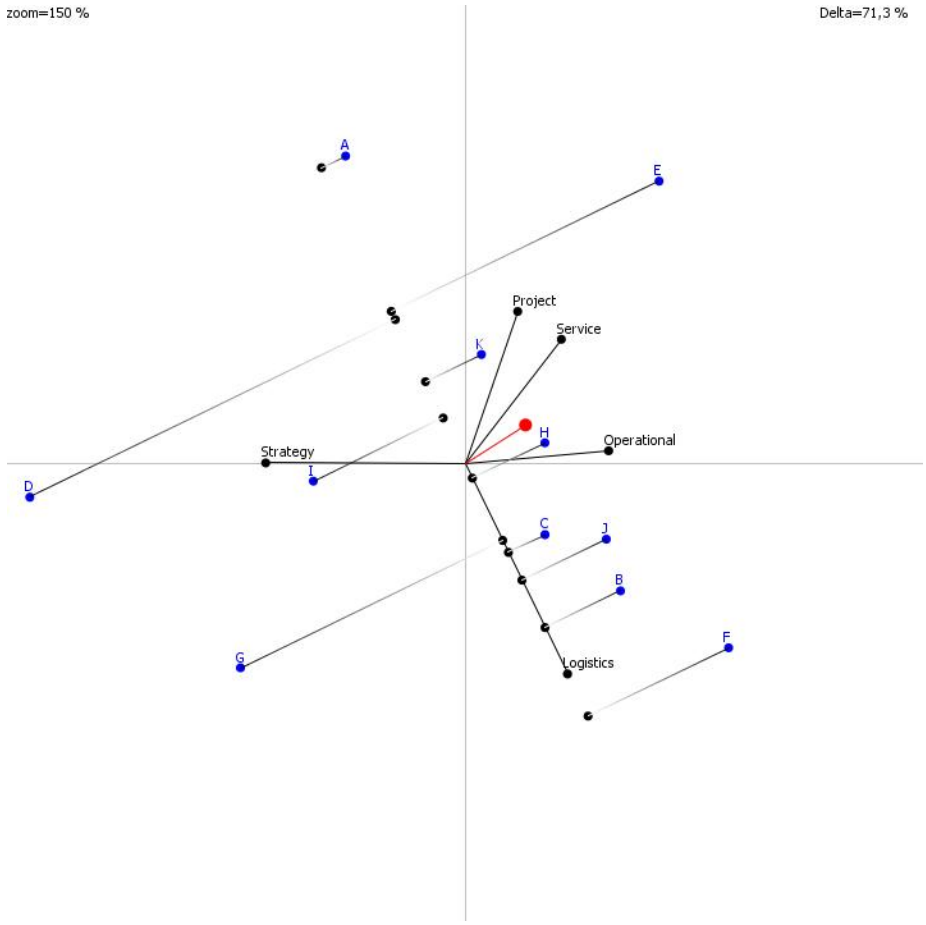


Figure 7 - Projections on a criterion axis

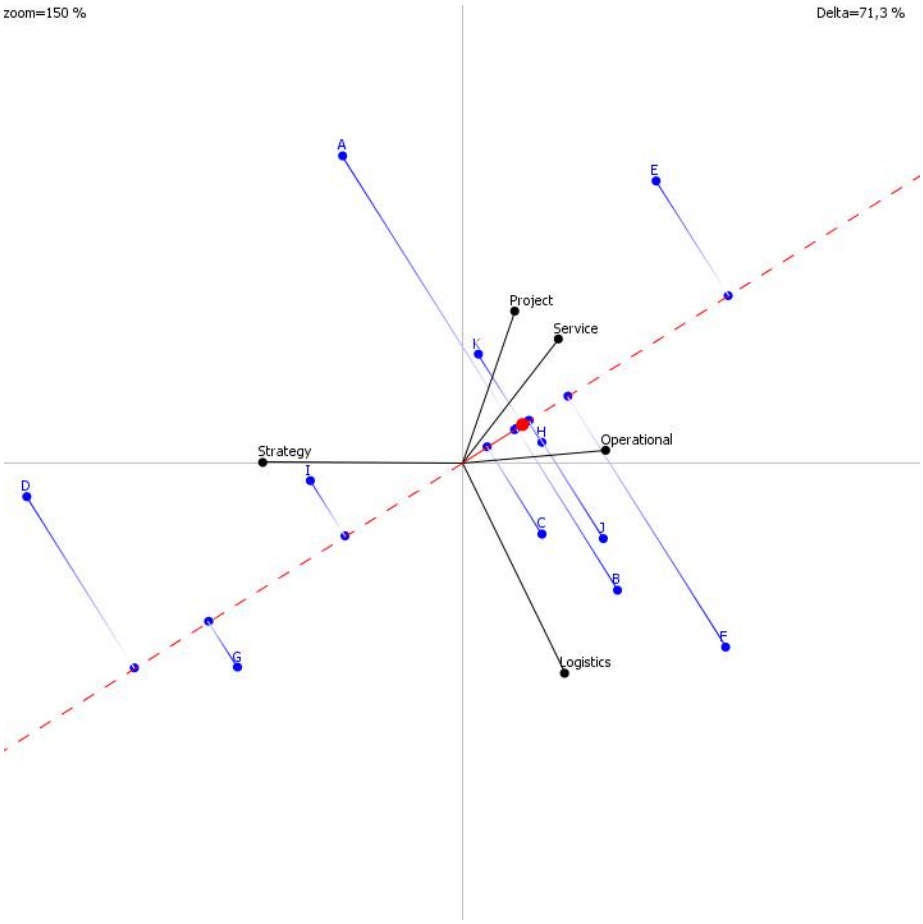


Figure 8 - Projections on the decision axis

iii. PROMETHEE II Ranking

The PROMETHEE II ranking offers a total ranking of the alternatives from the best (the first rank) to the worst (the last rank). They are scored between 1 and -1; 1 being the best. The ranking of the projects is represented in Figure 9. Project F is first with a score of 0.20, closely followed by project K, with a score of 0.19.

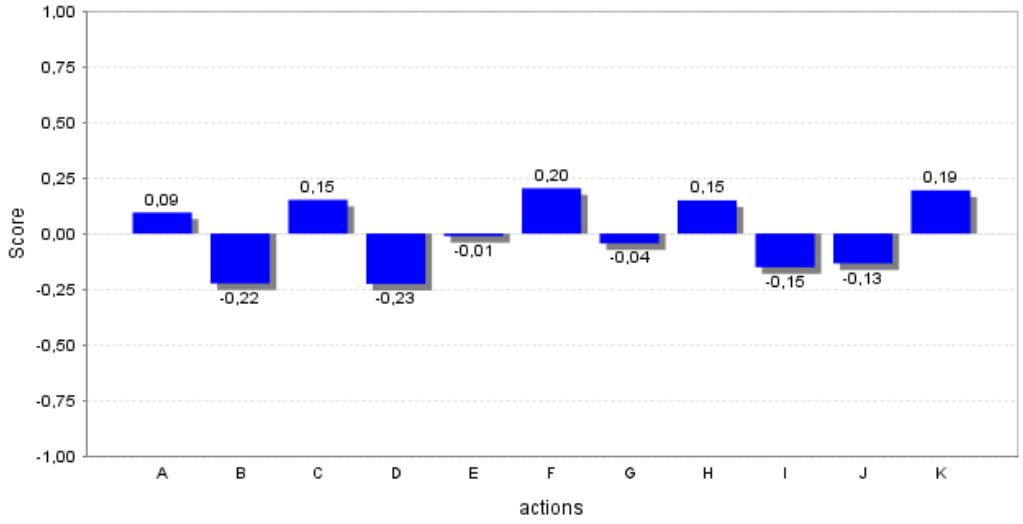


Figure 9 - PROMETHEE II ranking

In the previous section, we mentioned that the visual global ranking can be obtained by projecting the alternatives on the decision axis. In the Figure 10, we have grouped the two main categories, Quality and Costs, which allows avoiding any loss of information (as working in 2 dimensions). The delta value is, in that case equal to 100%. One can now observe that the projections of the alternatives on the decision axis do perfectly reflect the PROMETHEE II ranking, with the ordinal and cardinal information.

Another interesting point related to this visual configuration, is that it allows quantifying easily the Quality / Cost trade-off that could be done by choosing a project over another. Indeed, one can observe that choosing between F and K, which are almost equally scored in PROMETHEE II, is equivalent to choose between Quality and Costs.

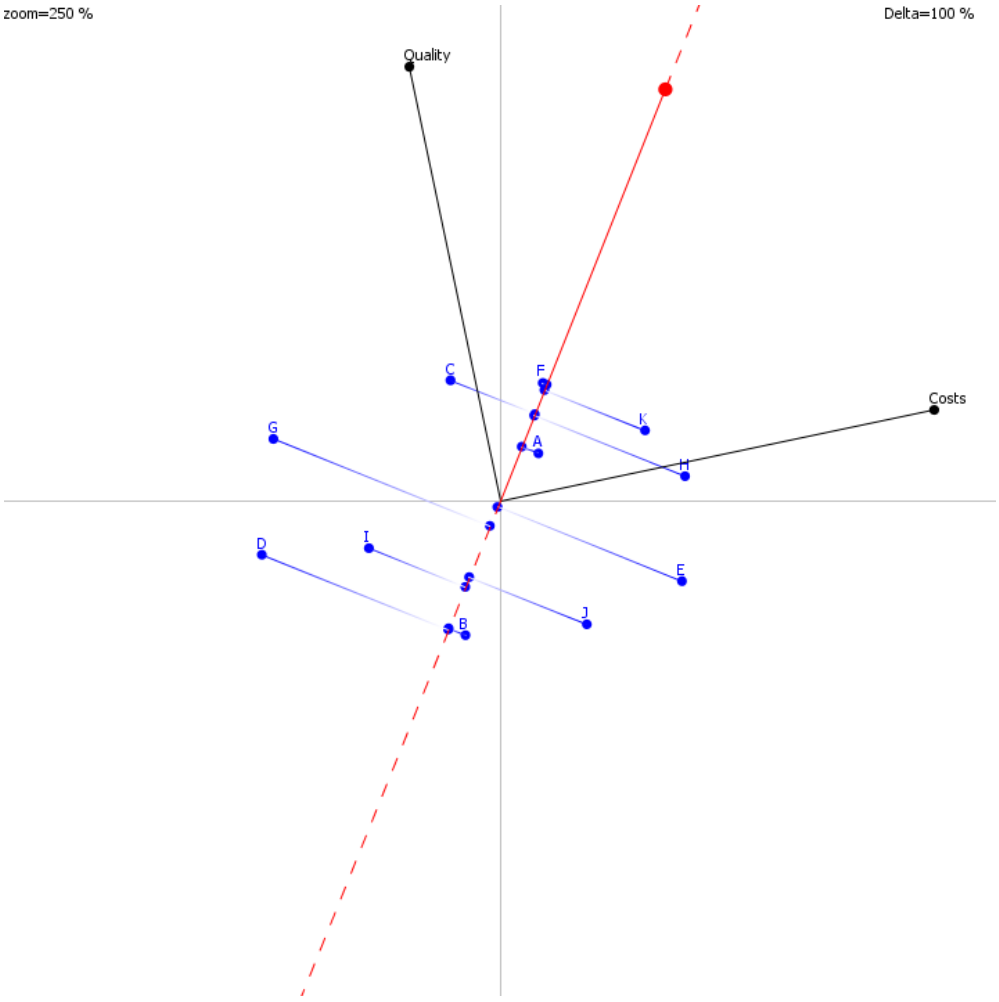


Figure 10 - Projections on the decision axis

iv. Sensitivity Analysis

In most multi-criteria analysis, the assessment of criteria weights is a crucial step. Indeed, these may deeply influence the global score calculation. Therefore, it is really important to be able to perform sensitivity analysis.

In D-Sight, this is done by using the stability intervals. They give, for each criterion or category (according to the decision maker's choice), the interval in which the weights may-vary without affecting the ranking.

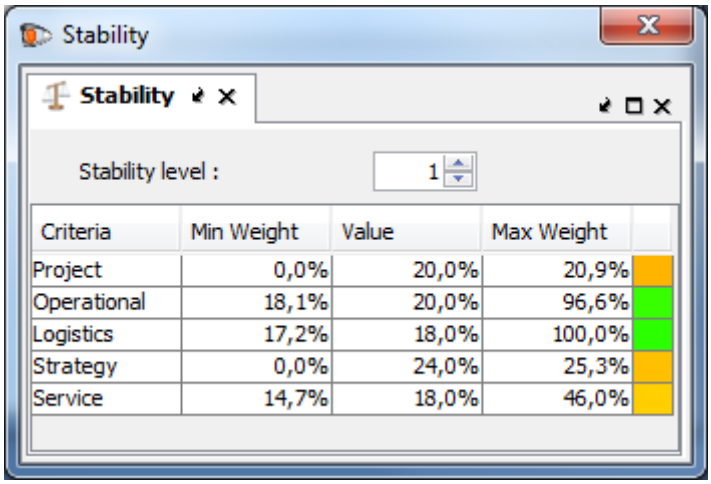


Figure 11 - Stability Intervals

We can observe in Figure 11, that some of these values are rather robust while others are more sensible. Let us emphasize an important point here: one could think that the Logistics category is stable because the weight can increase from 18% to 100% without affecting the ranking (to the level 1). But on the other hand, it cannot even be decreased by 1% without affecting the ranking. That means that Logistics is only stable "on the right side". This table shows us that there exists some asymmetry in the stability.

Let's highlight that the following hypothesis is here considered: when a weight is changed, the other weights are proportionally changed, with respect to the initial ratios.

The stability level is the rank to which the stability is considered. In Figure 11, the level is one which means that we only look at the first alternative and in which intervals it stays first, regardless if the third alternative becomes second. The stability level can be calculated up to *n*. The bigger the level is, the smaller are the intervals, as constraints are added.

v. PROMETHEE I Ranking

A new representation of the PROMETHEE I ranking has been introduced in the beta version of D-Sight in 2009. It consists in representing the alternatives in a so-called diamond. The two axes used are the negative and positive flows as shown in Figure 12.

Considering the rules of PROMETHEE I (see section II), the incomparability between two alternatives can be observed when their projections lines (on Phi+ axis and Phi- axis) are crossing. An alternative is preferred to another, when it is above and without line crossing. The vertical axis is the net flow score, as it is obtained by substracting the Phi- axis to the Phi+ axis. This kind of representation allows thus to combine PROMETHEE I and PROMETHEE II ranking in the same chart.

Regarding the project selection, one can observe that the two most preferred projects with respect to PROMETHEE II, F and K, are also the two most preferred with respect to PROMETHEE I. However, there are here considered as "incomparable" as their lines are actually crossing over.

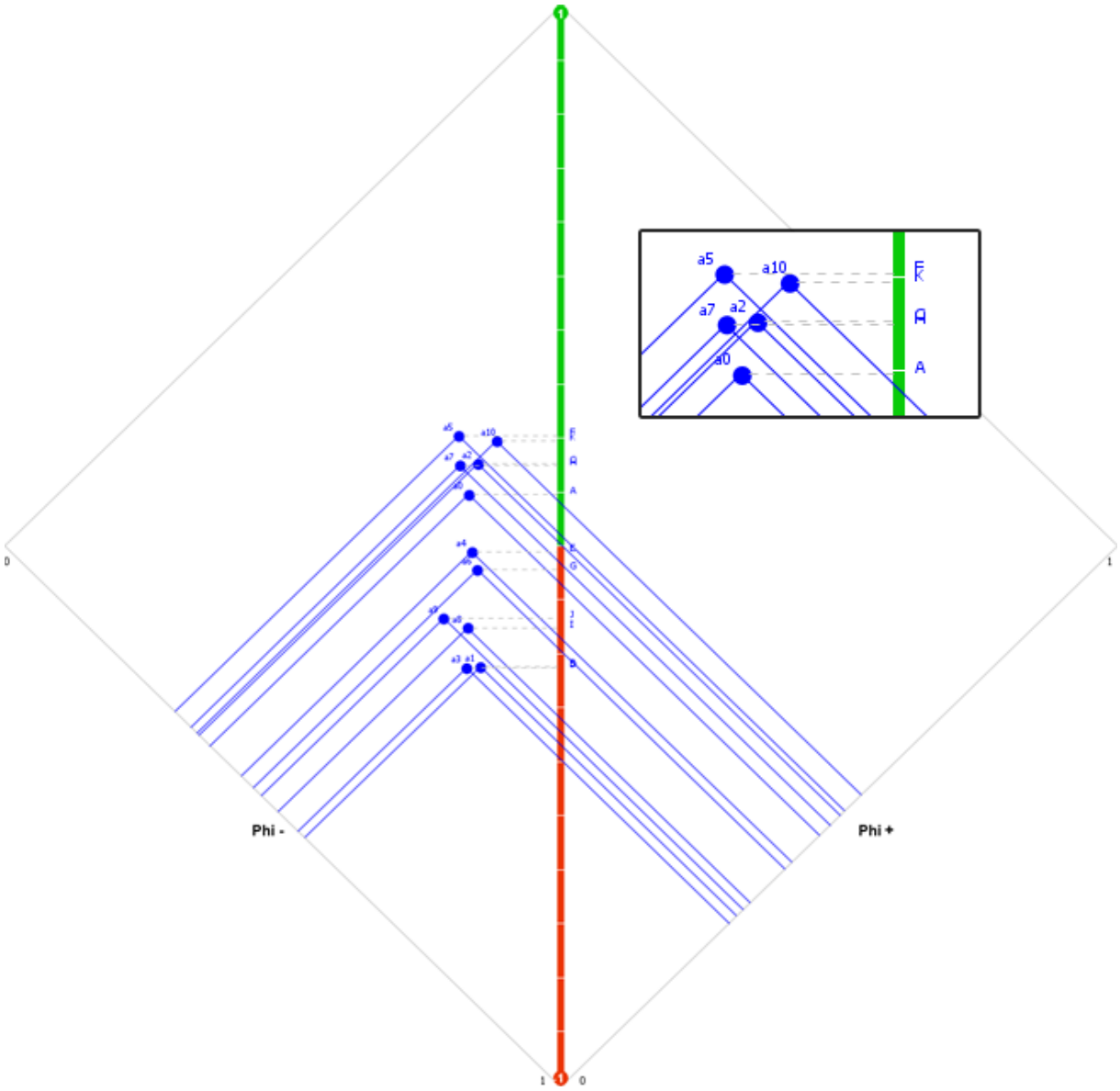


Figure 12 - PROMETHEE I Diamond

vi. Profiles

The previous analysis has led us to identify a sub group of alternatives that are more interesting than others. Clearly, F and K seem to be good candidates. A natural next step is thus to focus ourselves on the differentiation between these two options. The profiles of the alternatives can be compared two by two by using the Profiles tool. In Figure 13, F and K are being compared for all the level-2 categories. It is easy to see that they do not have similar profiles, especially for the Project, Logistics and the Strategy criteria.

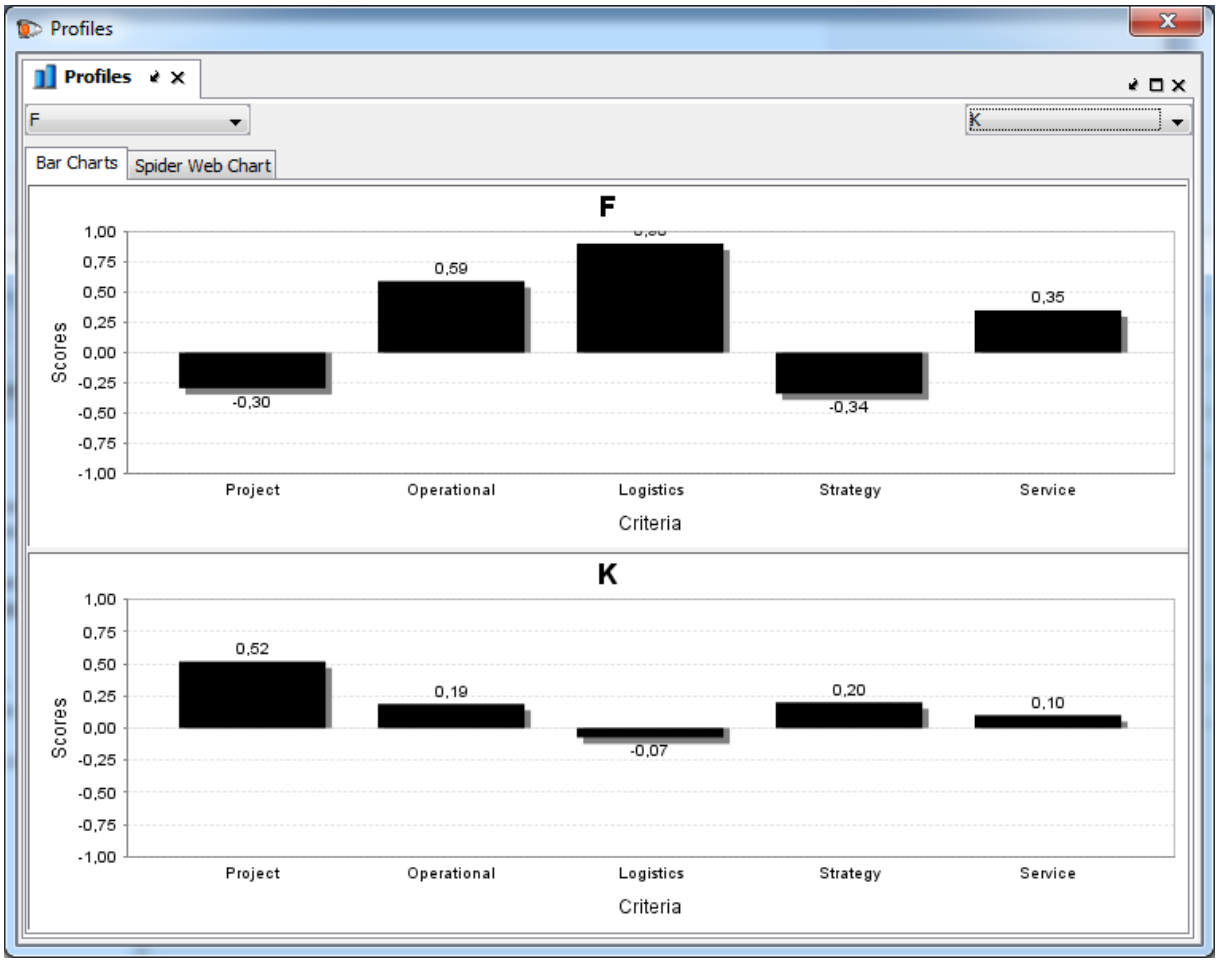


Figure 13 - Profiles bar chart

The same type of analysis can be made in a spider-web chart, as represented in Figure 14. In that case, we compare the two first alternatives, F and K, for all the sub criteria (level 3). We have just ungrouped all the categories, which has the consequence to automatically update the chart.

Thanks to this chart, one can observe that K (K is the one that is best on the Risks) has a more averagely good profile. On the other hand, F has strong points while it is very weak on others.

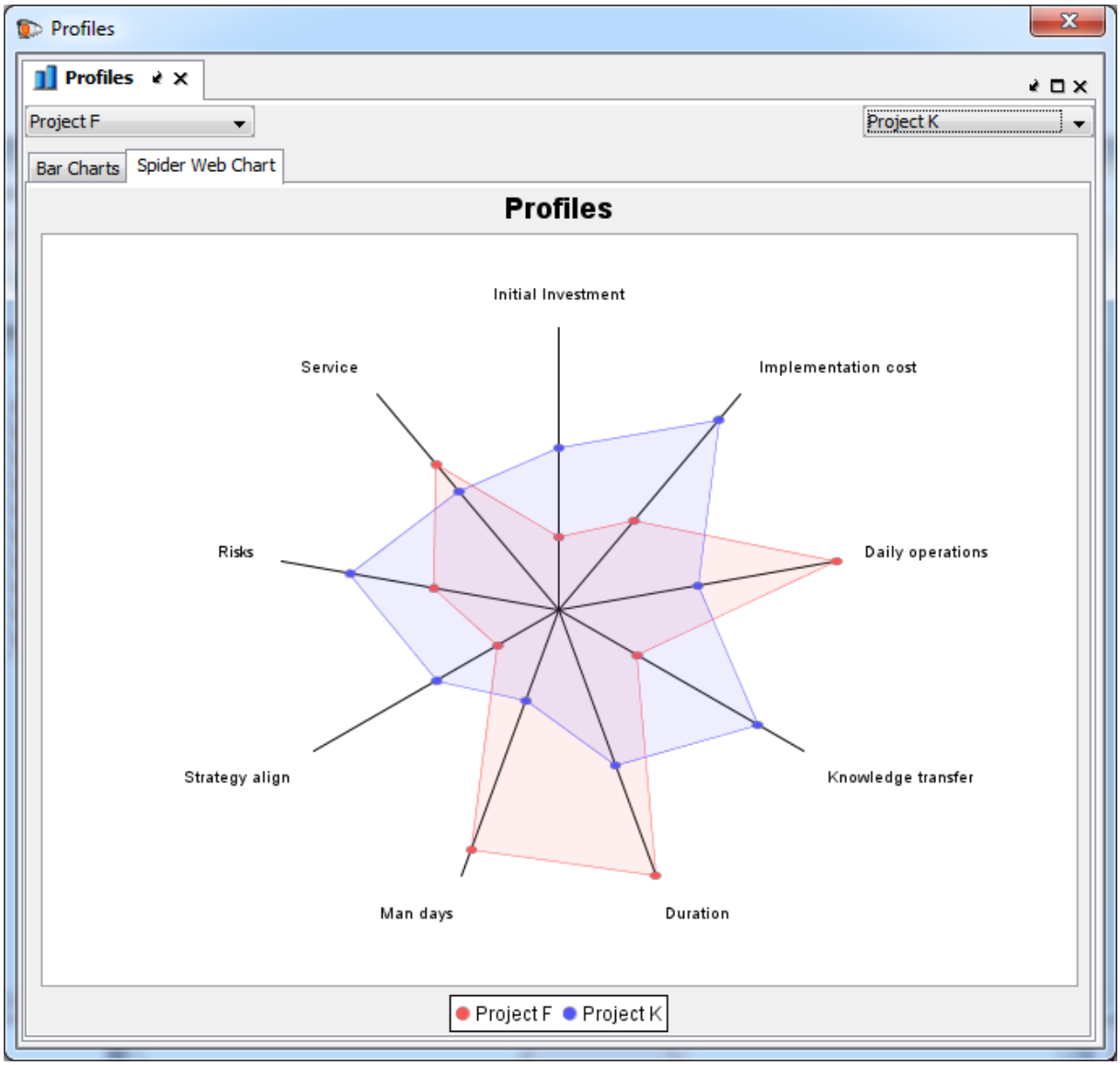


Figure 14 - Profiles spider web chart

vii. Project Portfolio Management - PROMETHEE V

We will now consider the case in which the decision maker has to select several projects. He thus needs to establish the best project portfolio. Having ranked all the projects by attractiveness, the decision maker will have to determine which projects he will select in order to respect some imposed constraints.

Literally, this problem consists in selecting the best subset of alternatives (with respect to their global scores) while considering different constraints. To illustrate this, we will use the sub-set optimization plugin that is available for D-Sight. This plugin is based on the PROMETHEE V method.

The process is divided in two steps:

1. A ranking of the alternatives / projects is established, considering the preferences of the decision maker. Thus they are ranked with respect to their attractiveness for the decision maker without taking into account, any constraints or relation between the alternatives.

2. The decision maker can provide different constraints such as a budget or a minimum number of alternatives having to be selected, for instance. A subset of alternatives is then found to maximize the total additive score of the subset while respecting all the established constraints.

We will now come back to the example in order to illustrate the use of this plugin. Let's consider that Production Inc. wants to implement different projects but needs to respect the following constraints:

- A limited Initial investment of 750.000 €.
- A limited Implementation Cost of 1.500.000€.
- The number of selected projects must be greater or equal to 5.
- If project A is selected, project I must be selected.
- If project I is selected, project C can't be and vice-versa.

The different constraints can be defined into an interface as illustrated in Figure 15 - Choosing a general type of constraint.

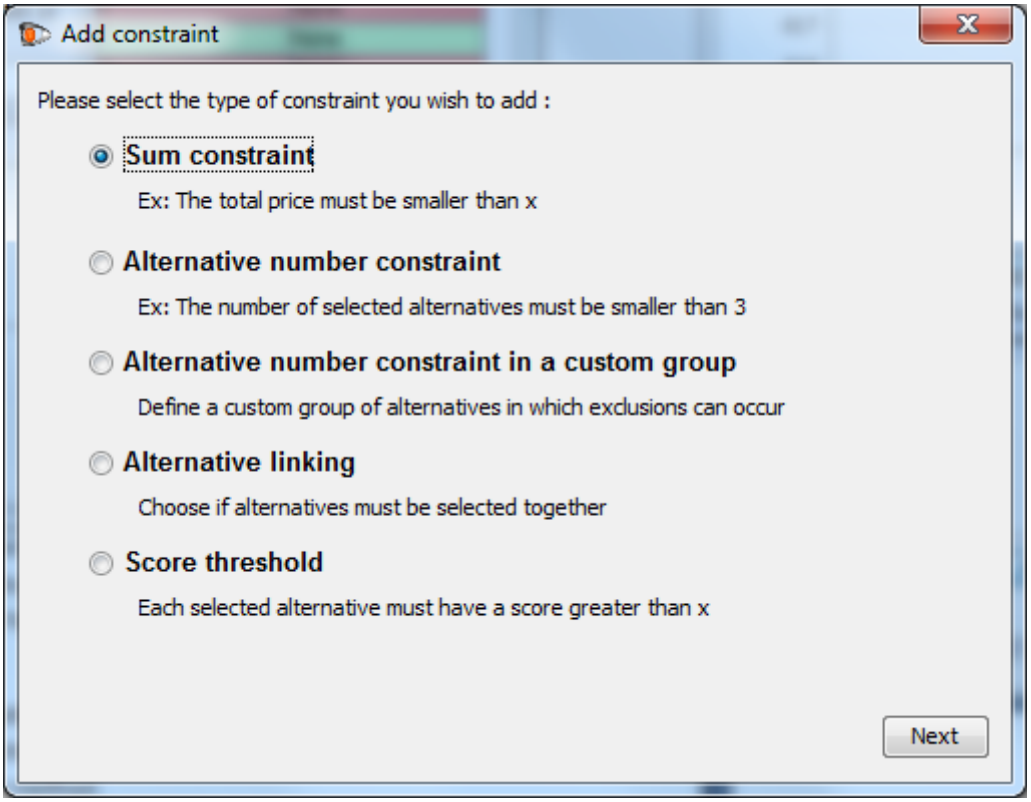


Figure 15 - Choosing a general type of constraint

As the constraints are being added, the subset is gradually computed taking into account the additional constraints. Finally, if there is at least an existing solution, the optimal subset is calculated. As illustrated in Figure 16 - Result of the project selection, the selected alternatives are highlighted in green in the table. The "Show Everywhere" button allows displaying the green (selected) and red (not selected) colors in all the charts and tables of the software. This can help to integrate the optimization results in the other tools in order to make an easy global analysis.

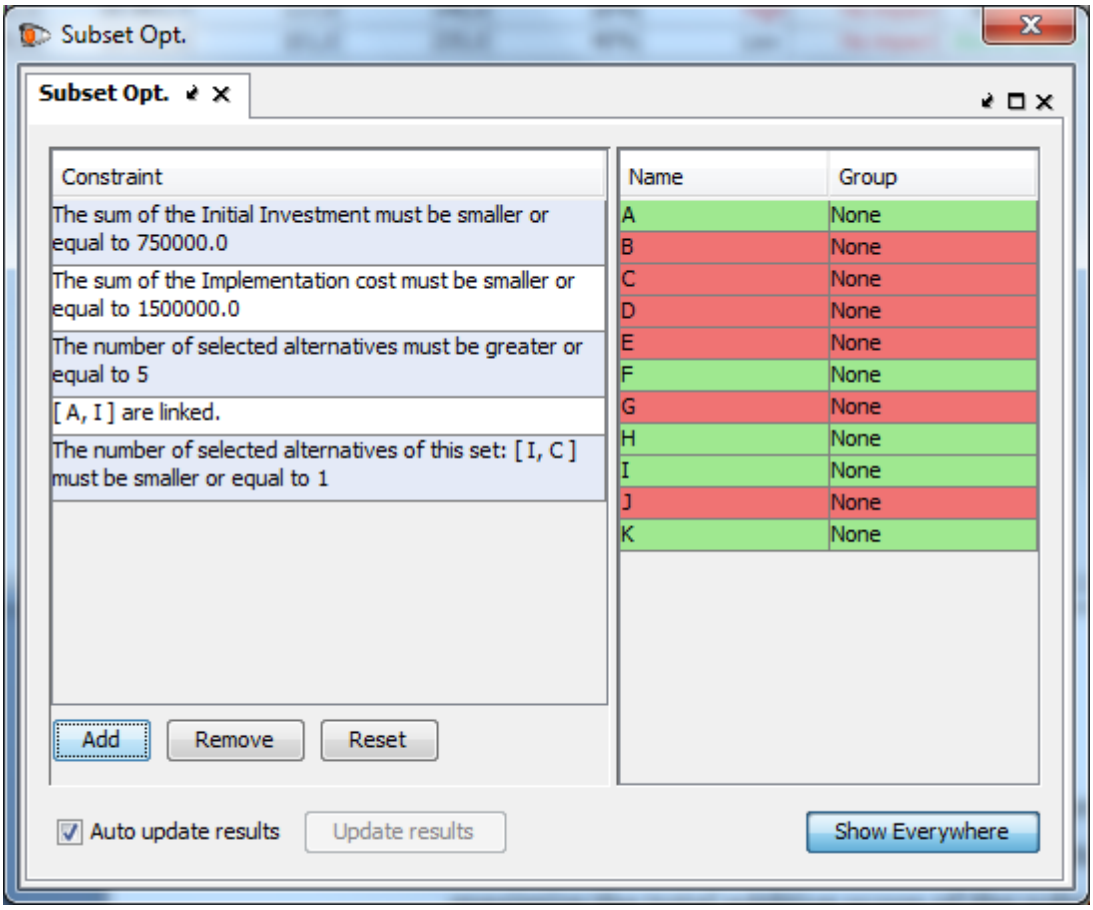


Figure 16 - Result of the project selection

Let's emphasize the fact that many types of constraints can be defined. Furthermore, custom groups can also be defined in order to use group related constraints.

viii. Multi-actors analysis

In this section, we will consider the case in which two decision makers are involved in the projects selection. Let us consider two managers, John and Jane.

As defined in the model, each participant works with the same set of alternatives and criteria (structured in the same way).

The participants can differentiate their analysis on three main points:

- The evaluation of the alternatives for the criteria: this case is relevant for criteria based on qualitative judgments given by different experts.
- The evaluation parameters: the actors can decide not to evaluate the criteria in the same manner. They can have different functions or different thresholds.
- The weights of the criteria: each stakeholder can weight the criteria according to his own preferences.

In the previous part of this article, John was the only decision maker in the selection process. We will consider that John and Jane will only weight the criteria differently. Indeed, Jane accords more importance to the Costs than to the Quality. She also has given different weights to the sub-categories.

In the Figure 17, we have represented the visual analysis and the global ranking according to John's preferences. We logically have the results previously presented.

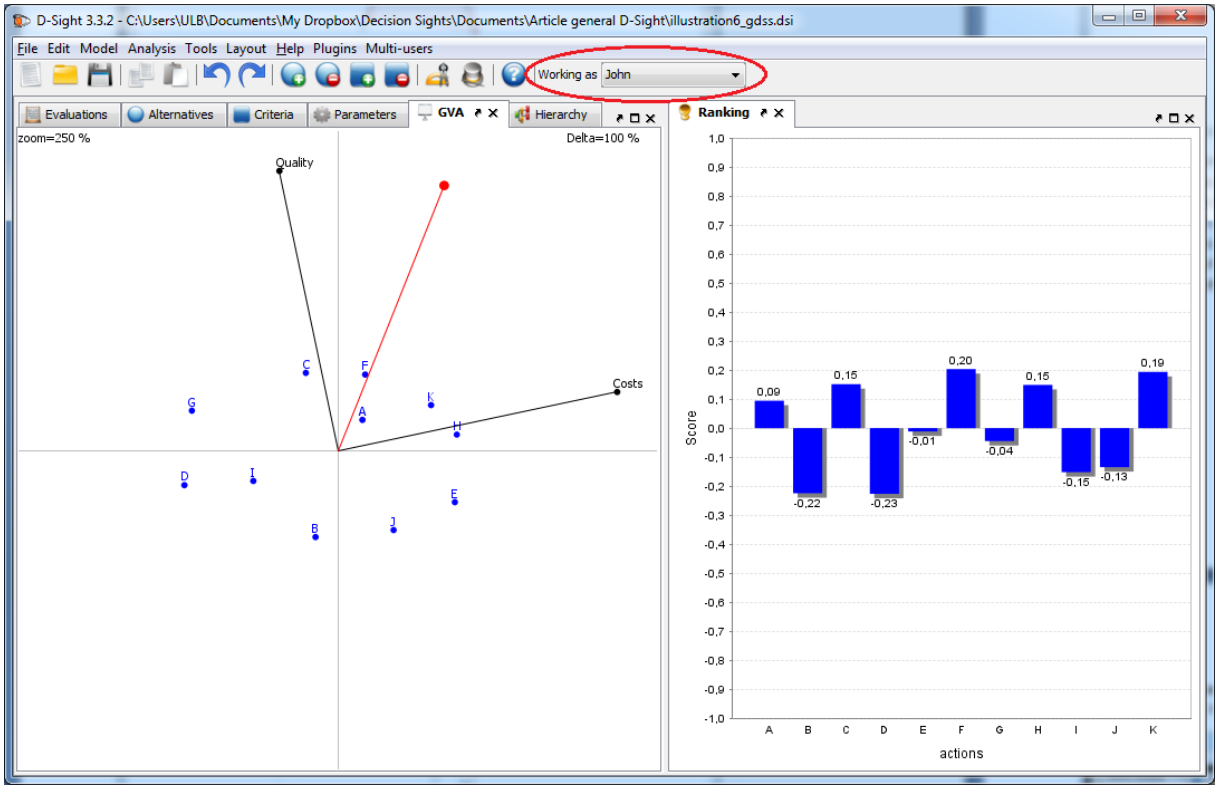


Figure 17 - Results for the user John

To change the current decision-maker, one has just to select the desired user in the list. The entire interface is automatically updated with the corresponding data and results. In the Figure 18, Jane's results are represented. The ranking of the alternatives is different as the GAIA plane is. The reader could expect the GAIA plane to be the same in the two cases, except for the decision axis, as only the weights have changed. As the weights of the sub-categories are not the same for John and Jane, the unicriterion scores of the alternatives for the Quality and the Costs are different which explains the computation of two different planes.

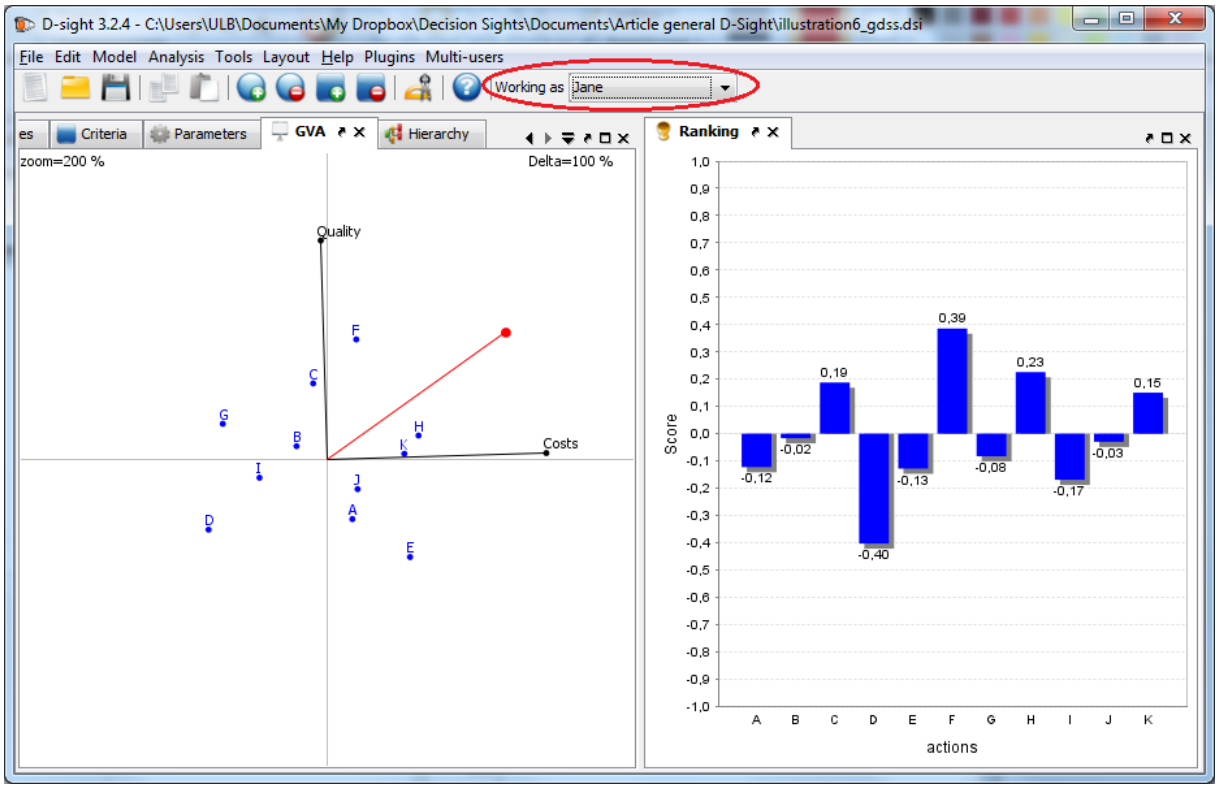


Figure 18 - Results for the user Jane

As we have now had a look at each stakeholder's results, we can now analyze the global results. A new dedicated window is open and is organized the same way than the main one. It is represented in Figure 19. Its look and feel can be set differently to be easily recognized by the user.

In the evaluation table, the projects are still represented in the rows but the columns do not represent the criteria anymore. Indeed, each column represents a decision maker. That means that this table contains the scores of the projects for the different stakeholders.

As each stakeholder is weighted, that allows computing a global aggregated score for all the projects. We can see in Figure 19 that the project F is the most preferred project while taking into account each stakeholder's point of view. Furthermore, a GAIA plane can also be represented with the aggregated users. In this representation, the points are used for the projects but, as expected, the axes now represent the actors. The decision axis (the axis without label), is computed with respect to the weights given to the decision makers in order to represent the direction of the most globally preferred project.

If we take a closer look at the GAIA plane, we can directly see that there is a group of alternatives, situated in the left part that will never be chosen if both decision makers have to agree on the solution.

In the right part of the plane, two different subsets of projects are observable (represented in more details in Figure 20 with the projections):

- The **conflicting** projects (K, C, H): those solutions are well scored but are not preferred the same way by each stakeholders. For instance, project K is very good according to John but is

only fourth according to Jane. In general, conflicting alternatives have crossing lines when projecting on the decision makers' axes.

- The best **consensus** projects (project F): those solutions are preferred by all the decision makers. They have no crossing lines when projecting on the decision makers' axis.

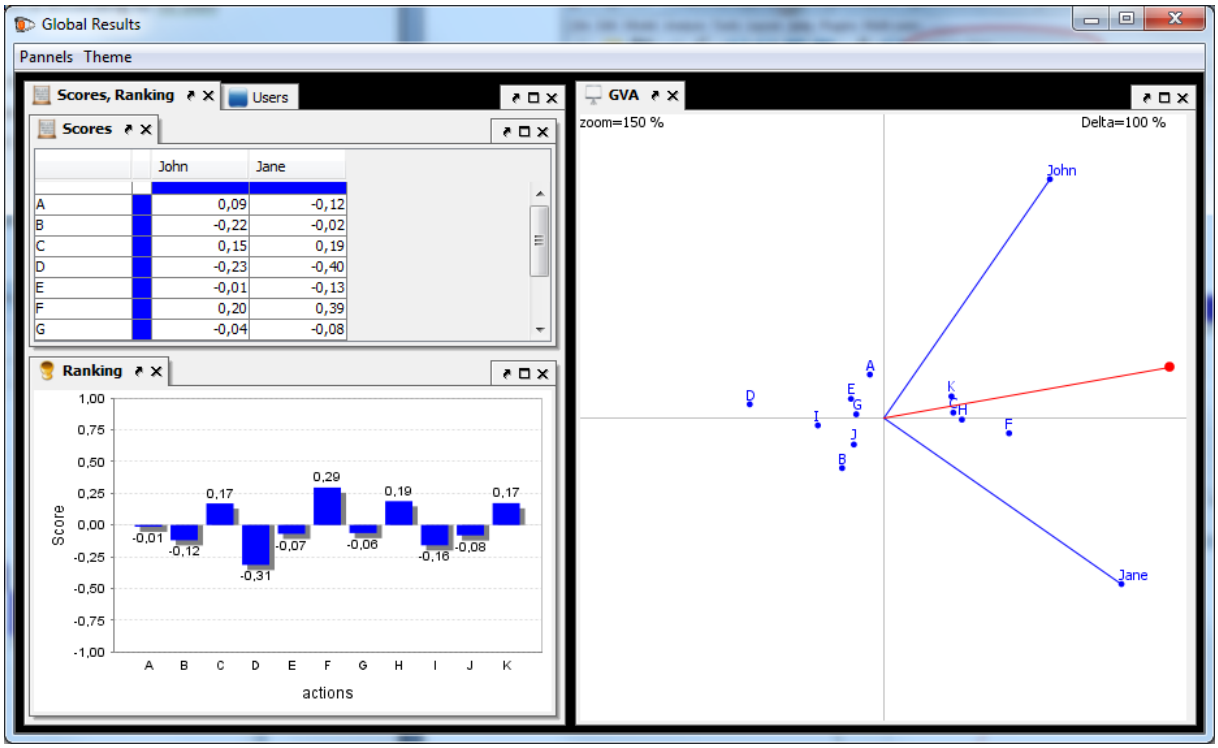


Figure 19 - Global aggregated results

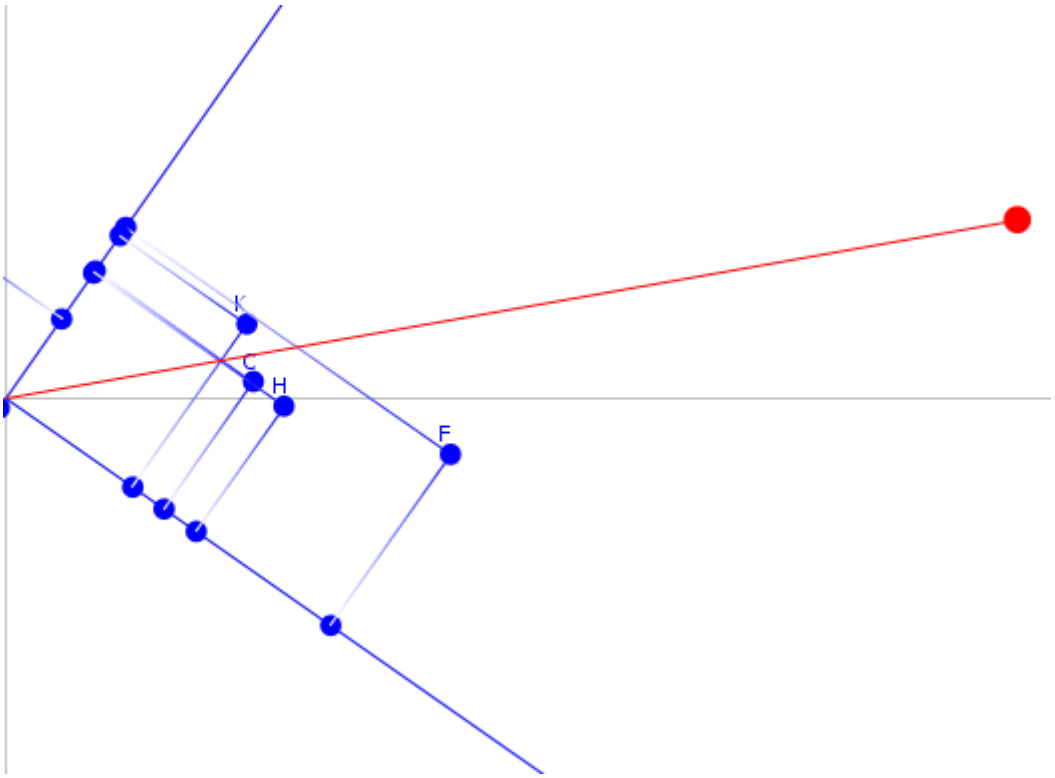


Figure 20 - Zoom in GAIA

The multi-actors plugin will be soon extended to an online group decision support system. This will allow the stakeholders to work remotely as well as having different roles (e.g. project manager, expert …) in the decision process.

V. Conclusion

In this paper, we presented D-Sight; the third generation of PROMETHEE & GAIA based software. This application includes classic functionalities (PROMETHEE I and II rankings, Gaia plane, Walking weights, Group decision support system …) as well as new extensions (A multi-level hierarchy of criteria, a new PROMETHEE I representation, explicit projections in GAIA, GAIA stick, GAIA criterion, Map visualization, How to improve …) in an up-to-date interface. D-Sight integrates tools from PROMCALC (such as the Decision Maker's Brain or the PROMETHEE V method) which were not present in Decision Lab 2000. The software can easily be interfaced with classic applications, automatically generate reports and presents a plugin system allowing its customization with dedicated tools. D-Sight is already used by several universities, research centers and companies. Their regular feedback leads to a continuous evolution of the software.

VI. Bibliography

1. M. Behzadian, R.B. Kazemzadh, A. Albadvi D. and M. Aghdasi, « PROMETHEE: A comprehensive literature review on methodologies and applications » European Journal of Operational Research, 200(1): 198-215, 2010.
2. J.P. Brans, « L'ingénierie de la décision; Elaboration d'instruments d'aide à la décision. La méthode PROMETHEE ». In R. Nadeau and M. Landry, editors, L'aide à la décision: Nature, Instruments et Perspectives d'Avenir, pages 183–213, Québec, Canada, 1982. Presses de l'Université Laval.
3. J.P. Brans and P. Vincke, « A preference ranking organisation method: The PROMETHEE method for MCDM» Management Science, 31(6):647–656, 1985.
4. J.P. Brans and B. Mareschal, « The Promcalc and Gaia decision-support system for multicriteria decision aid » Decision Support Systems, 12(4-5):297–310, 1994.
5. J.P. Brans and B. Mareschal «Promethee Methods» in Multiple Criteria Decision Analysis: State of the Art", edited by J. Figueira, S. Greco and M. Ehrgott, Springer, 2005.
6. http://www.d-sight.com/academic
7. http://www.d-sight.com/case-studies
8. Q. Hayez, B. Mareschal, Y. De Smet « New GAIA Visualization Methods », in the Proceedings of the Information Visualization 2009, Barcelona, 247-251, 2009
9. C. Macharis, J. P. Brans and B. Mareschal, « The GDSS PROMETHEE procedure (a PROMETHEE-GAIA based procedure for group decision support » Journal of Decision Systems, 7:283–307, 1998.
10. Macharis, C., Bernardini, A., De Smet, Y. and Hayez, Q. « PROMETHEE in a multi actors setting: the use of the Multi actor Multi Criteria Analysis (MAMCA) methodology with D-SIGHT », in the proceedings of the OR52 conference, London, 2010.
11. B. Mareschal and J.P. Brans. « Geometrical representations for MCDA, the GAIA module. » European Journal of Operational Research, 34:69–77, 1988.
12. B. Mareschal. « Weight stability intervals in multicriteria decision aid » European Journal of Operational Research, 33(1):54–64, 1988.
13. Mareschal, B. and De Smet, Y. « Visual Promethee: Developments of the PROMTHEE & GAIA multicriteria decision aid methods», in the Proceedings of the IEEE 2009 International Conference on Industrial Engineering and Engineering Management, Hong Kong, 1646-1649, 2009.

14. P. Vincke. Multicriteria Decision Aid. John Wiley & Sons, New York, 1989.