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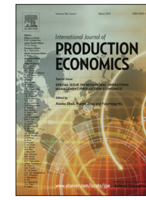


# A fast multicriteria decision-making tool for industrial scheduling problems

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ABSTRACT

In today's challenging industrial contexts, decision makers need versatile tools to quickly acquire, synthesize, simulate and optimize several solutions that can be compared from multiple points of view and according to various performance criteria. In the context of limited-time multicriteria decision-making problems, we have developed a planning and scheduling framework based on several hybrid tools composed of mathematical models, dedicated heuristics, stochastic local search meta-heuristics and simulation models. This paper focuses on improving the efficiency and accuracy of one of the components of the framework by quickly and accurately computing eigenelements. The computational approach overcomes both eigenvalue and eigenvector ill-conditioning through an inexpensive robust iterative refinement scheme based on a Newton–Kantorovich method and a QR algorithm with an improved stopping test. A dynamic version of the graphical synthetic views for decision makers is also presented, where it is possible to follow the evolutions of several iteratively improved solutions by any meta-heuristic. The validation of the component is done on an actual, highly constrained scheduling problem. The schedules provided by the plant information system or by the framework are ranked and visualized on the basis of five criteria. The available time for the decision-making process, list of orders and configurations of the machines determine the decision-making process, which consists either in rapidly computing several schedules or in comparing iteratively optimized schedules to evaluate the gains/losses of the criteria when switching from one schedule to another. Our tool can be used whenever ranking several solutions with multiple criteria is required.



## 1. Introduction

When considering actual industrial problems, generating or acquiring data is one side of the problem. The other side is the synthesis of the large amount of generated data. The information addressed to the decision makers must be as synthetic, complete, coherent and accurate as possible. And, last but not least, the displayed results have to be computed accurately in a short time so as to be compatible with the limited-time decision-making context. Since, in a wide variety of applications, the decision makers hesitate among solutions evaluated on several criteria, they need a multicriteria decision-making tool, see Araz and Ozkarahan (2007) and Józefowska and Zimniak (2008).

Our goal is to provide decision makers with a highly adaptable tool which must be able to quickly synthesize the performance measures of several solutions to be compared in a limited time. In order to fulfill our objective we develop a tool which allows us to obtain the best satisfactory solutions according to the decision makers' preferences, to incorporate gradation, tinge and fuzziness in the judgment of decision makers while comparing several solutions, to rank these solutions on the basis of several criteria and to present the solutions thanks to a graphical synthetic view. This last point requires to compute eigenelements quickly and accurately. Our hybrid method[1] optimizes a real-life scheduling problem.

The remainder of this paper is organized as follows. Section 2 presents our framework. Section 3 describes the multicriteria method. Section 4 is dedicated to the graphical view. Section 5

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[1] According to Talbi (2002) a hybrid model is the assembly of different units, at different levels of combinations. A hybrid model is instantiated to obtain a hybrid method grounded on these models.

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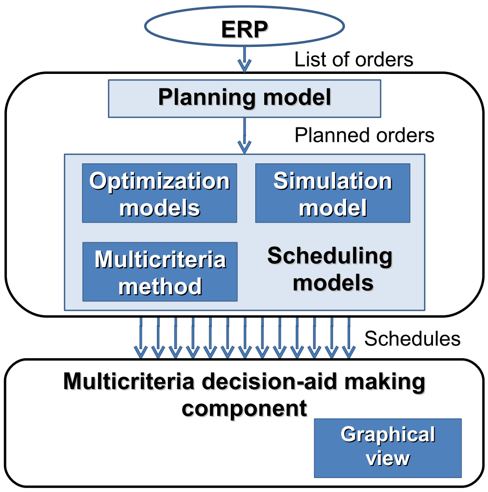


**Fig. 1.** The PlanOrdo framework.

details the computation of eigenelements. The industrial problem is explained in Section 6. The description of the Graphical User Interface and some results of our hybrid method are in Section 7. This paper terminates with our conclusions and perspectives.

## 2. Description of our framework

In the context of limited-time multicriteria decision-making problems, we have developed a framework named *PlanOrdo*, see Fig. 1. The aim of *PlanOrdo* is to provide the decision makers with a framework for optimization and simulation of planning and scheduling problems (Artiba et al., 2011). This framework provides an environment for comparing the performance of different *production-schedules* (what we call *solutions*) to be applied to a plant. The functioning of *PlanOrdo* is the following: a list of orders is retrieved from the Enterprise Resource Planning system (ERP) of the target plant and sent to the finite capacity planning model of *PlanOrdo*. If the selected list of orders is such that all orders can be processed with no overload, then several scheduling strategies are evaluated and compared. Each scheduling strategy is based on a hybrid model composed of a dedicated heuristic (a dispatching rule in charge of generating an initial solution), an optimization model (based on a general stochastic local search method, as defined by Hoos and Stützle, 2005), a simulation model and a multicriteria method, see Duvivier et al. (2007) and Roux et al. (2008) for more explanations.

According to the decision makers' preferences, the solutions are ranked in the multicriteria decision-making component on the basis of several criteria computed by the simulation model. However, when comparing two solutions, a decision maker often accepts a solution which is *worse* than some others from the point of view of the *main* criterion if this solution leads to significant improvements on some other criteria. The choice of the *best* solution taking into account several criteria is not evident. Consequently, we have completed our framework by adding in the multicriteria decision-making component a tool to visualize graphically and synthetically the solutions. It provides decision makers with complementary assistance in order to choose “the” solution to be applied to the actual plant, or to revise the selected list of orders to produce if no satisfactory solution can be found.

## 3. Multicriteria decision-making component

One important issue when comparing several solutions to be applied to the plant is to summarize the huge amount of resulting data so as to provide a synthetic and accurate view of the process to the decision makers. That is one of the reasons why we choose to embed the Promethee II multicriteria method (*Preference Ranking Organization METHod for Enrichment Evaluations*) and to develop a visualization tool based on GAIA (*Geometrical Analysis for Interactive Assistance*). For more details, see Brans et al. (1986) and Brans and Mareschal (1994). This graphical representation requires to compute eigenelements on the *results* given by Promethee II as explained in Sections 4 and 5.

One aim of this research is to combine efficiently the above-mentioned components, including the Promethee II multicriteria method and our visualization tool, named “*DynScoreCards*”, in one hybrid multicriteria optimization method. Promethee II provides a complete ranking based on pairwise comparisons of solutions. The objective associated with each criterion is either to minimize or to maximize the value of this criterion among the solutions. In the following paragraphs, $A_1, A_2, \ldots, A_n$ denote $n$ potential alternatives, i.e. solutions, and $C_1, C_2, \ldots, C_m$ are $m$ evaluation criteria. Each evaluation $C_j(A_i)$ must be a real number. Promethee II builds an outranking relation using a preference function, which represents the decision makers' preference $P_j(A_i, A_k)$ for a solution $A_i$ with regard to a solution $A_k$ on the $j$th criterion. This preference function translates the difference between the evaluations (i.e. performances) obtained by the two alternatives $A_i$ and $A_k$ in terms of the particular criterion $C_j$ into a preference degree ranging from 0 to 1.

The decision makers have to give additional information on each criterion $C_j$: the preference function $P_j$ and the weight $\omega_j$. According to the chosen preference function, uncertainty concerning the values of the criterion can be introduced via indifference ($q$) and/or preference ($p$ or $\sigma$) thresholds. The next step of Promethee II consists in computing the outranking index, which represents the strength of the decision makers' preference for solution $A_i$ over solution $A_k$. It is computed for each pair of solutions $A_i$ and $A_k$ as the weighted average of preferences computed for each criterion:

$$\pi(A_i, A_k) = \frac{\sum_{j=1}^{m} \omega_j \cdot P_j(A_i, A_k)}{\sum_{j=1}^{m} \omega_j}.$$

This index measures the preference for $A_i$ on $A_k$ over all the criteria. On the basis of these indexes, Promethee II computes positive and negative preference flows for each solution. Based on the difference between these flows, the net flow $\phi$ is obtained and used to rank the solutions:

$$\left.\begin{aligned} \phi^+(A_i) &= \frac{1}{n-1}\sum_{k=1}^{n} \pi(A_i, A_k) \\ \phi^-(A_i) &= \frac{1}{n-1}\sum_{k=1}^{n} \pi(A_k, A_i) \end{aligned}\right\} \phi(A_i) = \phi^+(A_i) - \phi^-(A_i).$$

The positive preference flow expresses how much a solution is dominating the other solutions, and the negative preference flow how much it is dominated by the other solutions. Based on the net outranking flows, Promethee II provides a total order of the solutions (Brans et al., 1986). Therefore, the solution $A_i$ outranks the solution $A_k$ if, and only if, $\phi(A_i) > \phi(A_k)$, and solutions $A_i$ and $A_k$ are indifferent solutions if, and only if, $\phi(A_i) = \phi(A_k)$.

Undeniably the major drawback of Promethee II is the number of additional parameters to be tuned (weights, types of criteria, and thresholds). However, this drawback is largely compensated by the adaptability of the resulting tool, which is able to incorporate gradation, tinge and fuzziness in the judgment of decision makers while comparing several solutions. Promethee II allows the discounting of one criterion while improving another criterion. This perfectly matches a situation where a decision maker accepts a solution which is worse than another on one criterion if this solution leads to significant improvements on some (or all) of the other criteria. Moreover, a sensitivity analysis shows that, in most