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Selection of new production facilities with the Group Analytic Hierarchy Process Ordering method

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ABSTRACT

This paper presents the Group Analytic Hierarchy Process Ordering (GAHPO) method: a new multi-criteria decision aid (MCDA) method for ordering alternatives in a group decision. The backbone of the method is the Analytic Hierarchy Process (AHP) which is separated into two hierarchies for a cost and a benefit analysis. From these two analyses, a partial ordinal ranking can be deduced, where three relations between alternatives exist: the preference, indifference, and incomparability. A complete cardinal ranking can also be deduced by dividing the score of the benefit analysis by the score of the cost analysis. Another particularity of GAHPO is the incorporation of 'fairness' when assigning weights to the decision makers. GAHPO has been developed to solve a real case: a selection of new production facilities with multiple stakeholders. By applying this method, we found four main advantages: significant reduction of time and effort in the decision process; easiness for the decision makers to arrive at a consensus; enhancement of the decision quality and documentation with justification of the decision made. In using the proposed method both efficiency and equity are achieved in the decision making process.

1. Introduction

Strategic decisions are fundamental to any company. They are usually not determined by a single decision-maker but by a group of decision-makers, who may have different objectives. In this case, two distinct methodologies are commonly used (Srdjevic, 2007): multi-criteria decision-making methods or voting system. The voting system has surely high democratic properties and bypasses the data requirements of multi-criteria approaches (Hurley & Lior, 2002) but moves stakeholder into a polarisation of their opinion and no intensity of their preferences can be measured. It is a head-count of yes or no. Therefore, a minority with strong convictions will unconditionally be beaten from a majority, whatever the strength of their opinion is. Furthermore, a voting system does not necessitate a modelling of the problem and therefore has difficulty to incorporate several criteria in the decision (Craven, 1992). Saaty and Shang (2007) recommend using AHP in order to resolve deficiencies of the conventional voting mechanism. AHP is a multi-criteria method developed by Saaty (1977, 1980) and applied in several area: banks (Seçme, Bayrakdaroglu, & Kahraman, 2009), manufacturing systems (Iç & Yurdakul, 2009; Li & Huang, 2009; Yang, Chuang, & Huang, 2009), operators evaluation (Şen & ÇInar, 2010), drugs selection (Vidal, Sahin, Martelli, Berhoune, & Bonan, 2010), site selection (Önüt, Efendigil, & Soner Kara, 2010), software evaluation (Cebeci, 2009; Chang, Wu, & Lin, 2009), evaluation of website performance (Liu & Chen, 2009), strategy selection (Chen & Wang, 2010; Li & Li, 2009; Limam Mansar, Reijers, & Ounnar, 2009; Wu, Lin, & Lin, 2009), supplier selection (Chamodrakas, Batis, & Martakos, 2010; Wang, Che, & Wu, 2010; Wang & Yang, 2009), selection of recycling technology (Hsu, Lee, & Kreng, 2010), firms competence evaluation (Amiri, Zandieh, Soltani, & Vahdani, 2009), weapon selection (Dagdeviren, Yavuz, & KilInç, 2009), underground mining method selection (Naghadehi, Mikaeil, & Ataei, 2009), software design (Hsu, Kao, & Wu, 2009), organisational performance evaluation (Tseng & Lee, 2009), staff recruitment (Celik, Kandakoglu, & Er, 2009; Khosla, Goonesekera, & Chu, 2009), construction method selection (Pan, 2009), warehouse selection (Ho & Emrouznejad, 2009), technology evaluation (Lai & Tsai, 2009), route planning (Niaraki & Kim, 2009) and many others. This paper presents the Group Analytic Hierarchy Process Ordering (GAHPO), which improves the AHP on several points. We separate the cost and benefit criteria of the AHP, which simplify the appraisal and provide a more accurate result, as will be shown later. Results are then partially aggregated for an ordinal partial ranking or fully aggregated for a cardinal complete ranking. The new GAHPO method is also adapted for group decisions. The task to assign weights (importance) to the different decision-makers of the group is often a difficult one. We propose a new simple and fair method, where the weights of the members are judged by the other members of the group.

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The paper starts with a literature review on the Analytic Hierarchy Process, followed by the description of the new proposed method and then finalised by an application of production facilities selection.

2. Analytic Hierarchy Process

AHP decomposes the problem into small parts in order to facilitate the decision-maker in the appraisal task. First, a hierarchy structuring the problem is constructed (Fig. 1). The top of the hierarchy represents the goal. Below we have the criteria, sub-criteria and alternatives. The appraisal can be constructed top–down or bottom–up (Fig. 2) but always using pairwise comparisons. It allows the user to concentrate only on the question ‘‘How much *A* is better than *B*?’’ and to ignore temporary the other criteria and alternatives. The comparisons are entered into a matrix. If a matrix is sufficiently consistent, priorities can be calculated with the formula:

$$Aw = \lambda_{max} w \tag{1}$$

where *A*, comparison matrix; λ_{max}, principal eigenvalue; *w*, vector of the priorities.

The comparison matrix contains redundant information. This redundancy serves the purpose of refining the final result as it makes the approach less dependent on one single judgement. The AHP model provides a feedback to the decision maker on the consistency of the entered judgements by a measure called consistency ratio (CR):

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{2}$$

$$\text{and} \quad \mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

where CI, consistency index; *n*, dimension of the comparison matrix; λ_{max}, principal eigenvalue; RI, ratio index.

The ratio index (RI) is the average of the consistency index of 500 randomly generated matrices. If the consistency ratio is higher than 10%, it is recommended to revise the comparisons in order to reduce the inconsistency. Once all local priorities are available, they are aggregated with a weighted sum in order to obtain the global priorities of the alternatives.

3. Analytic hierarchy process ordering

Later, it was proposed (Azis, 1990; Clayton, Wright, & Sarver, 2001; Wedley, Choo, & Schoner, 2001) to decompose the model into further subproblems, in separating criteria with opposite direction in different hierarchies: benefits versus costs. The reason of this additional decomposition is that criteria on the same direction are much easier to compare than two in opposite directions like a criterion to be minimised and another to be maximised. In this paper, we introduce the concepts of partial ordinal ranking

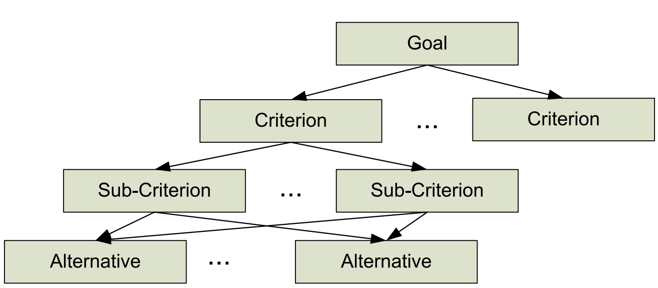

Fig. 1. Hierarchy used in the AHP.

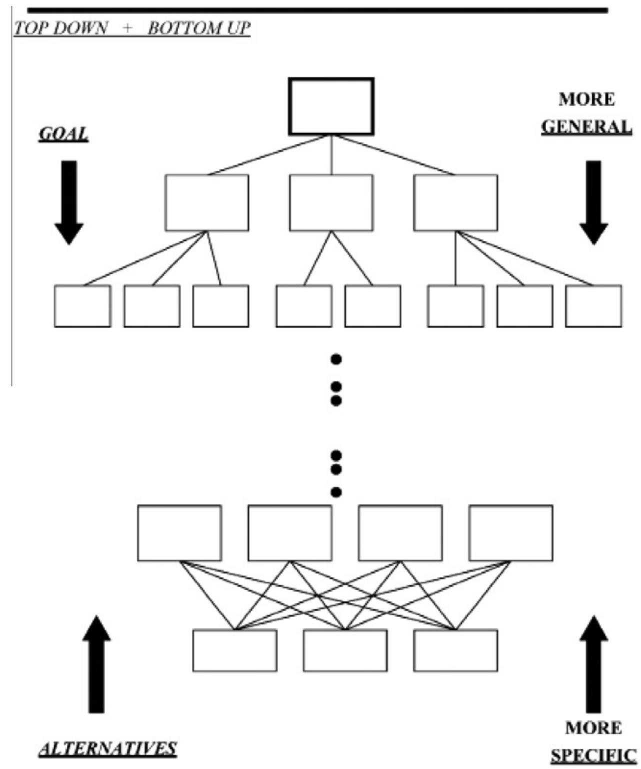

Fig. 2. Top–down or bottom–up appraisal (Chan & Chan, 2004).

(cost and benefit ranking are not aggregated) and complete cardinal ranking (cost and benefit ranking are aggregated).

In some problems, an order of alternatives is sufficient to take a decision. A partial ordinal ranking can be derived from the cost and benefit analysis, where:

1. *Alternative A* ***is better than*** *Alternative B* if Alternative A is ranked better than Alternative B in the cost and benefit analysis (Fig. 3).
2. *Alternative A is* ***indifferent*** *to Alternative B* if Alternative A has the same score than Alternative B in the cost and benefit analysis (Fig. 4).
3. *Alternative A is* ***incomparable*** *to Alternative B* if Alternative A is better in one analysis and worst in the other analysis (Fig. 5).

Incomparability does not exist in the standard AHP. This status is important as it reveals that we cannot decide which of two alternatives is the dominant one: an alternative is better on some aspects but worst on others. In order to decide, which alternative is better, further discussion between the decision-makers moderated by the analyst is needed. This further debate may require additional information. However if a debate cannot be hold, for example because the decision-makers are unavailable, the cost and benefit analysis can be merged in one ranking. First, the

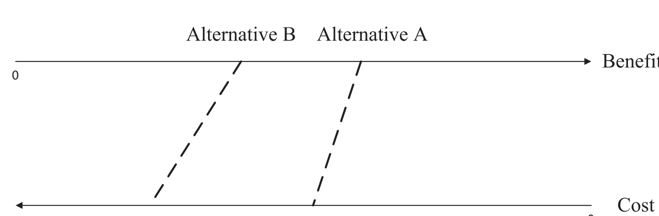

Fig. 3. Graphical representation of the preference relation.