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A Web-based decision support system with ELECTRE III for a personalised ranking of British universities

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ABSTRACT

Reliance upon multi-criteria decision methods, like ELECTRE III, has increased many folds in the past few years. However, ELECTRE III has not yet been applied in ranking universities. League tables are important because they may have an impact on the number and quality of the students. The tables serve an indication of prestige. This paper describes a three-tier Web-system, which produces a customised ranking of British Universities with ELECTRE III reflecting personal preferences, where information is uncertain and vague. Using this case study, the benefits of ELECTRE III in the ranking process are illustrated.

1. Introduction

Professor William Cooper is particularly known through his work on DEA (Data Envelopment Analysis) [26]. His paper [17] has been elected as one of the most influential papers published in the European Journal of Operational Research. Professor Cooper has applied DEA widely to the performance analysis in the public and private sectors, especially in education. He was the first (founding) Dean at Carnegie Mellon University's School of Urban and Public Affairs (now the H.J. Heinz III School of Public Policy and Management, USA) and a founding member of the Graduate School of Industrial Administration at Carnegie Mellon. He always strives for the improvement of the quality in education as it can be seen in his papers [3,5,10,15,18,19].

The evaluation of education with ranking lists of universities has become, over the past few years, increasingly popular. Some examples in United Kingdom are the *Times Higher Education*, *The Complete University Guide*, *The Guardian University Guide* and the *Sunday Times University Guide* all of which produce leagues tables based on statistical data from the Higher Education Statistical Agency (HESA) and the National Student Survey (NSS). These rankings have a sizeable impact on universities as they may have some indication of prestige and a direct influence on the number and quality of applicants. However the ranking of universities does not use rigorous methodologies like ones used in Professor Cooper's work. The methodology used to rank universities is a simple weighted sum, which has several limitations. First, the weights are predetermined with very little, if any, justification of their value. Therefore, it is assumed that the criteria have the same importance (i.e. weight) for everybody. This is clearly not true as each person is different and has different preferences. Moreover, commercial league tables use a simple aggregation, which is compensatory and does not differentiate between universities having strengths in different areas.

This paper has been prepared to celebrate the 95th birthday of Professor Cooper and his motivation to evaluate education with new methods. We have thus developed a new interactive online way to rank universities with the multi-criteria decision method ELECTRE III [42] (http://www.pbs.port.ac.uk/IshizakaA/). As ELECTRE III may be complicated for new users, a simple and an advanced version has been developed. These two versions are user-friendly, free, Web accessible and have tailored functionalities, which is not the case for the old commercial off-the-shelf software supporting the ELECTRE III (http://www.lamsade.dauphine.fr/english/software.html). However, the commercial software was used to validate the results of our Web decision support tool.

Hereinafter, we will review methods used for rankings universities. In Section 3, the ELECTRE III algorithm is described. Section 4 describes the design and implementation of the decision support tool, and Section 5 evaluates the implemented system. Finally, the concluding section summarises the main points arising from this project.

2. Rankings systems

2.1. Commercial rankings

Several commercial universities ranking schemes are annually published. Alongside, criticisms of these rankings have also increased [13,34,37,51,53,55]. These leagues tables are based on a weighted sum of performances, which has some methodological problems. As each criterion is measured in a different unit, they need to be transformed

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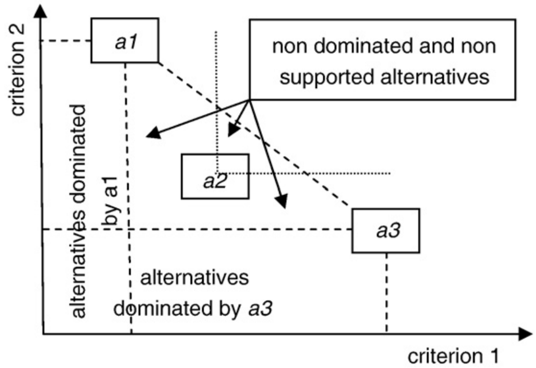

Fig. 1. Non-dominance in interpretation of DEA radial models. Note: Alternatives *a1* and *a3* are supported optimal solutions; *a2* is an optimal non supported solution, the DEA does not consider *a2* as an efficient solution because it is not on the efficient frontier. This type of problem occurs only in DEA radial models. Non-radial DEA models do not have such a problem. Therefore, *a1* becomes efficient in the non-radial DEA models.

to commensurate units in order to be summed together. The problem is that numerous ways of standardising exist (commercial rankings generally uses *z*-transformation) and they often lead to a different final ranking. An example can be found in [39], where the authors emphases that "prior normalization of data is not a neutral operation, and the final result of aggregation may well depend on the normalization method used". The same normalisation problem is also observed in the Analytic Hierarchy Process (AHP), where different normalisations may lead to a rank reversal [7,30]. Moreover, AHP is difficult to use with a large volume of data, due to the high number of pairwise comparisons required [29].

2.2. DEA

Data Envelopment Analysis (DEA) is an often used ranking technique [2,33,44,46,47], which does not require any normalisation. The global score of each Decision Making Unit (DMU) is defined as the ratio of the sum of its weighted output levels to the sum of its weighted input levels. The analogy with multi-criteria methods is striking if we replace the name "DMU" with "alternatives", "outputs" with "criteria to be maximised" and "inputs" with "criteria to be minimised". The particularity of this method is that weights are not allocated by users or experts; moreover it does not employ a common set of weights for all alternatives. Instead, for each alternative a different set of weights is calculated with a linear optimisation procedure. The aim of the optimisation is to select weights in order to highlight their particular strength. Some constraints are added in order to ensure that when these weights are applied to all other candidates, none of the scores exceed 100%, the perfect efficiency. DEA has been widely used to rank universities or schools [1,4–6,9–11,14,16,18,23,25,31,32] and in many other sectors as compiled in [24]. However, there are some limitations to DEA, which are highlighted below:

- "DEA is not designed to select a single winner" [21,52]. DEA identifies all alternatives that are located on the efficient frontier as the best alternatives without distinction. When the list of alternatives is large, the number of efficient alternatives may also be large. Further analysis must then be applied to select the best alternative. We know that multiplier restriction method (e.g., cone ratio) has been developed to reduce the number of efficient DMUs. It is possible to identify a single best alternative, using DEA [26]. See also [46,47].
- "The ranking of inefficient alternatives depends upon which DEA model is used for performance evaluation" [12,45]. See [48].
- "A conventional use of DEA does not consider the weakness of some candidates"[45,52]. Any alternative which has the highest score on one criterion is often regarded as efficient, irrespectively of how low it scores on all other criteria. This issue is due to the flexibility in allocating weights in its conventional use, which allows DEA to focus on a few criteria, not putting importance on the others. Note that a new type of DEA [46,47] does not have such a problem. See also [48].
- "DEA becomes less discriminating as more information is provided" [52]. This problem derives from the critic above. The likelihood that one alternative scores well on one criterion increases with the number of criteria. Thus, unlikely other decision supports methods, the more criteria you have, the less discriminating the method becomes.
- Alternatives that are not on the efficient frontier are not considered as candidates for the final selection [12]. The conventional use of DEA does not recognise optimal non supported alternatives as efficient. See Fig. 1.
- All alternatives on the efficient frontier serve as a ranking basis for all other alternatives even if some non-efficient alternatives may be more attractive than efficient alternatives [12]. See Fig. 2.

There is an extensive literature which describes techniques to improve the DEA. They generally require more information from the user. The most used techniques use value judgements to constrain weight (multiplier) flexibility [54]. However the exercise of bounding the weights is not trivial as restrictions are subjective and depends on the measurement units of the different inputs and outputs [45]. In order to help the user, visual methods have been developed [8,23]. These methods are time-consuming and difficult to use with a large amount of inputs and outputs. Of course, this study is fully aware of the recent study [48] that restricts weight (multiplier) by strong complementary slackness condition. Hence, the approach does need any subjective information for weight restriction.

2.3. Ranking with pseudo-criteria

The multi-criteria ranking methods described above, alongside the shortcomings described, are not adapted for uncertain, indeterminate and imprecise data, as explained below:

- Imprecise criteria, because of the difficulty of determining them: students evaluate some criteria (e.g. "*Student satisfaction*", "*Graduate prospects*") for the university, where they are studying but judgements are made without a common reference with the other universities [13].
- Indeterminate criteria, because the method for evaluating the criteria is selected relatively arbitrarily between several possible definitions. For example, does the "*Staff/student ratio*" incorporate part-time

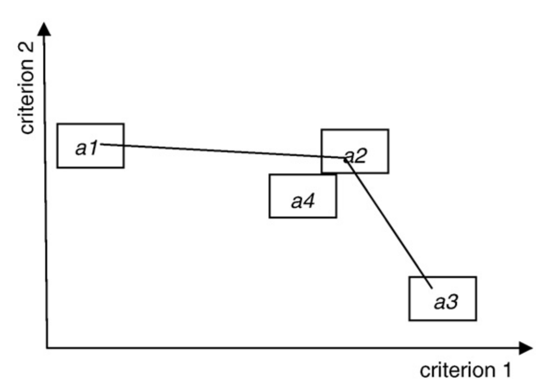

Fig. 2. Importance among alternatives in DEA. Note: Alternatives *a1*, *a2* and *a3* are on the efficient frontier serve a ranking basis for *a4* in the DEA radial model with the assumption of convexity on efficiency frontier. The assumption excludes the alternative *a4*. The alternative is on a higher linear or convex indifference utility curve. The type of problem does not occur in DEA non-radial models. It is true that DEA needs to incorporate information for consensus building among decision makers.