Towards sustainable cloud services: MCDA approach

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Abstract

Cloud technologies are important in the growing need for advanced information systems, enabling location-independent delivery of products or services. However, it is essential to consider their environmental sustainability amidst their expanding capabilities. In this work, we propose using the ARAS-COMET approach, a hybrid method for assessing the considered alternatives. Furthermore, to verify the robustness of the results, a simple sensitivity analysis is applied to examine the impact of different weight distributions on the ranking. The presented approach showed that it has the right to be used in a real-world scenario to make decisions regarding the sustainability of cloud solutions.

Keywords: Green Clouds, Sustainability, MCDA, Servers assessment, Sensitivity Analysis

1. Introduction

The number of information systems used by everyday users involves a tremendous amount of energy used to power them. Moreover, a significant amount of heat is produced during this process [1]. Together with additional parameters, they have a disruptive impact on the environment, making it necessary to identify which solutions are preferable to others [2]. The term green systems capture the essence of strategies that optimally balance efficiency and energy management to provide the best possible solutions while meeting specific sustainability requirements [3]. Therefore, it is crucial to promote the most preferred solutions and identify responsible information systems.

Among the more frequently used solutions offered by information systems is cloud computing [4]. They enable the use of physically inaccessible resources, thus providing the possibility to use dedicated high-power computing machines. The number of such solutions is constantly growing, and the offers of each variant differ [5]. Therefore, it is worth making a comprehensive analysis of cloud computing providers in terms of their mode of operation and quality of energy management. One of the possible way to analyze the quality of available decision variants is to use Multi-Criteria Decision Analysis (MCDA) methods [6].

In this paper, we conduct the evaluation of the computing clouds using the ARAS-COMET approach to provide the most rational choice regarding sustainable development goals. The Additive Ratio ASsessment (ARAS) method was used for establishing the expert model. Then, based on that, the Characteristic Objects Method (COMET) was applied to assess the Characteristic Objects (COs) and to determine the rankings of considered alternatives. To provide a comprehensive view of the obtained results, a sensitivity analysis was performed. Different scenarios of criteria weights were used as the input parameters to verify their impact on rankings changes. The study aims to identify optimal solutions by evaluating the available cloud computing options. It is a fundamental element in providing the most efficient solutions while considering sustainability assumptions.

2. Related works

Due to technological development and the increasing demand for computing machines, cloud computing solutions are increasingly becoming popular solutions to meet end-user requirements. The significance of this problem is such that a significant amount of research work has been devoted to this direction. To choose the most appropriate selection options, various techniques are used to determine the rationality of individual decision options. To present the research papers related to the area of cloud services assessment using the MCDA methods, Table 1 shows selected works concerning this field.

Table 1. Review of related works regarding the cloud services assessment.

MCDA Methods	Alternatives	Criteria	Sensitivity analysis	Reference
ANP, VIKOR	3	20	For benefit criteria	[3]
AHP, Grey-TOPSIS	7	19	Weights scenarios	[4]
FL-BWM	7	7	Weights scenarios	[7]
AHP	3	5	Users preferences	[5]
E-FPROMETHEE	6	10	Weights scenarios	[8]
AHP, TOPSIS	7	5	Changes in attributes	[2]
PFS-MARCOS	12	10	Comparison of methods	[9]
Z-number BWM	5	5	Weights scenarios	[10]
WNN-EDAS	15	9	Weights scenarios	[11]

3. Practical problem

In our study, we used the data obtained in the research by Chonglin Gu [1]. The authors examined the impact of using a specific energy source on the cost and carbon emissions when using specific server configurations to host cloud services. Furthermore, they described two approaches, where in the first one they tried to optimize for the cost of the server room, while in the second one they tried to optimize for carbon emissions. Because of today's approach to minimizing carbon emissions, we focused on this particular approach in our study. For this, we aggregated the data to obtain a decision matrix to decide on the best possible server configuration. Accordingly, seven criteria were considered such as: C_1 - number of servers [Unit]; C_2 - number of CPU cores [Unit]; C_3 - RAM capacity [Gb]; C_4 - used power when idle [W]; C_5 - peak power used [W]; C_6 - cost [$]; C_7 - carbon emission [Ton].

Table 2. Decision matrix for the cloud solutions assessment problem.

$\mathbf{A_i}$	$\mathbf{C_1}$	$\mathbf{C_2}$	$\mathbf{C_3}$	$\mathbf{C_4}$	$\mathbf{C_5}$	$\mathbf{C_6}$	$\mathbf{C_7}$
$\mathbf{A_1}$	3300	8	128	54	90	1736.16	10.57
$\mathbf{A_2}$	2800	16	144	84	140	1841.61	11.38
$\mathbf{A_3}$	3200	8	128	65	100	1739.27	10.70
$\mathbf{A_4}$	2500	16	144	90	150	2068.41	15.02

These criteria describe the four alternatives that were used to create the decision matrix shown in Table 2. In the case of our study, we used an approach in which each criterion is equivalent and the ARAS method is used as an expert evaluating Characteristic Objects in the COMET method in order to obtain the most objective result. To this end, based on the decision matrix and criteria weights presented in Table 2, the assessment of the considered decision variants is performed.

4. Results

Minimum, maximum, and mean values from the decision matrix presented in the previous section were used to create Characteristic Objects. The creation of model identification was split into two steps. In the first step, the ARAS method was used to establish the expert model to evaluate the COs. It allowed for the creation of the Matrix of Expert Judgment (MEJ). In the second step, the created COMET multi-criteria model with the expert function determined by the ARAS method was used to evaluate a set of alternatives. The computed preference values were then used to determine the final positional ranking as follows: A_1 (0.8769) $\succ A_2$ (0.5914) $\succ A_3$ (0.6435) $\succ A_4$ (0.1441).

Alternative A_4 received a preference of 0.1441, which is significantly low regarding other decision variants, marking this alternative as a very poor choice. Then the preferences of alternatives A_3 and A_2 are very close, from which we can conclude that they are very similar according to their attractiveness combining the aspect of performance efficiency and sustainability. In the case of our problem, alternative A_1 turned out to be the most rational choice obtaining a preference score of 0.8769. Most importantly, this alternative is characterized by the lowest low carbon emission out of all considered decision variants. Moreover, its cost is the lowest as well as peak power.

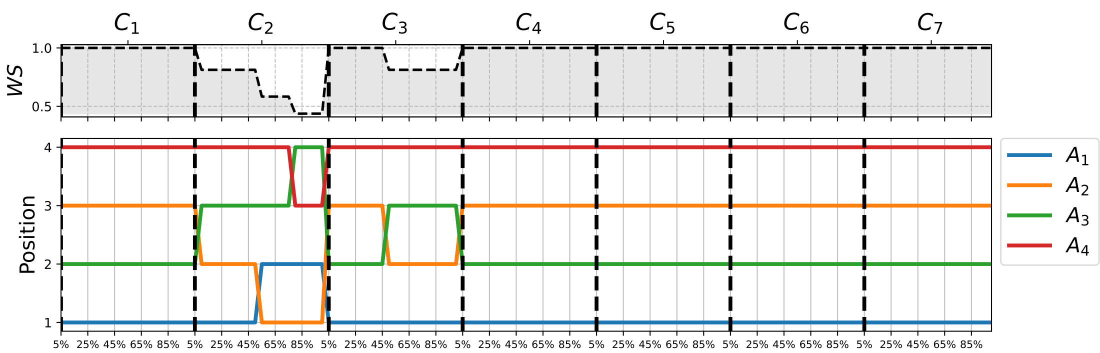

Fig. 1. Different criteria weights scenarios assessment flow for increasing weight of single criterion.

A sensitivity analysis was carried out based on the results obtained and the test scenarios prepared considering the different distribution of criteria weights. Figure 1 shows the evaluation flow of the alternatives as the individual criterion values change. To establish the consistency of these rankings, the rank similarity coefficient WS was used, and its values for individual changes are also shown in the visualization. Figure 1 shows the test case, which considered increasing the relevance of each criterion while decreasing the values of the other parameters. The significant impact of changes in the relevance of the number of CPU cores (C_2) and RAM capacity (C_3) is noticeable. The sensitivity analysis has shown that, for the other criteria, there are no changes from the reference ranking, which shows high resistance to modifications in the relevance of the input parameters. However, for criterion C_2, the first change in the ranking is already noticeable with a 10% increase in the significance of this criterion, which translates into a promotion of alternative A_2 to the second position in the ranking. On the other hand, with an increase of 55% of the initial value, alternative A_2 is ranked at position 1. Furthermore, the WS rank similarity coefficient differed from 1 to 0.5. The former indicates identical rankings, while the second shows significant discrepancies. The remaining changes in ranking are visible for changes reaching 85% and affect the change in ranking for alternatives A_3 and A_4.

5. Conclusions

Choosing the most rational decision variant can be complex, but multi-criteria decision analysis methods offer a partially objective way to select the preferred solution and reach consensus among experts. By combining sensitivity analysis techniques, these methods become effective tools for decision-making, providing comprehensive knowledge and awareness of potential ranking changes. When selecting server configurations for cloud data centers, it's crucial to consider both performance and environmental sustainability. A study found the most rational alternative with the lowest carbon emissions and good performance. However, sensitivity analysis revealed that different weight distributions can significantly impact rankings, emphasizing the need for further research.

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