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ORIGINAL ARTICLE

Improving the Cosine Consistency Index for the analytic hierarchy process for solving multi-criteria decision making problems

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Abstract Analytic Hierarchy Process (AHP) is one of the popular decision support systems for multi-criteria decision making problems. The AHP has different theories for prioritization, consistency evaluation and consistency improvement, a review of which is presented in this study before diving deep into the core contribution. Consistency evaluation is one of the key computations while using the AHP. This paper describes a method that can be employed to improve the consistency of the judgment matrix utilized by using the Cosine Consistency Index (CCI). The approach described uses a cosine maximization method to revise the entries in the judgment matrix on an iterative basis until the CCI is improved. The recommended method entails that it is possible to modify any judgment matrix to achieve CCI of desired level. Finally, the proposed algorithm is tested with numerical examples and improved CCI values are validated through paired

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sample *t*-test. The results of this study showed that the algorithm significantly improves CCI values with the inclusion of proposed approach.

1. Introduction

The Analytic Hierarchy Process (AHP) is one of the more popular decision-making techniques that are widely utilized to address Multi-Criteria Decision-Making (MCDM) problems. This method breaks down the problem into a hierarchy of sub-problems. Then from the elicited judgments from experts on the comparative performance or criticality of the sub-problems, priorities are computed. These priorities enable the decision making related to sorting, ranking or selecting the most suitable alternative in MCDM problems [1]. One of the biggest advantages of a AHP approach is that it helps decision makers to dissect a complex issue into its constituent parts in a manner that is more simplistic [2–6]. However, as a MCDM tool, it does have inherent disadvantages and the way in which criteria are aggregated is often criticized as potentially risking a loss of information, for example, in situations in which trade-offs between good and bad scores occur. Furthermore, AHP involves a large amount of pairwise comparisons [4], which could sometimes become tiring during judgment elicitation. Moreover, some of the studies adopt fuzzy set theory [7] and analytical network process [8,9] to offset the limitations in traditional AHP. Also various theories exist as to which decision making processes can effectively help a group of people to mutually agree on problems and opportunities. Techniques such as structuring, ordering, grading and evaluating have been comprehensively explored across a wide variety of studies relating to group decision making processes [10]. Previous research into AHP as a MCDM tool has indicated that it can be very effective when applied to a group decision problem because it allows the priorities of each participant to be accurately estimated [11–15] and subsequently improved through quantitative methods [16–18] before being aggregated into a set of preferences that reflect the requirements of each participant [19–24].

In order to ensure that AHP is implemented in an effective manner, it is important to ensure that the judgment matrix upon which it is based has a Cosine Consistency Index (CCI) that is approximately equal to 1. According to the literature [25], it is acceptable for a CCI to be above 0.90, but anything below 0.90 is unacceptable. However, while their insights are useful, they failed to extend how CCI can be improved. Constructing a judgment matrix that delivers an acceptable CCI is extremely challenging because it is very difficult to compare the various elements of the matrix, and the human capacity to do so is limited. Moreover, some recent studies on decision making in hierarchical collaborative production planning [26], knowledge discovery [27] and service-oriented enterprise architecture [28] have

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