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Comparison of Multiple Attributes Decision Making techniques in Reservoir Operation

Gaurav H. Rangari[1], Buddharatna J. Godboley[2]

[1]*Civil Engineering Department, J D College of Engineering and Management, (DBATU, Lonere),* Nagpur, India

[2]*Civil Engineering Department, St. John College of Engineeringand Management,* Palghar, *(Mumbai University) India*

Abstract

Development of any nation depends on its natural resources such as water which can fulfill all the required demand. Dam storages tend to decrease in its storage capacity due to fulfillment of the demand of the downstream area as there is no outsource of water during the summer season. To operate this low storage dam during the drought season brings the concept of optimization into the real-life situation. In optimization target release values need to be decided based on different methods. One such method multiple attributes decision making (MADM) having different techniques such as simple additive weighting (SAW), weighted product method (WPM), analytic hierarchy process (AHP), technique for order preference by similarity to ideal solution (TOPSIS) and preference ranking organization method for enrichment evaluations (PROMETHEE) are employed in this study. These are the decision-making methods which decide the best possible alternative among the various alternatives available for the attributes considered. Number of alternatives and attributes are the considered parameters involved in these MADM methods.

Keywords: *Optimal release; Target releases; Multiple attributes decision making (MADM), SAW, WPM, AHP, TOPSIS, PROMETHEE.*

I. INTRODUCTION

With the rising of new technologies, expansion of area to be developed requires bare lands which cause the process of deforestation which in turn affect the ecosystem in alarming way. This process relates to increase in global warming that hampers the glacier to melt and less rainfall in the specific area. Due to low rainfall there is a need to store water in the bulk amount which can be utilize during most drought season or summer season as there will be no rainfall

in summer season. The water stored in a dam/reservoir starts reside as there is a huge demand at the downstream area of the dam. In this situation it becomes challengeable task for the operator to decide in what quantity the water has to be released so as to achieve the criteria of equitable distribution of water among its users. The quantity of water which is required to be released from the reservoir is termed as optimal release values. This optimal release values are obtained using different optimization techniques like nonlinear programming (NLP), genetic algorithm (GA), particle swarm optimization (PSO), jaya algorithm (JA) etc. To obtain the optimal release values, target release values (or maximum demands) needs to be decided for the optimization techniques. Different procedures are available to obtain the target demand (or target release) values. Those procedures include the net irrigation a requirement (NIR) from which demand is calculated that can be treated as target release values. Another method is by taking the maximum value of LBC, RBC and UIR from the previous year data which can be added and treated as the target release values. Sometimes it becomes difficult to find the target release values because of unavailability of on-site data which is a must considered parameter for the analysis. To set the target release values, MADM techniques is employed which has been applied successfully in various research application. Optimal releases, as the main objective of any optimization technique in reservoir operation can also be obtained using MADM techniques. MADM methods have been applied in different engineering fields which show its wide applicability. The obtained best selective can have the single application only, as to select the summation value of RBC release, LBC release and UIR as the target release values or to use the best alternative parameter as a optimal release values for the specified month. This paper presents one such application of MADM techniques with different methods such as SAW, WPM, AHP, TOPSIS and PROMETHEE as the input process data and output obtained results in the reservoir operation.

Abrishamchi et al. (2005) first time applied the MCDM techniques in Iran for urban water management to select the best possible solution for distribution of both available and the transmitted water in the city. SAW method is applied in selecting the best criteria among the various water grid options (Ashbolt and Perera (2017). A comprehensive literature review on PROMETHEE is explained by Behzadian et al. (2010) for its application in various technical and non-technical fields. A combined approach of Non-Dominated Sorting Genetic Algorithm (NSGA-II) and TOPSIS is used to achieve the optimal pump scheduling in water systems (Carpitella et al. 2018). Disadvantage of the PROMETHEE method and use of PROMCALC- a user friendly software described by Keyser and Peeters (1996). A different perspective is involved in TOPSIS method with some modification and rank reversal approach (Garcia-Cascales and Lamata, 2012). The maintenance of water networks across the cities becomes a tough job due to insufficient budget which puts extra pressure on municipalities is solved by finding proper performance assessment (Ismaeel and Zayed, 2018). Different weights are applied using PROMETHEE in water distribution network considering 28 alternatives and 15 criteria (Marques et al., 2017). Comparison of data envelopment analysis (DEA), a MCDM method with the PROMETHEE to obtain the suitable irrigation planning for sri ram sagar project (Raju and Kumar, 2006). As mentioned earlier, MCDM methods are applicable to different scenarios, one such application in placing the employees to a suitable position in a company using the four (SAW, AHP, TOPSIS and PROMETHEE) MCDM methods (Widianta et al., 2018). Weighting criteria is an important factor in decision making process (Yilmaz and Harmacioglu, 2010). Reduction of water loss in water supply system is achieved using AHP method (Zyoud et al., 2016). Best alternatives are identified under uncertain future demand for the water distribution network (Cunha et al., 2019). Prioritization of alternatives for practical canal operation using entropy method for the weight's calculation (Shahdany and Roozbahani, 2015). Assessment of the flexible manufacturing systems by applying hybrid MADM method in industries (Rao, 2008). Combination of MADM with the fuzzy logic in industrial manufacturing environment (Rao and Patel, 2009).

II MULTIPLE ATTRIBUTES DECISION MAKING

In multiple criterion decision making (MCDM), decision makers are required to make the decisions in the presence of multiple conflicting criteria. MADM is one of the types of MCDM, which is opted to arrive at suitable selection or choice from a bunch of different alternatives. To arrive at a choice, various MADM methods are introduced such as simple additive weighing (SAW), weighted product method (WPM), analytic hierarchy process (AHP), technique for order preference by similarity to ideal solution (TOPSIS) and preference ranking organization method for enrichment evaluations (PROMETHEE). SAW method is the simplest among all of the MADM method (Fishburn, 1967). WPM is equivalent to SAW, but instead of addition of product of assigned weights and the measures of performance of alternatives, there is multiplication of these two variables (Miller and Starr, 1969). Saaty (1980) developed a most effective and widely used AHP method which is mostly preferred over the previous two methods of MADM. (Hwang and Yoon, 1981) developed TOPSIS method which is based on notion that the selected alternative should have the least Euclidean distance from the ideal solution and the farthest from the worst ideal solution.

Before proceeding with the process of any MADM methods, weights are the important factor which can be assumed or calculated. Weights are assigned in case of assumed weights to each attribute by keeping the sum of weights of individual attributes to 1. In the case of weights calculation, AHP method is used to find the acceptable weight which may be apply further to various MADM methods. Six attributes namely, gross storage, LBC release, RBC release, UIR, evaporation loss and inflows are decided with respect to the parameters related to dam/reservoir. After analyzing these six attributes, attributes are considered as beneficial and non-beneficial depending upon its positive or negative effects. So, a decision matrix is created in which each element represents a value in MCM with respect to particular year.

III METHODOLOGY

Step by step procedure for all the MADM techniques is solved for one month i.e. june month out of the 12 months, as the procedure is same for the rest of the months. First matrix of the given data is same for all the methods such as SAW, WPM, AHP, TOPSIS and PROMETHEE for the june month which is shown in the matrix M_{axa}.

WPM is solved with the same procedure as SAW has proceeded, to calculate the score values of the alternative's product are used instead of addition. Based on the decreasing order of the score values, ranking of different alternatives is obtained.

AHP is different in its procedure than SAW and WPM as it involves a greater number of steps to obtain the best ranked alternative. First, the pair-wise comparison matrix using a relative importance scale, where the judgments are given by applying the fundamental scale of the analytic hierarchy process (Saaty, 2000). In pair-wise comparison matrix, attributes are compared with attributes. 1 is assigned to those attributes which is compared to it, with this the main diagonal of the pair-wise comparison matrix will be 1. 3,5,7,9 are assigned based on the relative importance of the attributes representing 'moderate importance', 'preferred importance', 'most preferred importance', and 'absolute importance'. Whereas 2,4,6,8 represents the compromise between 1,3,5,7,9. Second, obtain the relative normalized weight for each attribute by taking the geometric mean of each row and divide the geometric mean by sum value of all geometric mean (GM) of each row. Third, consider pair-wise comparison matrix as A_1 matrix and weights as A_2 matrix. Product of A_1 and A_2becomes A_3 matrix, which is divided by $A_2$to term it as A_4. Maximum eigen value λ_{max} is mean value of matrix A_4. Consistency index CI= $(\lambda_{max}\text{-M})/(\text{M-1})$ represents the deviation from the consistency, where M is the number of attributes. Random index (RI) is obtained from table using the number of attributes. Finally, consistency ratio CR= CI/RI which is acceptable up to a value of 0.1, is calculated and the rest procedure is same as explained in SAW.

TOPSIS is applied by converting the decision matrix into the weighted normalized matrix which is obtained by multiplying each element with the corresponding attributes weights. The best solution is the most positive value and the anti-best value is the lowest positive value, which are obtained by finding these values for each criterion. The gap measures of each alternative to these best and anti-best solution is determined. Relative closeness based on this gap measures is obtained so that their descending order can be achieved.

PROMETHEE (Brans and Vincke, 1985) is the method used to obtain the ranking alternatives as the previous methods studied. This method includes the comparison of alternatives with alternatives for the criteria or attributes. The comparison is compared by constructing dominance matrix which is the total number of attributes considered in the study. In present study, six dominance matrices are obtained as C1, C2, C3, C4, C5 and C6. Weights are assigned, which is obtained by AHP, to each dominance matrix. 0 and 1 are the numerical value which represents the alternative dominating and dominated by the other alternative. In dominance matrix, alternative with respect to row is dominating other alternatives with respect to columns and alternative with respect to column is dominated by other alternatives with respect to rows. Final matrix is obtained by adding all the dominance matrix elements. In final matrix, sum of respective row and column are obtained to find the net dominance of alternative. From the net dominance, ranking is obtained and finally, the best alternative is selected.

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