Group Decision Support System for Multicriterion Analysis
A Case Study in India

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Abstract

The selection of the best irrigation system is examined in the multiobjective context for a case study of Sri Ram Sagar Project, Andhra Pradesh, India. Eight performance criteria, on farm development works, environmental impact, supply of inputs, conjunctive use of water resources, productivity, farmers' participation, economic impact and social impact are evaluated for thirteen irrigation systems. Analytic Hierarchy Process (AHP) is employed to overcome the difficulties arising from the complexity, subjectivity and lack of group consensus in the evaluation of an irrigation system. Spearman rank correlation coefficient is employed to assess the correlation between different ranking pattern. Group consensus is achieved through Geometric ranking rule (multiplicative ranking). Studies revealed that AHP is quite accessible and conductive to group consensus building. Comparison of the results indicated that the methodology is quite versatile and can be used in any field of engineering and management with suitable modifications.

1 Introduction

Multicriterion Decision Making (MCDM) methods are gaining importance because of their inherent ability to judge different alternative scenarios for possible selection of the best which may be further analyzed in depth for its final implementation. Multicriterion decision support systems (MCDSS) are computer based systems that employ multiple criteria decision methods as part of a decision support system (Jelasi, Jarke, and Stohr 1984). They explained the requirements of MCDSS i.e., 1) an extensive data base 2) a portfolio of multiple criteria methods 3) user friendly interface. A number of multicriterion decision support techniques have emerged in recent years that use varying computational approaches to arrive at the most desirable solution and thereby 'recommend' a course of action (Saaty 1992). On the other hand, development of water resources for projects such as irrigation has played an important role in the improvement of socio-economic conditions in developing countries. However, in recent years, there has been a general, growing disappointment in the levels of productivity, benefits, and sustainability of many irrigation schemes. At the same time, and for the foreseeable future, shrinking budgets for development and operation and management (O & M) of schemes necessitate improvements in project performance in place of new developments. To cater to this situation, performance of irrigation systems (command area under each distributory) can be evaluated and strategies can be developed to choose the best one which in turn can be used for formulating guidelines to improve the performance and efficiency of other existing ones. In this study terms of irrigation systems and distributories are used interchangeably.

2 Decision support system

An integrated interactive menu driven software MCDMGDSS is developed to consider Multicriterion analysis in group decision making environment. MCDMGDSS consists of software modules Multicrit, Correl, Group, Help. Multicrit covers seven MCDM methods, namely, ELECTRE-1, ELECTRE-2, PROMETHEE-2, EXPROM-2 (Extension of PROMETHEE-2 in distance based environment), Analytic Hierarchy Process (AHP), Compromise Programming (CP) and STOPROM-2 (Stochastic extension of PROMETHEE-2). Multicrit has the capability to graphically display the ranking pattern. Correl includes Spearman and Kendal rank correlation methods which are useful to compute the correlation coefficient values. Group includes group decision making methods i.e., Pairwise comparison majority rule, Sum-of-the-ranks rule, Additive ranking rule, Geometric ranking rule (multiplicative ranking). Help contains three segments, about MCDM methods, MCDM algorithm & inputs, Exit to DOS.

In the MCDMGDSS, decision maker has the option to work with any of the MCDM methods of his choice or all to rank different alternatives. Decision maker has the option to submit any of the ranking pattern of his choice for group decision making analysis. He can prefer any one or all of the four group decision making techniques for aggregation since combination of group decision making techniques can increase the chances of reaching a consensus or can atleast constitute a richer basis for bargaining and negotiation. In the present study, Analytic Hierarchy Process (AHP) is demonstrated in group decision making environment. Spearman rank correlation coefficient is employed to assess the correlation between the ranks. Methodology of AHP is briefly discussed here.

Analytic Hierarchy Process is an MCDM technique based on priority theory. It deals with complex problems which involve the consideration of multiple criteria simultaneously. Its ability (1) to incorporate data and judgements of experts into the model in a logical way, (2) to provide a scale for measuring intangibles and method of establishing priorities, (3) to deal with interdependence of elements in a system, (4) to allow revision in a short time, (5) to monitor the consistency in the decision maker 's judgements, (6) to accommodate group judgements if groups can not reach a natural consensus, makes this method a valuable contribution to the field of MCDM (Saaty and Ghoolamnezhad 1982). It is capable of a) breaking down a complex, unstructured situation into its component parts, b) arranging these parts, or variables, into a hierarchic order, c) assigning numerical values 1 to 9 to subjective judgements on the relative importance of each variable, and d) synthesizing the judgements to determine the overall priorities of the variables (Golden, Wasil, and Levy 1989). Eigen vector approach is used to compute the priorities of the elements in each pairwise comparison matrix. Eigen vector corresponding to maximum eigen value (λ_{max}) is then weighted with the weight of higher level element which is used as the criterion in making the pairwise comparisons that constitute the matrix in consideration. The procedure is repeated by moving downward along the hierarchy, computing the weights of each element at every level, and using these to determine composite weights for the succeeding levels. Since small changes in elements of pairwise comparison matrix imply a small change in λ_{max} , the deviation of the latter from matrix size N is a deviation of consistency. This is represented by (λ_{max} - N) / (N-1) and termed as Consistency Index (CI). When the consistency has

been calculated, the result is compared to those of the same index of a randomly generated reciprocal matrix from the scale 1 to 9, with reciprocals forced. This index is termed as Random Index (RI). The ratio of CI to average RI for the same order matrix is called the Consistency Ratio (CR). A CR of 0.1 or less is considered acceptable. The reciprocal property is preserved in these matrices to improve consistency. If consistency ratio is significantly small the estimates are accepted. Otherwise, an attempt is made to improve consistency by obtaining additional information.

3 Results and discussion

The above methodology is applied to the case study of thirteen canal distributories of Sri Ram Sagar Project, Andhra Pradesh, India. Eight different performance criteria, on farm development works, environmental impact, supply of inputs, conjunctive use of water resources, productivity, farmers' participation, economic impact, and social impact are evaluated for selecting the best distributory. These are denoted as OFD, EIM, SOI, CWU, PRO, FAP, ECI, and SCI respectively. All the criteria are assumed to be qualitative due to lack of precise quantitative information. A three stage procedure is employed to select the best distributory. In the first stage weightage of the performance criteria is obtained. In the second stage, group decision making concept is incorporated. In the third stage, global priority of each distributory is obtained.

3.1 Stage 1 : weightage of performance criteria (level 2 to level 1)

Three irrigation management experts are chosen for the decision making process because of their extensive knowledge and involvement in the planning of irrigation systems over a long duration and are termed as Irrigation System Planning (ISP) committee. This committee is involved in the listing of the attributes and structuring the hierarchy in the present analysis as shown in Fig 1. Level 1 corresponds to the objective of the good distributory, level 2 corresponds to the performance criteria and level 3 corresponds to the alternatives (distributories). Data is collected by interview so that questions about the meaning of criteria could be dealt with. It is decided to meet each farmer individually to avoid the danger of monotonous response without rationality. Total 347 individuals (329 farmers and 18 authorities) belonging to thirteen distributories are interviewed over a duration of 7 months. These distributories are termed as D1, D2, D3, D4 ....and D13 for academic purpose. Analytic Hierarchy Process is employed to obtain the weightage of each performance criteria. Both farmers and authorities are introduced to Saaty's 1-9 ratio scale with examples and requested to express his/her preferences for each of the eight performance criteria at the second level with respect to the overall goal of selecting good distributory (level 1). This requires 28 pairwise comparisons on Saaty's scale. This is based on the size of the pairwise comparison matrix N x N i.e., N(N-1)/2 where N=8. Among 64 elements/responses (8 x 8 matrix), eight diagonal elements are of value 1. Among the other available 56 elements, the value of the 28 elements are simply reciprocal of other 28 based on reciprocal theorem (Saaty 1992). In the questionnaire, questions are asked about only 28 elements of upper triangular matrix corresponds to pairwise comparison matrix. Eigen vector approach is employed to find the weightage of the criteria, consistency index, and the consistency ratio corresponding to maximum eigen value (Saaty and Ghoolamnezhad 1982). User can modify his/her views in pairwise comparison matrix until judgements (consistency ratio) are satisfactory. Pairwise comparison matrices corresponding to all the 347 individuals (329 farmers and 18 authorities belonging to thirteen distributories) are recorded and weightage of the performance criteria is obtained by the above procedure. It is observed that (results are not presented due to space limitation) judgements are satisfactory i.e., consistency ratio is less than or approximately equal to 0.1. Economic impact is given first position by 76.5% farmers in distributory D1, 40.0% farmers in D3, 57.7% farmers in D4, 72.4% farmers in D5, 88.9% farmers in D6 and 22.2% authorities of the project. In these distributories individuals felt the need of social upliftment and more agricultural productivity. In the remaining distributories economic impact is given first position by all respondents. This may be due to the risk aversive attitude of the farmers who are concerned about their personal goals rather than national goals. Second position is occupied either by social impact or productivity.

3.2 Stage 2 : group decision making

It became difficult to arrive at a group consensus on the priority of the performance criteria obtained from stage 1 of the analysis. This is due to lack of interaction between farmers (since most of the interviews are held separately), and individuals inability to arrive at a natural consensus even among the available ones. To overcome this drawback, a pairwise comparison matrix of each individual (distributorywise) is aggregated to arrive at a group pairwise (distributorywise) comparison matrix by geometric mean approach (Golden, Wasil and Levy 1989). Distributorywise aggregation is chosen due to the computational difficulties while aggregating all the 347 individual pairwise comparison matrices at a time. Table 1 presents the distributorywise weightages of the performance criteria, consistency ratio with respect to the overall goal of selecting good distributory. It is observed that economic impact, social impact and productivity occupied first, second and third positions respectively. In case of authorities social impact occupied the first position followed by economic impact and productivity. Consistency ratio varies from 0.01109 to 0.05365 indicating the satisfactum of judgements. Later, these 14 sets of weightages (13 distributories and one authority related) are geometrically aggregated (Saaty 1992) to obtain the average weightage of performance criteria corresponding to all 347 individuals and presented in Table 1. The priorities of the criteria in the decreasing order are economic impact (0.309), social impact (0.223), productivity (0.148), environmental impact (0.081), conjunctive use of water resources (0.062), on farm development works (0.061), farmers participation (0.057), and supply of inputs (0.052). Economic impact dictates the choice of the good irrigation system. These weightages are used for calculating the global priorities of distributories which are discussed in the next section. However, 14 sets of weightages are subsequently used for the sensitivity analysis studies. Notations in Table 1 are as follows: Dist represents Distributory, NP represents number of individuals, row 14 represents priorities of authorities, row 15 represents geometrical average of 347 individuals , CONRA represents Consistency Ratio.

3.3 Stage 3 : priority of distributories (level 3 to level 2)

Preferences of thirteen distributories at the third level with respect to the each performance criteria at the second level require 78 pairwise comparisons. This task is assigned to the committee members. For this purpose summarized report obtained from the farmers and authorities response survey is presented to the committee for their assistance. They are also helped by the concerned officials and status reports. In this study several rounds of discussions are held before arriving at consensus pairwise comparison matrix (CPCM) for all the criteria. It is observed that (results are not presented due to space limitation) distributories D1, D2, D3 and D4 are given 2 times importance as compared to D5 for on farm development works. In case of environmental impact , D5 is given 2 times importance as compared to D1, D2, D3 and D4. Similarly, pairwise comparisons of D8 with other distributories are also differed both for environmental impact and on farm development works. Similar pairwise comparisons are observed when comparing D10, D11 and D13 with other distributories. For supply of inputs, distributories D1, D2 and D3 are given 1, 2, and 2 times importance as compared to D6 and 2, 3, 3 times in case of conjunctive use of water resources. Similarly D8 is given 3 times importance as compared to D1 for supply of inputs, 4 times for conjunctive use of water resources. In case of productivity , D1 and D2 are given 3 times importance as compared to D5. In case of farmers' participation, D5 is given 3 times importance as compared to D1 and D2. Similarly D8 is given 3 times importance as compared to D1 for productivity and it is 7 times in case of farmers' participation. For economic impact, D8 is given 9, 4, 9, 9,4,6, 5 times importance as compared to D1 to D7. In case of social impact, these are 3, 4 , 2, 4, 4, 4, 5 indicating that economic impact is very high in case of D8 when compared to D1, D3 and D4. Farmers' participation achieved a high consistency ratio of 0.1002 which is slightly beyond the normal value of 0.1. For on farm development works, environmental impact , supply of inputs, and social impact these values are in the range of 0.0922 to 0.0953. In case of economic impact criterion, consistency ratio is less (0.0726) compared to all other criteria. Above pairwise comparisons are based on the available data with experts in the form of reports etc., expertise with the distributories and their ability to correlate the real (irrigation system) situation. Table 2 shows the global priorities and the ranking of each distributory. The summation of the products of the local priorities of distributories by the higher level average local priorities of performance criteria (corresponds to geometric mean) yields the global priority of each distributory. It is observed that distributories D8 and D11 occupied first and second positions respectively with a priority value 0.2352 and 0.1706 respectively. Least positions are occupied by distributories D12, D13 with priority values of 0.0414 and 0.0388 respectively. In this study ISP committee classified the distributories as four categories i.e., very good, good, medium and poor based on the global priority values. Distributories D8 and D11 falls under very good category, D1, D3, D7 falls under good category , D2, D4, D6, D9 falls under medium category and D10, D12, D13 falls under poor category. Extensive sensitivity analysis studies indicated that the ranking pattern is quite robust to the parameter changes upto the first three positions. Spearman rank correlation coefficient is employed to assess the correlation between different ranking pattern. Degree of correlation ranges from 0.939 to 0.994 indicating the good measure of association between different ranking pattern. In the present analysis distributory D8 is found to be the best which may be further analyzed in depth for its final implementation. Guidelines can be formulated in realistic conditions based on the scenario in D8 to improve the other distributories in the similar manner (Srinivasa Raju 1995).

4 Conclusions

Group decision support system MCDMGDSS is employed in performance evaluation studies to a case study of Sri Ram Sagar Irrigation Project, Andhra Pradesh, India. From the analysis of results the following conclusions are drawn:

1. It is observed that economic impact is given higher importance followed by social impact/ productivity by most of the individuals.

2. Distributories D8 and D11 occupied the first and second positions respectively.

3. Analytic Hierarchy Process is found to be suitable for complex group decision making situations where subjectivity plays a major role.

5 References

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Table 1 Priority of performance criteria

Dist	NP	OFD	EIM	SOI	CWU	PRO	FAP	ECI	SCI	CONRA
1	23	.057	.073	.052	.066	.175	.069	.285	.223	.01323
2	17	.054	.076	.046	.065	.155	.058	.318	.228	.01635
3	25	.065	.082	.058	.074	.174	.066	.250	.232	.01296
4	26	.057	.078	.053	.070	.148	.070	.282	.244	.01109
5	29	.059	.079	.050	.065	.148	.061	.310	.228	.02503
6	18	.058	.072	.042	.054	.117	.053	.364	.240	.02387
7	33	.061	.081	.049	.063	.136	.056	.350	.205	.02334
8	38	.060	.080	.049	.061	.122	.053	.371	.203	.03258
9	27	.058	.086	.053	.060	.133	.048	.346	.215	.03587
10	33	.064	.081	. 053	.058	.134	.050	.354	.206	.03781
11	21	.063	.087	.053	.053	.145	.052	.328	.219	.04405
12	19	.066	.087	.056	.060	.148	.057	.303	.222	.04840
13	20	.067	.093	.056	.059	.163	.055	.288	.219	.05365
14	18	.067	.084	.058	.061	.198	.059	.222	.251	.02930
15	347	.061	.081	052	.062	.148	.057	.309	.223	

Table 2 Global priorities of distributories

Dist	OFD	EIM	SOI	CWU	PRO	FAP	ECI	SCI	Global Priority	Rank
	0.061	0.081	0.052	0.062	0.148	0.057	0.309	0.223		
D1	0.063	0.054	0.064	0.081	0.091	0.083	0.070	0.074	0.0729	3
D2	0.052	0.042	0.066	0.073	0.084	0.055	0.048	0.051	0.0563	7
D3	0.083	0.078	0.063	0.071	0.071	0.063	0.055	0.059	0.0633	5
D4	0.038	0.041	0.043	0.045	0.050	0.048	0.042	0.045	0.0438	10
D5	0.055	0.083	0.069	0.075	0.075	0.077	0.047	0.048	0.0590	6
D6	0.063	0.060	0.051	0.051	0.060	0.059	0.04 3	0.046	0.0503	9
D7	0.045	0.050	0.045	0.044	0.052	0.049	0.076	0.080	0.0637	4
D8	0.270	0.213	0.251	0.219	0.183	0.203	0.317	0.171	0.2352	1
D9	0.039	0.045	0.041	0.046	0.050	0.045	0.058	0.065	0.0534	8
D10	0.041	0.046	0.043	0.046	0.045	0.046	0.041	0.047	0.0437	11
D11	0.163	0.201	0.170	0.154	0.162	0.184	0.132	0.227	0.1706	2
D12	0.044	0.044	0.053	0.049	0.041	0.050	0.035	0.043	0.0414	12
D13	0.043	0.041	0.041	0.045	0.036	0.038	0.036	0.042	0.0388	13