IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 2 Ser. I (Mar. - Apr. 2019), PP 58-67
www.iosrjournals.org

Decision Support System to Prioritize Irrigation Structures in Rehabilitation Programs

N. Abdelazim[1], M. Samy[2], K. Toubar[3]
[1]*(PhD Researcher, Faculty of Engineering, Ain Shams University, Egypt)*
[2]*(Professor of Hydraulics, Faculty of Engineering, Ain Shams University, Egypt)*
[3]*(Doctor of Engineering, Ministry of Water Resources and Irrigation, Egypt)*
Corresponding Author: N. Abdelazim

Abstract: *Rehabilitation programs of irrigation structures are essential in maintaining their functionality and increasing their life time. In irrigation systems involving large number of structures, prioritizing these structures in the rehabilitation program is essential in decision making process and budget allocation. In this study, a decision support system (DSS) was developed to prioritize and rank irrigation structures in the rehabilitation program. The developed DSS adopted the technique of Analytic Network Process (ANP) performed through the Super Decision (SD) V2.6.0 software. The developed DSS was applied to prioritize 140 Egyptian irrigation structures located in the River Nile irrigation system based on eight criteria. Results were checked using the well-known technique of Classic Multi Criteria Decision Making (CMCDM). The developed DSS proved high ability to deal with the huge amount of data collected with high accuracy for structures' prioritization.*

Key words: *Irrigation structures, Decision Support System, Rehabilitation, Prioritization, Super Decision, Classic Multi Criteria Decision Making.*

Date of Submission: 27-02-2019 Date of acceptance: 13-03-2019

I. Introduction And Literature Review

Increasing pressure is being placed on Egypt's limited water resources by expanding population. A rehabilitation program for irrigation structures as part of an integrated water resources management plan was developed by the Egyptian government to improve water distribution efficiency, decrease water lost through irrigation system, and reduce probabilities of failure of these structures[1]. Developing a Decision Support System (DSS) that prioritizes and ranks irrigation structures in rehabilitation program is of great importance especially for budget allocation. Many aspects should be considered in the developed DSS such as engineering aspects, environmental aspects, socio-economic aspects, etc.

Available, in the literature, one may find many published research works in the fields of developing DSS and prioritization of rehabilitation programs. Shehab-Eldeen and Moselhi[8] presented an automated system for selecting the most suitable trenchless rehabilitation method for sewer pipes. The system utilized two modules; data-base management system and DSS. Hlavinek et al.[4] used the CARE-S software to study rehabilitation of sewer networks. They reported that the software helped the user in making his final decision. Mishra et al.[6] used the SWAT software for prioritizing the structure/engineering based management of the Banha watershed in India to reduce sediment load. Tagherouit et al.[9] applied a fuzzy expert system to hydraulic and structural data of a small combined sewer network in Laval, Canada. Results showed how the system may be used to establish rehabilitation priorities for each pipe section. El-Gafy et al.[3] designed a DSS to maximize economic value of irrigation water in Egypt. They concluded that proposing a cropping pattern at the governorate level is better than at the national level as it provides a more reliable and accurate view. Bosch and Aguado[2] used multi criteria decision making system to prioritize the works planned for a dam case study. Ioan and Ioan[5] presented a case study on the choice of the best technical solution for the rehabilitation of water distribution network pipelines. They used the Analytic Network Process (ANP) method for selection. They performed their calculations using the Super Decisions (SD V2.6.0) software.

The present study comprises three main parts: i) Collecting data of 140 Egyptian irrigation structures located in the River Nile irrigation system, ii) Developing a Decision Support System (DSS) using SD V2.6.0 software to prioritize these structures in the rehabilitation program, and iii) Check results of the developed DSS using Classic Multi-Criteria Decision Making. It is hoped to give a new insight to engineers and decision makers.

II. Material And Methods

In the present study, it was stressed on the techniques of data collection to guarantee fair accurate data that helps in dealing with these very important lifesaving structures. Also, major attention was paid to the techniques for developing of decision support system (DSS).

Techniques for data collection: Various techniques were used to collect data using special equipment and experienced personnel depending on the required type of data, as shown hereafter:

Visual inspection: Situ visits were organized with predesigned short list including photos of the structure and comments from personnel about the structure problems.

Topographic and bathymetric surveying: Topographic surveying was conducted in the site of the structure to add thorough details to the site satellite images. Land surveying comprised measurements of levels, distances, dimensions of elements, etc. Bathymetric surveying focused on scour and river bed elevations using echo-sounder mounted beneath the side of a boat. A mesh was formed to accurately measure the river bed configurations. The process was conducted through the method of sections (25m apart) ended after 5m in natural land in both sides of the bank.

Underwater inspection and dewatering: A specialized team was hired for the job to carry out the following activities:

- Cleaning the floor from silts and deposits using air lift.
- A monitor connected to the underwater camera enabled view of the inspected elements.
- Divers followed the instructions from the technical staff to locate any irregularity, crack or damage in the submerged parts.
- For some selected vents, underwater photography and video filming (pier to pier) were performed to investigate walls, the concrete floor, grooves, gates, and other underwater parts.
- If photos and videos showed that underwater parts are in bad conditions, dewatering was performed to have a clearer image.
- For dewatering, cofferdams were placed in the maintenance grooves and water pumps were used to evacuate water until we have a completely dry vent.

Techniques for developing the Decision Support System (DSS):

Lately, these techniques gained more attention from engineers worldwide to reach more objective selection of the optimum alternative for any given engineering problem. The most famous types of DSS techniques are:

Condition index (CI) is one of the oldest and most well-known DSS techniques. A scale (usually from 1 to 100) is built by experts where each scale value denotes a distinct structure condition. The studied structure is given a scale value according to its condition. The value of condition index helps in decision making regarding rehabilitation of the structure[2].

Risk analysis involves the stochastic quantitative approach used to study events or loads that can cause failure of the structures, and deterministic approach used when a rapid evaluation of a series of cases is needed to prioritize some risk reduction over others[2].

Fuzzy inference system consists of a set of "if-then" rules defined over fuzzy sets generally formed by using "expert knowledge"[9].

Integrated Model for Sustainable Value Assessments (MIVES) combines multi-criteria decision-making and multi-attribute utility theory. It was checked and applied in the field of industrial construction[2].

III. The Developed Decision Support System (DSS)

The proposed DSS was constructed through the Super Decision SD V2.6.0 software based on the Analytic Network Process (ANP, 1996) technique. It is the modern version of Analytic Hierarchy Process (AHP, 1980). AHP is mathematically general and robust decision theory that was validated through numerous applications. In ANP models, the strategic criteria allow decisions to be made according to their merits of benefits, opportunities, and risks. The control criteria are associated with a network of influences. These two types of criteria (strategic and control) are used to synthesize the priorities of the alternatives.[5, 7]

The developed DSS was applied to prioritize 140 Egyptian irrigation structures located in the River Nile irrigation system based on eight criteria. Results were checked using Classic Multi-Criteria Decision-Making (CMCDM) organized in spreadsheets.

IV. Application Of The Developed DSS

The following steps were taken in applying the developed DSS:

Step 1: Identifying decision-making criteria: Eight decision-making criteria were selected and identified for the prioritization of alternatives (structures) as shown in table no A-1.

Step 2: Identifying alternatives (structures): The 140 Egyptian irrigation structures under study were given the codes from A1 to A140 and are shown in table A-3.
Step 3: Forming ANP structure: The ANP was modeled in the SD V2.6.0 software. To structure the detailed ANP model, clusters were used to group goals in one cluster and criteria in the other as shown in figure no 1.

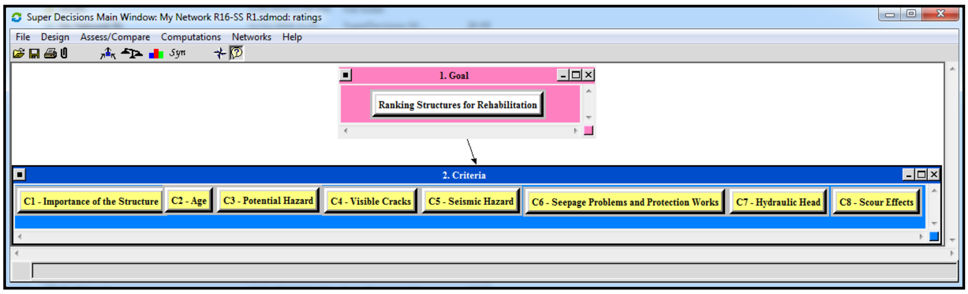

Figure no 1: Clusters in SD software

Step 4: Data Entry: Three types of data are entered (see figure no 2 and figure no 3):

- The weights for decision-making criteria are entered in the direct input data entry table,
- Data of alternatives (structures) is entered in the SD rating table, and
- Weight of each structure regarding each criterion is entered in the SD rating table through the edit drawdown menu.

Five numbers were selected as weights using the Saaty scale (from 1 to 9)[7] with a unique meaning for each Saaty value as shown in table no A-2. The selected numbers were 1, 3, 5, 7, and 9 as each of these numbers has a distinct definition.

Step 5: Performing the calculation matrices: The main calculation process in SD V2.6.0 software is conducted through the pair-wise comparison matrix.

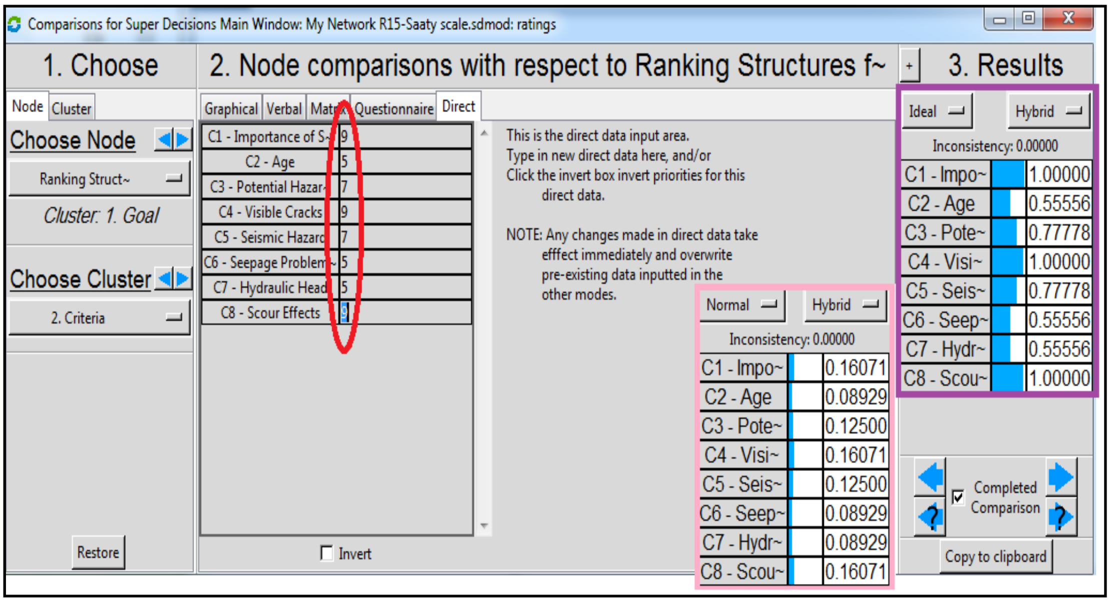

Figure no 2: Weights entry per criterion based on Saaty scale

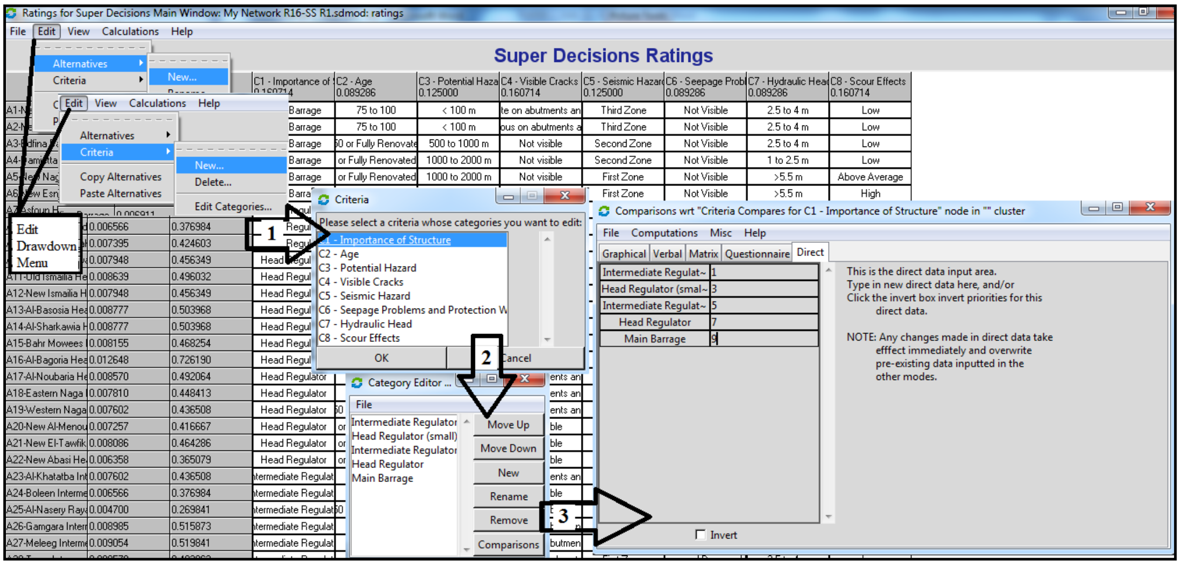

Figure no 3: SD rating table

Pair-wise comparison matrix gives the relations between the used criteria through numbers, and is obtained from the pair comparisons SD software output (called the questionnaire, figure no 4). The questionnaire values are calculated for any element in clusters depending on its influence on other elements in another cluster (external dependence) and its influence on other elements in the same cluster (internal dependence). For (n) number of criteria, there are "0.5 n (n-1)" pair-wise comparison rows. Each row represents the relation between two criteria.

The value of the number revealed in some row gives the pair-wise comparison between the two criteria and its color is corresponding to the dominant criterion. In the present model, n equaled 8 and so, the pair-wise comparison rows equaled 28 (figure no 4). Table no 1 gives the pair-wise comparison matrix of the study case "Matrix {A}" showing the values of pair comparisons for all the criteria C1 to C8 based on the questionnaire.

Determining consistency of the pair-wise comparison matrix is a step conducted to guarantee that relations among criteria are consistent and not random. This was accomplished through consecutive calculations:

- Table no 2 was obtained by normalizing the values of matrix {A} with the sum of values per column,
- The local priority vector {X} was determined by calculating the average of each row in table no 2,
- Matrix {A} is multiplied by the vector {X} as shown in table no 3,
- The eigenvalue λ_{max} was calculated as the average of the values obtained from dividing {AX} by {X} for each row $\lambda_{max} = \text{Average}\ \frac{\{AX\}}{\{X\}} = 8.136$,
- The Consistency Index (CI) was calculated $CI = \frac{\lambda_{max} - n}{n-1} = 0.019$ (n = 8 criteria),
- The average stochastic uniformity coefficient (R) was determined using table no 4[7]. As the order of Matrix {A} = 8, then R = 1.41,
- The Consistency Ratio (CR) is calculated ($CR = \frac{CI}{R} = \frac{0.019}{1.140} = 0.013$), and
- If CR > 0.1, the pair-wise comparisons are random and not trustworthy[7]. In this model, the pair-wise comparison matrix was consistent as CR = 0.013 < 0.1.

Step 6: Ranking of alternatives (structures):

The software calculation outcomes (see table no A-3) were:

- **Total Number** is a value used to calculate the normal number of the alternative.
- **Ideal Number** of an alternative is the ratio between the Total Number of this alternative and the maximum value of all alternative Total Numbers.
- **Normal Number** is the number denoting the priority rank of the alternative. It is the ratio between the Ideal Number and the sum of all the Ideal Numbers of all alternatives.

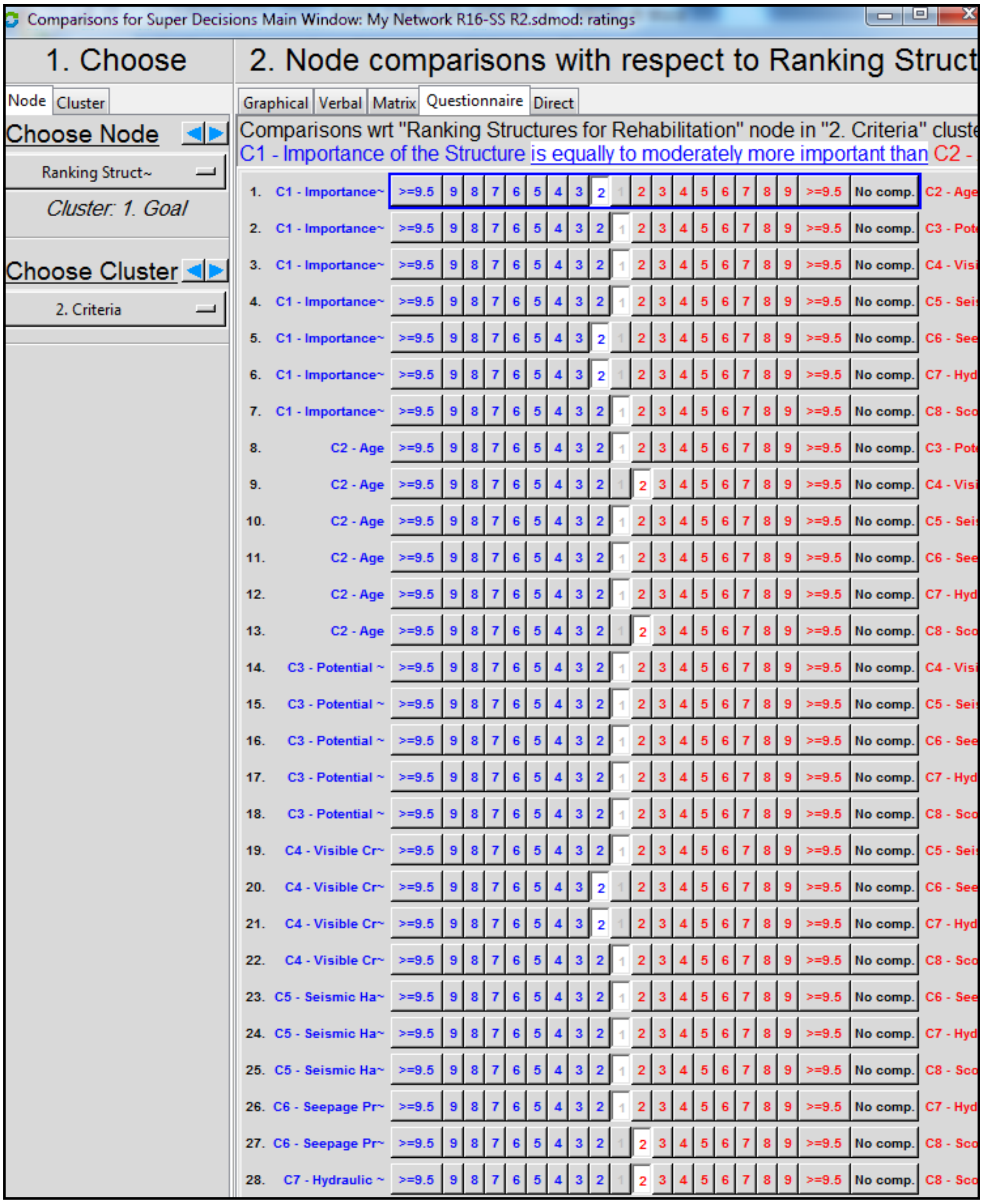

Figure no 4: The questionnaire

Table no 1: Pair-wise comparison matrix {A}

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0.5	1	1	1	0.5	0.5	1
C2	2	1	1	2	1	1	1	2
C3	1	1	1	1	1	1	1	1
C4	1	0.5	1	1	1	0.5	0.5	1
C5	1	1	1	1	1	1	1	1
C6	2	1	1	2	1	1	1	2
C7	2	1	1	2	1	1	1	2
C8	1	0.5	1	1	1	0.5	0.5	1

Table no 2: Normalizing the values of matrix {A}

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.091	0.077	0.125	0.091	0.125	0.077	0.077	0.091
C2	0.182	0.154	0.125	0.182	0.125	0.154	0.154	0.182
C3	0.091	0.154	0.125	0.091	0.125	0.154	0.154	0.091
C4	0.091	0.077	0.125	0.091	0.125	0.077	0.077	0.091
C5	0.091	0.154	0.125	0.091	0.125	0.154	0.154	0.091
C6	0.182	0.154	0.125	0.182	0.125	0.154	0.154	0.182
C7	0.182	0.154	0.125	0.182	0.125	0.154	0.154	0.182
C8	0.091	0.077	0.125	0.091	0.125	0.077	0.077	0.091

Table no 3: Calculation of Consistency Index (CI)

$$X = \begin{vmatrix} 0.094 \\ 0.157 \\ 0.123 \\ 0.094 \\ 0.123 \\ 0.157 \\ 0.157 \\ 0.094 \end{vmatrix} \qquad AX = \begin{vmatrix} 0.764 \\ 1.283 \\ 1.000 \\ 0.764 \\ 1.000 \\ 1.283 \\ 1.283 \\ 0.764 \end{vmatrix} \qquad \frac{AX}{X} = \begin{vmatrix} 8.115 \\ 8.163 \\ 8.128 \\ 8.115 \\ 8.128 \\ 8.163 \\ 8.163 \\ 8.115 \end{vmatrix}$$

Table no 4: R as a function of {A} Matrix order (After Saaty [7])

Matrix Order	1	2	3	4	5	6	7	**8**	9	10	11	12
R	0	0	0.58	0.9	1.12	1.24	1.32	**1.41**	1.45	1.49	1.51	1.48

The alternative having the highest Normal Number is set as the highest priority. Results in table no A-3 denoted that “A16-Bagoria Head Regulator” is the first structure requiring urgent attention and “A71-Mesrea Intermediate Regulator” requiring the least attention.

V. Check Results Of The Developed DSS Using CMCDM

For the required check to be accomplished, series of spreadsheets (SSs) were presented:

- SS1 was the main CMCDM spreadsheet as shown in table no A-4. It contained:
  - **Col. 1:** The eight preset criteria adopted in the developed DSS.
  - **Col. 2 to 6:** The CMCDM ranking system containing the weights (from 1 to 5), which were set based on the categories for each criterion. As an example, for the criterion C4 (Visible cracks), categories were set to denote degrees of crack visibility and dimensions.
  - **Col. 7 to 9:** Other weights (from 1 to 5) set based on the structural, hydraulic and environmental-social shares of each criterion.
- SS2 contained alternative data.
- SS3 contained calculations following the CMCDM method.
- SS4 contained alternatives’ (structures) ranking.

Good agreement was noticed between structures’ ranking obtained by the developed DSS and that by CMCDM method. However, due to lack of accuracy in calculations of CMCDM method, in some cases, more than one alternative gained the same priority. This was not the case in the results of the developed DSS where every alternative had its own priority in the ranking table as shown in table A-3.

VI. Summary And Conclusion

In this study, a decision support systems (DSS) was developed through SD V2.6.0 software. The DSS was employed to prioritize the rehabilitation of 140 Egyptian irrigation structures located in the River Nile irrigation system. The results of the developed DSS were checked using the well-known CMCDM organized through spreadsheet technique.

The developed DSS proved to have the capability of dealing with huge data of an entire irrigation system with high accuracy, less time consumption, less user effort, and less possible human errors.

Applying the developed DSS showed that for the study case, Bagoria Head Regulator is the first structure requiring urgent attention and Mesrea Intermediate Regulator requires the least attention.

Symbols and Abbreviations

AHP	Analytic Hierarchy Process	DSS	Decision Support System
ANP	Analytic Network Process	R	Average stochastic uniformity coefficient
CI	Consistency Index	SD	Super Decision
CMCDM	Classic Multi-Criteria Decision Making	SSi	Spreadsheet No. i
CR	Consistency Ratio	λ_{max}	The eigenvalue

References

[1]. African Development Bank, "Master Plan Study for the Rehabilitation/Replacement of Major Hydraulic Structures on the Nile", Appraisal report, October 2009. (https://www.africanwaterfacility.org/fileadmin/uploads/awf/Projects/AWF-Project-appraisal-report-EGYPT-MASTER.pdf).

[2]. Bosch F. and Aguado A., "Decision-making through Sustainability", The 6th IAHR Int. Sym. on Hydraulic Structures and Water System Management. Portland, Oregon, USA, pp. 577-586, 2016. Doi.10.15142/T3700628160853.

[3]. El-Gafy I., El-Ganzori A., and Mohamed A., "Decision support system to maximize economic value of irrigation water at the Egyptian governorates meanwhile reducing the national food gap", J. of Water Science, Vol. 27, pp. 1–18, 2013.(https://www.sciencedirect.com/science/article/pii/S1110492913000027).

[4]. Hlavinek P., Kubik J., Prax P., Simcikova P., and Sulcova V., "Application of decision support system for sewer network rehabilitation", Integrated Urban Water Resources Management, Springer, Netherlands, pp. 159–170, 2006. DOI: 10.1007/1-4020-4685-5_17.

[5]. Ioan A. and Ioan G., "Choosing a Water Distribution Pipe Rehabilitation Solution Using the Analytical Network Process Method", J. of Water, Vol. 10, Issue 4, 2018 (https://doi.org/10.3390/w10040484).

[6]. Mishra A., Kar S., Singh V., "Prioritizing Structural Management by Quantifying the Effect of Land Use and Land Cover on Watershed Runoff and Sediment Yield", Water Resources Management, Springer, Vol. 21, Issue 11, pp:1899–1913, 2007. DOI 10.1007/s11269-006-9136-x.

[7]. Saaty R., "Decision Making in Complex Environments", ISBN Number 1-888603-00-3, 2016; (https://www.superdecisions.com/sd_resources/v28_man02.pdf)

[8]. Shehab-Eldeen T. and Moselhi O., "A decision support system for rehabilitation of sewer pipes", Canadian J. of Civil Eng., Vol. 28, pp. 394–401, 2001. DOI: 10.1139/cjce-28-3-394.

[9]. Tagherouit W., Bennis S., and Bengassem J., "A Fuzzy Expert System for Prioritizing Rehabilitation of Sewer Networks", J. of Computer-Aided Civil and Infrastructure Eng., Vol. 26, pp. 146–152, 2011, DOI: 10.1111/j.1467-8667.2010.00673.x.

Appendix (A)

Table no A-1: Decision-making Criteria

No.	Criterion	Description
C1	Importance of the Structure	Including; Structure size, Irrigated land served by the structure, Width of structure waterway, and Purpose of the structure (Irrigation, Traffic, Navigation, Supply, Power, etc).
C2	Age	Defines the number of years from commissioning or from full renovation.
C3	Potential Hazard	Defines the distance to inhabited areas downstream the structure (m).
C4	Visible Cracks	Defines the effect of cracks on structures stability based on its visibility, location, length and depth.
C5	Seismic Hazard	Defines the seismic zone that tells the strength of seismic activity in the region where the structure is located.
C6	Seepage Problems and Protection Works	Defines the visibility of seepage, its location, and strength. Hence defining another structural factor.
C7	Hydraulic Head	Defines the water head sustained by the structure.
C8	Scour Effects	Defines the maximum scour depth due to water flow through the structure.

Table no A-2: Saaty fundamental scale[7]

1	Equal	4	Moderately to Strongly more dominant	7	Very Strongly more dominant
2	Equally to Moderately more dominant	5	Strongly more dominant	8	Very Strongly to Extremely more dominant
3	Moderately more dominant	6	Strongly to Very Strongly more dominant	9	Extremely more dominant

Table no A-3: The 140 Alternatives and Output ranking table using the developed DSS

Alternatives	Totals	Ideal	Normal	Ranking
A16-Bagoria Head Regulator	**0.7262**	**1.0000**	**0.0126**	**1**
A88-Baleiana Km 3.73 Intermediate Regulator	0.6548	0.9016	0.0114	2
A98-Al-Kesra Head Regulator	0.6548	0.9016	0.0114	3
A61-Al-Tessaa Intermediate Regulator	0.6508	0.8962	0.0113	4
A79-Al-Gendia Head Regulator	0.6389	0.8798	0.0111	5
A2-New Delta Barrages Damietta Branch	0.6270	0.8634	0.0109	6
A1-New Delta Barrages Rosetta Branch	0.5913	0.8142	0.0103	7
A70-Old Hamama Intermediate Regulator	0.5873	0.8087	0.0102	8
A47-Elahon Intermediate Regulator	0.5833	0.8033	0.0102	9
A130-Abo Ragwan Intermediate Regulator	0.5675	0.7814	0.0099	10

Alternatives	Totals	Ideal	Normal	Ranking
A77-Al-Bedah Intermediate Regulator	0.5675	0.7814	0.0099	11
A91-Baleiana Intermediate Regulator	0.5635	0.7760	0.0098	12
A40-Kafr Rabee Intermediate Regulator	0.5476	0.7541	0.0095	13
A75-Al-Saforia Head Regulator	0.5397	0.7432	0.0094	14
A84-Qheft Intermediate Regulator	0.5397	0.7432	0.0094	15
A87-Al-Ashraf Intermediate Regulator	0.5357	0.7377	0.0093	16
A139-Mesheiraf Canal Head Regulator	0.5317	0.7322	0.0093	17
A6-New Esna Barrage	0.5317	0.7322	0.0093	18
A116-Tahta Intermediate Regulator	0.5278	0.7268	0.0092	19
A27-Meleeg Intermediate Regulator	0.5198	0.7158	0.0091	20
A29-Renewed Akhmeem Intermediate Regulator	0.5159	0.7104	0.0090	21
A26-Gamgara Intermediate Regulator	0.5159	0.7104	0.0090	22
A73-Al-Kawasem Intermediate Regulator	0.5119	0.7049	0.0089	23
A92-Deshna Intermediate Regulator	0.5079	0.6995	0.0088	24
A119-Al-Qhadaba Canal Head Regulator	0.5040	0.6940	0.0088	25
A13-Al-Basosia Head Regulator	0.5040	0.6940	0.0088	26
A14-Al-Sharkawia Head Regulator	0.5040	0.6940	0.0088	27
A11-Old Ismailia Head Regulator	0.4960	0.6831	0.0086	28
A17-Al-Noubaria Head Regulator	0.4921	0.6776	0.0086	29
A57-Al-Bahr Al-Sagheer Head Regulator	0.4921	0.6776	0.0086	30
A28-Tema Intermediate Regulator	0.4921	0.6776	0.0086	31
A7-Asfoun Head Regulator	0.4881	0.6721	0.0085	32
A129-El-Ayat Intermediate Regulator	0.4841	0.6667	0.0084	33
A69-Sheab Shanawan Head Regulator	0.4722	0.6503	0.0082	34
A15-Bahr Mowees Head Regulator	0.4683	0.6448	0.0082	35
A51-Hassan Wassef Head Regulator	0.4683	0.6448	0.0082	36
A5-New Naga Hammadi Barrage	0.4683	0.6448	0.0082	37
A21-New El-Tawfiki Head Regulator	0.4643	0.6393	0.0081	38
A58-Dekernes Intermediate Regulator	0.4643	0.6393	0.0081	39
A132-El-Hawamdia Intermediate Regulator	0.4603	0.6339	0.0080	40
A41-Al-Santa Intermediate Regulator	0.4603	0.6339	0.0080	41
A140-Al-Semsemia Canal Head Regulator	0.4603	0.6339	0.0080	42
A12-New Ismailia Head Regulator	0.4563	0.6284	0.0079	43
A10-Al-Behery Rayah Head Regulator	0.4563	0.6284	0.0079	44
A100-Al-Bohia Head Regulator	0.4484	0.6175	0.0078	45
A18-Eastern Naga Hammadi Head Regulator (Al-Faroukia)	0.4484	0.6175	0.0078	46
A65-Bahr Tanah Head Regulator	0.4365	0.6011	0.0076	47
A19-Western Naga Hammadi Head Regulator (Al-Foadia)	0.4365	0.6011	0.0076	48
A23-Al-Khatatba Intermediate Regulator	0.4365	0.6011	0.0076	49
A138-Om Khalifa Canal Head Regulator	0.4325	0.5956	0.0075	50
A68-Al-Khatatba Spillway	0.4325	0.5956	0.0075	51
A113-Al-Rahmania Intermediate Regulator	0.4325	0.5956	0.0075	52
A63-Sedfa Intermediate Regulator	0.4286	0.5902	0.0075	53
A83-Al-Hobeil Intermediate Regulator	0.4246	0.5847	0.0074	54
A37-Sorod Intermediate Regulator	0.4246	0.5847	0.0074	55
A9-Al-Nasery Rayah Head Regulator	0.4246	0.5847	0.0074	56
A96-Al-Gergawia Head Regulator	0.4206	0.5792	0.0073	57
A67-Al-Safraa Intermediate Regulator	0.4206	0.5792	0.0073	58
A50-Sariaos Intermediate Regulator	0.4206	0.5792	0.0073	59
A59-Meet Assem Intermediate Regulator	0.4206	0.5792	0.0073	60
A20-New Al-Menoufy Head Regulator	0.4167	0.5738	0.0073	61
A36-Al-Safia Intermediate Regulator	0.4167	0.5738	0.0073	62
A78-Al-Meana Head Regulator	0.4127	0.5683	0.0072	63
A107-Meet Azoon Intermediate Regulator	0.4127	0.5683	0.0072	64
A85-Takhfeef Al-Kesra Intermediate Regulator	0.4127	0.5683	0.0072	65
A74-Al-Shoala Head Regulator	0.4127	0.5683	0.0072	66
A66-Baqhour Intermediate Regulator	0.4127	0.5683	0.0072	67
A56-Matay Intermediate Regulator	0.4127	0.5683	0.0072	68
A52-El-Giza Head Regulator	0.4127	0.5683	0.0072	69
A30-Meet Ghamr Intermediate Regulator	0.4048	0.5574	0.0070	70
A93-Qhebah Intermediate Regulator	0.4048	0.5574	0.0070	71
A42-Masraf Dairout Regulator	0.4008	0.5519	0.0070	72
A38-Basioun Intermediate Regulator	0.4008	0.5519	0.0070	73
A102-Al-Khaleeg Al-Abbasy Head Regulator	0.4008	0.5519	0.0070	74
A3-Edfina Barrage	0.3968	0.5464	0.0069	75
A62-Al-Khazendaria Intermediate Regulator	0.3929	0.5410	0.0068	76

Alternatives	Totals	Ideal	Normal	Ranking
A94-Sohag Intermediate Regulator	0.3929	0.5410	0.0068	77
A127-Belkhas Intermediate Regulator	0.3929	0.5410	0.0068	78
A35-Al-Salehia Intermediate Regulator	0.3929	0.5410	0.0068	79
A53-Tanta Al-Melahia Head Regulator	0.3929	0.5410	0.0068	80
A99-Al-Tahtawia Head Regulator	0.3889	0.5355	0.0068	81
A118-Tanta Intermediate Regulator	0.3889	0.5355	0.0068	82
A112-Al-Kawamel Head Regulator	0.3889	0.5355	0.0068	83
A33-Al-Qharanein Intermediate Regulator	0.3889	0.5355	0.0068	84
A115-Meet Yazeed Head Regulator	0.3849	0.5301	0.0067	85
A24-Boleen Intermediate Regulator	0.3770	0.5191	0.0066	86
A8-Al-Kalabia Head Regulator	0.3770	0.5191	0.0066	87
A120-Meet Bera Head Regulator	0.3770	0.5191	0.0066	88
A90-Shanhour Intermediate Regulator	0.3770	0.5191	0.0066	89
A44-Shoubrabas Intermediate Regulator	0.3730	0.5137	0.0065	90
A46-Bahr Mowees Km 24 Intermediate Regulator	0.3730	0.5137	0.0065	91
A55-Bahr Teera Head Regulator	0.3651	0.5027	0.0064	92
A22-New Abasi Head Regulator	0.3651	0.5027	0.0064	93
A136-El-Korashia Head Regulator	0.3651	0.5027	0.0064	94
A97-Owlad Ismail Intermediate Regulator	0.3571	0.4918	0.0062	95
A121-Al-Atf Head Regulator	0.3571	0.4918	0.0062	96
A123-Donkola Intermediate Regulator	0.3532	0.4863	0.0062	97
A117-Al-Wady Al-Sharky Head Regulator	0.3532	0.4863	0.0062	98
A122-Al-Sersawia Head Regulator	0.3532	0.4863	0.0062	99
A106-Salebat Sohag Intermediate Regulator	0.3532	0.4863	0.0062	100
A31-Danshal Intermediate Regulator	0.3532	0.4863	0.0062	101
A114-Kamshesh Intermediate Regulator	0.3492	0.4809	0.0061	102
A101-Al-Neanaia Head Regulator	0.3492	0.4809	0.0061	103
A76-Al-Ganadla Intermediate Regulator	0.3373	0.4645	0.0059	104
A109-Al-Khamseen Intermediate Regulator	0.3373	0.4645	0.0059	105
A43-Al-Boustan Km 28.5 Intermediate Regulator	0.3373	0.4645	0.0059	106
A32-Beltag Intermediate Regulator	0.3373	0.4645	0.0059	107
A95-Naga Tamam Intermediate Regulator	0.3373	0.4645	0.0059	108
A39-Abo Al-Shokouk Intermediate Regulator	0.3333	0.4590	0.0058	109
A133-El-Nagail Head Regulator	0.3294	0.4536	0.0057	110
A86-Takhfeef Sohag Intermediate Regulator	0.3294	0.4536	0.0057	111
A4-Damietta Dam	0.3294	0.4536	0.0057	112
A131-El-Wasta Intermediate Regulator	0.3214	0.4426	0.0056	113
A34-Al-Rahebeen Intermediate Regulator	0.3175	0.4372	0.0055	114
A103-Al-Taref Intermediate Regulator	0.3175	0.4372	0.0055	115
A45-Al-Nasery Rayah Km 82 Intermediate Regulator	0.3135	0.4317	0.0055	116
A134-Mehalet Menouf Intermediate Regulator	0.3095	0.4262	0.0054	117
A81-Zaghlola Head Regulator	0.3095	0.4262	0.0054	118
A64-Al-Badary Intermediate Regulator	0.3095	0.4262	0.0054	119
A137-El-Nagar Head Regulator	0.3095	0.4262	0.0054	120
A111-Menouf Intermediate Regulator	0.3056	0.4208	0.0053	121
A128-Zawiat Al-Bahr Spillway	0.3056	0.4208	0.0053	122
A108-Bahwash Intermediate Regulator	0.3016	0.4153	0.0053	123
A104-Bahr Al-Maash Head Regulator	0.2976	0.4098	0.0052	124
A82-Al-Dalgamon Intermediate Regulator	0.2937	0.4044	0.0051	125
A60-Barhamtoush Intermediate Regulator	0.2937	0.4044	0.0051	126
A89-Baleiana Berdees Km 14.2 Intermediate Regulator	0.2897	0.3989	0.0050	127
A48-Sakola Intermediate Regulator	0.2857	0.3934	0.0050	128
A72-Al-Hassaina Intermediate Regulator	0.2778	0.3825	0.0048	129
A124-Bahr Seif Head Regulator	0.2738	0.3770	0.0048	130
A25-Al-Nasery Rayah Km 71 Intermediate Regulator	0.2698	0.3716	0.0047	131
A80-Eastern Hafez Head Regulator	0.2659	0.3661	0.0046	132
A105-Al-Abd Intermediate Regulator	0.2579	0.3552	0.0045	133
A54-Western Rashedia Head Regulator	0.2341	0.3224	0.0041	134
A49-Mazora Intermediate Regulator	0.2302	0.3169	0.0040	135
A135-Bahr El-Mallah Km 3.9 Intermediate Regulator	0.2183	0.3005	0.0038	136
A110-Gezeirat Al-Hagar Intermediate Regulator	0.2183	0.3005	0.0038	137
A125-Kasr Baghdad Intermediate Regulator	0.2063	0.2842	0.0036	138
A126-Mehalet Marhoom Intermediate	0.1786	0.2459	0.0031	139

Alternatives	**Totals**	**Ideal**	**Normal**	**Ranking**
Regulator				
A71-Mesrea Intermediate Regulator	**0.1508**	**0.2077**	**0.0026**	**140**

Table no A-4: SS1 in CMCDM

Criteria	**Ranking system**					**Structural**	**Hydraulic**	**Env-Soc**	**Weight**
C1	1	2	3	4	5	0	2.5	2.5	5
	IR (small)	HR (small)	IR	HR	MB				
C2	1	2	3	4	5	3	0	0	3
	< 25 or FR < 10	25 to 50 or FR < 25	50 to 75	75 to 100	> 100				
C3	1	2	3	4	5	0	0	4	4
	> 2000 m	1000 to 2000 m	500 to 1000 m	100 to 500 m	< 100 m				
C4	1	2	3	4	5	5	0	0	5
	Not visible	Discrete on abutments	Discrete on abutments and piers	Continuous on abutments and piers	Continuous on vents keystone / roof				
C5	1	2	3	4	5	4	0	0	4
	1st Zone	2nd Zone	3rd Zone	4th Zone	5th Zone				
	(0.1 g)	(0.125 g)	(0.15 g)	(0.2 g)	(0.25 g)				
C6	1	2	3	4	5	3	0	0	3
	Not Visible	Slightly Visible	Discrete Seepage Through One Vent	Minor Seepage and Damaged Revetments	Important Seepage and Poor Revetments				
C7	1	2	3	4	5	1	2	0	3
	<1 m	1 to 2.5 m	2.5 to 4 m	4 to 5.5 m	>5.5 m				
C8	1	2	3	4	5	3	2	0	5
	Low	Below Average	Average	Above Average	High				

IR: Intermediate Regulator, HR: Head Regulator, MB: Main Barrage, FR: Fully Renovated

N. Abdelazim. “Decision Support System to Prioritize Irrigation Structures in Rehabilitation Programs.” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 16, no. 2, 2019, pp. 58-67