Ain Shams Engineering Journal xxx (xxxx) xxx

Contents lists available at ScienceDirect

Ain Shams Engineering Journal

journal homepage: www.sciencedirect.com

Full Length Article

New approach for the rehabilitation of irrigation canals based on implementation priority

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A R T I C L E I N F O

Keyword:
Project Execution Priority
Water Saving
Irrigation Canal lining
Rehabilitation Priority

A B S T R A C T

This study presents a novel method for selecting irrigation canals for rehabilitation based on implementation priorities. The method integrates factors such as canal condition, water demand, environmental considerations, and socioeconomic aspects to identify canals that require immediate attention. The study outlines a step-by-step process and discusses its potential benefits in guiding decision-making for effective canal rehabilitation programs. The methodology explores beneficiaries' satisfaction with their canal performance and applies the "project execution priority index" concept to the network of understudy irrigation canals. Results show that only one of the 11 canals with the highest priority was rehabilitated, while five were executed despite being included in the second priority. Three canals were implemented, and these canals deserve the third priority, indicating the success of the "Project Execution Priority Index" concept in prioritizing field implementation processes. This approach can guide decision-making for effective canal rehabilitation programs and improve the current situation.

1. Introduction

The Egyptian irrigation network spans over 32,000 km in total length [1]. Water loss during the transfer and distribution process is a significant issue due to several fundamental reasons, including: (i) the nature of the soil where open canals are excavated, (ii) the extensive lengths of the canal network, (iii) hot weather and humidity, (iv) the design and geometry of the waterways, (v) improper handling and management of water, (vi) insufficient periodic maintenance and monitoring of the waterways, and (vii) a lack of community and environmental awareness regarding the gravity of water issues and their impacts on various aspects of life [2].

National projects are crucial due to their substantial budgets, extensive efforts, and limited implementation time. To ensure their success, it is important to create a well-designed index sheet that considers all relevant parameters influencing the project's outcomes and expected returns. The Egyptian National Rehabilitation and Lining Project, which is a multidisciplinary development endeavor, involves numerous parameters that influence the order of implementation priorities and locations. From an engineering perspective, it is logical to prioritize areas that are severely distorted and deviated from the intended design conditions, such as those with low hydraulic efficiency and insufficient water reaching the intended destinations. The primary objective of this study is to maximize the benefits derived from the allocated budget and ensure the desired positive effects are achieved as quickly as possible.

Efficiently managing and maintaining irrigation canals is vital for sustainable agriculture and optimal water resource utilization. However, many existing irrigation systems face challenges like inadequate maintenance, aging infrastructure, and limited funds [3,4].

Abbreviations: AASHTO, American Association of State Highway and Transportation Officials; ANP, Analytical Network Process; CSFs, Critical success factors; d_r, Accepted error rate (5–10%); G.I., Group index; L.L., Liquid limit; n_o, The sample size (capita); P.I., Plasticity index; P.L., Plastic limit; PI, The priority index of the canal that can be determined by multiplying each corresponding risk factor (r) from 1 to 5 by the total weight of the item (w); Q_{cal}, Actual-running discharges that can be computed using the measured dimensions of the existing network canal cross-sections; Q_D, The Official design discharges; r, The risk factor from 1 to 5; r_1, Ratio of the rural beneficiaries in the area under study (3.25 million in Assiut) to the total rural beneficiaries in Egypt (57.6 million); RH, Relative Humidity (%); T_{max}, Maximum temperature (°C); T_{min}, Minimum temperature (°C); w, The relative weight from 1 to 3, according to the severity degree of the canal condition; W.S., Wind Speed (Km/h); $Z_{\propto}/2$, The two-tailed area under the normal curve, where $\alpha = 0.05$ and the value is 1.96.

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https://doi.org/10.1016/j.asej.2024.102831
Received 1 January 2024; Received in revised form 8 April 2024; Accepted 17 April 2024

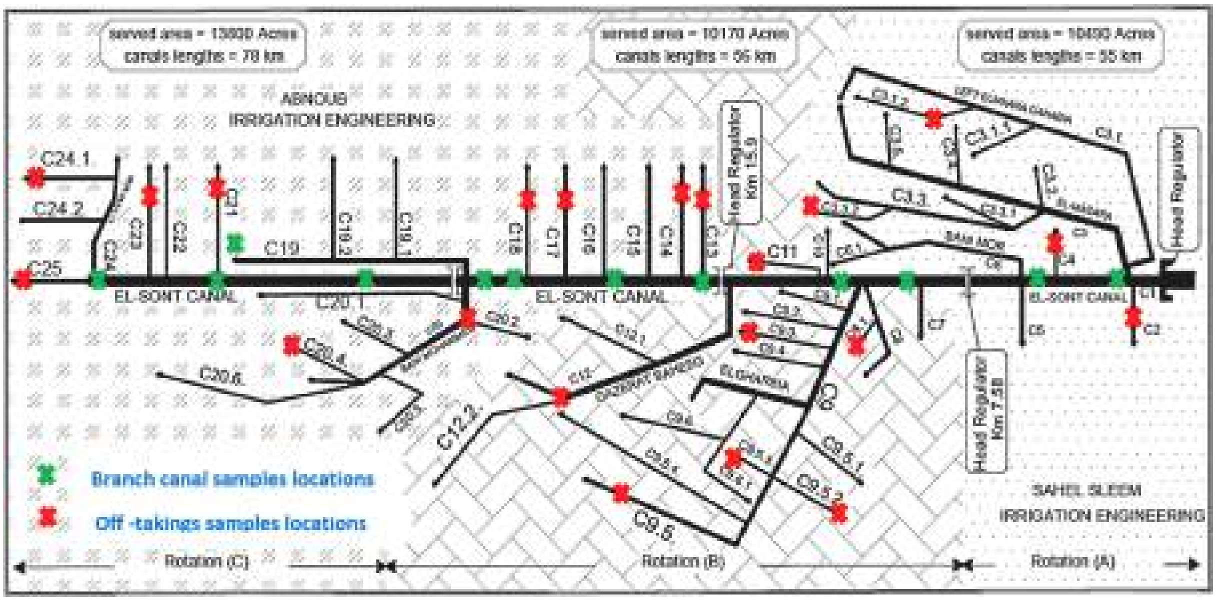


Fig. 1. Sketch for El-Sont Branch canal and its network (irrigation rotations, served area and length).

Fig. 2. Soil sampling from bed.

Fig. 3. Soil sampling from side slope.

Consequently, canals deteriorate, water conveyance capacity decreases, and water distribution becomes inefficient. To tackle these issues, a new approach has emerged: prioritizing and implementing rehabilitation measures for irrigation canals based on implementation priorities. This approach utilizes specific criteria and assessment techniques to guide decision-making. By adopting this approach, irrigation authorities and stakeholders can make the most of their limited resources and effectively rehabilitate canals, improving their performance and lifespan.

The implementation priority-based approach systematically evaluates irrigation canals to identify rehabilitation needs and prioritize interventions [5]. This evaluation involves a comprehensive assessment of factors such as canal condition, water loss, conveyance efficiency, and their impact on regional agricultural productivity. By quantifying these parameters, decision-makers can pinpoint critical areas that need immediate attention and allocate resources accordingly.

The implementation priority-based approach offers a key advantage by addressing urgent issues first and optimizing available resources. By prioritizing critical areas that have a substantial impact on water conveyance and agricultural productivity, the approach ensures that limited resources are allocated where they can have the greatest impact. This targeted approach enhances the overall performance of irrigation systems and proves to be a cost-effective solution compared to a general rehabilitation program [6].

Furthermore, the implementation priority-based approach encourages the involvement of local communities and stakeholders in the decision-making process. By incorporating their input and considering their needs, the approach promotes ownership and sustainability of the rehabilitation efforts. This participatory approach fosters collaboration and empowers local communities to actively contribute to the success of the rehabilitation initiatives. In conclusion, the implementation priority-based approach for rehabilitating irrigation canals offers a systematic and efficient strategy to address the challenges faced by existing systems. By prioritizing interventions based on specific criteria and involving local communities, this approach optimizes resource allocation, enhances canal performance, and promotes sustainable agricultural practices. The successful implementation of this approach can significantly contribute to improving irrigation systems overall, ensuring a reliable water supply for agricultural activities, and supporting the economic development of regions that depend on irrigation.

2. Literature review

The government has allocated a special budget for rehabilitation activities aimed at improving the functionality and physical condition of irrigation canals. Due to budgetary constraints, these activities will be

Table 1
El-Sont branch canal Soil Classification According to AASHTO System.

No.	Results location	Modified L. L.	Value of P. L.	Plasticity index P. I	% Passing from No200	Soil classification	Group index G. I.	Soil type	Depth
	Km 0.3	54.7	45.9	8.9	9	A2-7	0	Clayey sand	All the tested depths
	Km 5	57.8	38.1	19.7	35.6	A7-5	4	Clayey	
	Km 10	38.0	27.1	10.9	35.4	A7-6	2	Clayey	
	Km 16	48.5	29.2	19.3	47.5	A7-5	3	Clayey	
	Km 20.95	55.2	40.9	14.4	35.4	A7-5	3	Clayey	
	km 25.75	54.7	27.9	26.7	46.4	A7-5	5	Clayey	
	km 26	37.5	26.6	10.9	35.0	A7-6	0	Clayey	
	km 33.5	53.1	36.0	17.1	49.7	A7-5	4	Clayey	
	End at km 39.75	39.9	28.5	11.4	36.6	A6	3	Clayey	

Table 2
The off-taking canals' soil classification according to AASHTO system.

No. of canal	Results location	Modified L. L.	Value of P. L.	Plasticity index P. I	% Passing from No200	Soil classification	Group index G.I.	Soil type	Depth
C2	Southern El Nabary	54.7	45.9	8.9	9	A2-7	0	Clayey sand	All the tested depths
C3.1.2	El faiama	48.7	33.4	15.3	36.3	A7-5	1	Clayey	
C4	Elghawayesh	39.9	22.6	17.3	39.7	A6	3	Clayey	
C3.3.2	Elgamasiaa	60.7	32.2	28.6	35.2	A7-5	4	Clayey	
C8.1	Elbaharwa	54.7	26.5	28.2	16.6	A7-6	4	Clayey	
C11	Right Elsont Ganabiat	46.2	31.5	14.7	35.1	A7-5	1	Clayey	
C9.3	Western Elnasara	48.9	34.2	14.7	36.1	A7-5	1	Clayey	
C9.5.3	Diab branch	44.9	25.2	19.7	37.0	A7-6	3	Clayey	
C9.5.2	Bani Zaied	55.4	31.5	23.9	27.1	A2-7	3	Clayey sand	
C9.5	Hablass	60.5	30.5	30.0	15.6	A7-6	4	Clayey	
C12	Baheeg	60.9	38.2	22.7	37.3	A7-5	4	Clayey	
C13	Bani Rezah	54.7	27.9	26.7	27.1	A2-7	3	Clayey sand	
C14	Abnoub branch	40.2	31.9	8.3	35.5	A5	0	Silt	
C17	ElSawalem	48.4	26.0	22.4	25.6	A2-7	2	Clayey	
C18	Elrawatwb	55.3	44.4	10.9	35.8	A7-5	0	Clayey	
C20	Bani mohammed	37.5	26.8	10.8	36.7	A6	1	Clayey	
C20.4	Elmansouraa branch	45.0	26.0	19.0	36.4	A7-6	2	Clayey	
C21	Shakelkeel	41.5	27.7	13.8	17.9	A2-7	1	Clayey sand	
C23	Elmaabda Northern	53.1	35.8	17.3	49.7	A7-5	2	Clayey	
C24.1	Sahel Emaaabdaa	34.7	27.7	6.9	16.3	A2-6	0	Clayey sand	
C25	Emtedad Elsont	39.9	28.7	11.2	39.1	A6	1	Clayey	

carried out in stages. Therefore, it is necessary to analyze the priority of rehabilitation.

Several factors need to be considered when selecting irrigation canals for rehabilitation. One important factor is the need to enhance the conveyance efficiency, reliability, and durability of the system to ensure sustainable and equitable provision of irrigation water [3]. Another factor is the chronic lack of maintenance that has affected many irrigation and drainage systems, leading to insufficient water delivery in canal networks [4].

During the rehabilitation process, it is crucial to identify and address the underlying causes of slope failures in irrigation and drainage canals. These causes may include piping, seepage forces, erosion, and mechanical dredging [5]. Additionally, the economic viability of rehabilitation projects should be assessed, taking into account both the costs and benefits of the project [6]. Lastly, the environmental performance of irrigation systems should be considered, as many existing systems fail to meet modern standards [7].

The selection of irrigation canals for rehabilitation can be optimized by considering several factors. Firstly, conducting a survey of the irrigation commands in different agro-climatic zones can help identify the technical and non-technical factors that limit the performance of canal irrigation systems [8]. Secondly, the design of the irrigation canals should take into account factors such as resistance to temperature change, foundation settlement, and water loss. It has been observed that a new type of light metal plate canal, such as the trapezoid transversely reinforced galvanized steel plate, offers improved structural integrity for irrigation canals [9]. Additionally, it is important to study the causes of water shortages in canal tails and implement rehabilitation measures to enhance hydraulic performance [1]. Finally, the rehabilitation of irrigation systems should be accompanied by a socio-economic profile and technical measures that facilitate their successful implementation [10].

Priority in selecting canals for rehabilitation can be determined by developing a priority list of canal groups. From the highest priority group that has available canals at the time of the service request [11,12], a canal is selected. These priority lists are created based on various interference measurements and tend to remain unchanged for relatively long periods [13]. However, periodic reassessment of the priority lists is necessary to ensure the utilization of the best lists, especially when new construction or seasonal vegetation changes may impact interference [13].

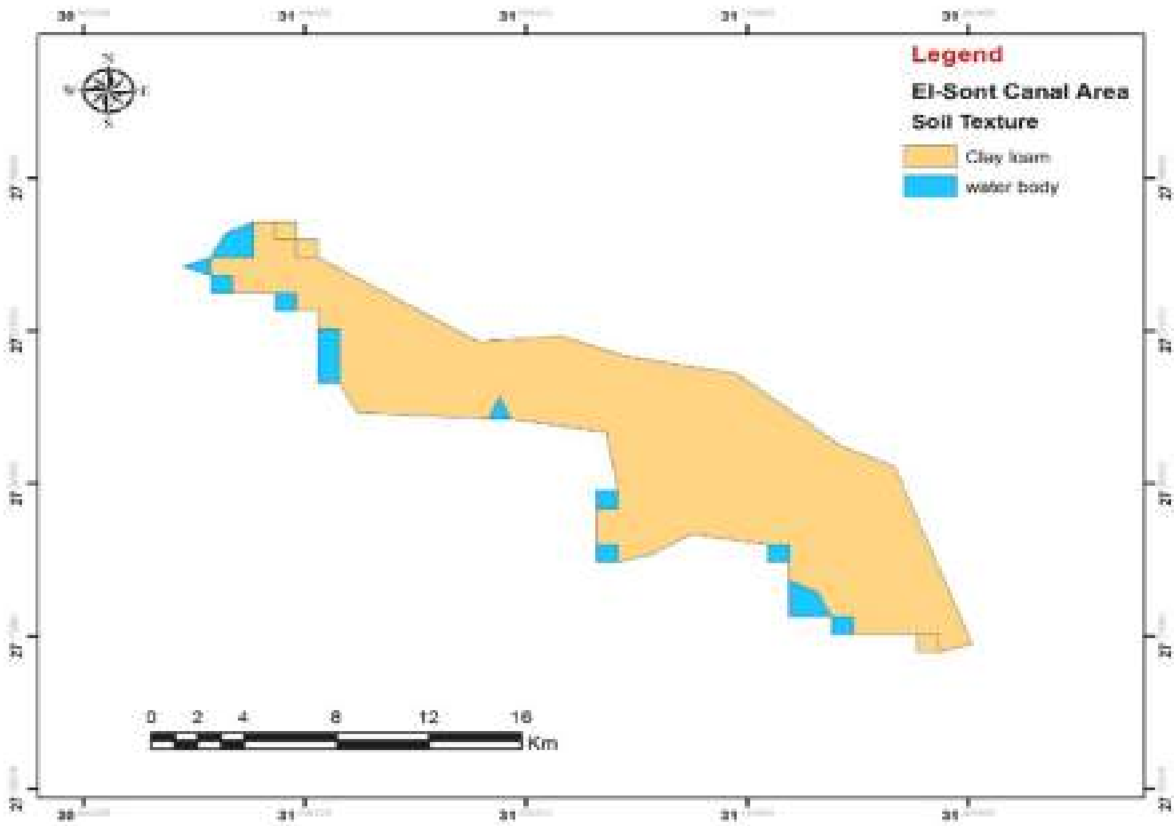


Fig. 4. Map of soil texture of El-Sont canal area (According to FAO Soil Classification).

Table 3
Meteorological data of El-Sont canal and its network (AAMS, 2021) [19] (year 2021).

Month	T max (°C)	T min (°C)	RH %	Wind speed (km/h)	Sunshine (hrs/day)	ETo (mm/ day)
Jan	21.4	**7.1**	**58.9**	13.5	**8.9**	3.73
Feb.	21.6	7.3	57.4	15.9	9.7	4.49
Mar.	27.1	11.3	43.4	18.6	9.9	7.03
Apr.	32	15.1	34.4	17.1	10.3	8.87
May	38	21.1	28.9	18	11.4	11.33
Jun.	36.9	22.3	29.1	**19.3**	**12.3**	**11.63**
Jul.	38.9	24.6	**27.9**	14.7	12.2	10.85
Aug.	**39.1**	24.2	28.1	14.5	11.9	10.55
Sep.	35.2	21.4	39.5	18.1	10.8	9.3
Oct.	32.4	17.6	44.2	14.9	10.0	7.09
Nov.	28.6	13.4	50.7	**9.9**	9.4	4.52
Dec.	20.3	7.7	54.7	10.7	9.0	**3.24**
Average	**31.0**	**16.1**	**41.4**	**15.4**	**10.5**	**7.7**

T max = Maximum temperature (°C).
T min = Minimum temperature (°C).
RH = Relative Humidity (%).
W.S = Wind Speed (Km/h).

When rehabilitating irrigation canals, it is crucial to prioritize the implementation process. One approach is conducting a comprehensive hydraulic design review, which may involve increasing capacity, improving water level control, water distribution, flow measurement, and installing canal performance monitoring equipment [4]. Another method is to assess the physical condition of the irrigation networks and irrigation performance indices to determine maintenance priority. The Analytical Network Process (ANP) method can be used for this purpose, taking into account factors such as irrigation performance indices, area width, irrigation status, estimated cost, and distance from the warehouse to the intake [14].

In addition, rehabilitation and improvement works, including canal lining and water supply expansion, are vital for increasing the actual irrigated area [3]. Lastly, it is recommended to utilize appropriate technologies and rehabilitation techniques, such as on-site concrete casting, precast concrete slabs, and prefabricated membranes, to minimize water leakage from the canals [15].

A project execution priority index is a measure utilized to evaluate the performance and efficiency of a project [16]. It takes into account various factors that influence project performance, including critical success factors (CSFs) [14]. These factors are determined through surveys and expert opinions, and their relative weights are modeled and validated using regression techniques [17]. The index establishes a scientific foundation for resource allocation and decision-making during the project execution phase [18].

The literature indicates that several factors influence the decision-making process regarding rehabilitation. These factors include water availability in the irrigation canals, the performance of the canals, co-ordination between farmers, irrigation engineers, and technicians, soil characteristics, canal lengths, weather conditions, humidity levels, canal geometry, water management practices, periodic maintenance, follow-up procedures, and the need for lining.

Therefore, the current research aims to apply the concept of the “project execution priority index” to the irrigation canal network under study. This concept will be applied using the collected and measured data from the canals. The objective is to assess whether the implementation has been carried out appropriately in terms of priority, starting with the most influential canals among those covered by the rehabilitation project in each area. This study introduces a novel method that considers multiple factors to identify canals with the highest implementation priorities.

Table 4
Results of the questionnaire for the three irrigation rotations.

No.	Question	Rotation (A)			Rotation (B)			Rotation (C)		
		Agree	Not all the time	Disagree	Agree	Not all the time	Disagree	Agree	Not all the time	Disagree
Axis (1) Water availability in the irrigation canals										
1	Water reaches the end of the canal in sufficient quantity.	15	8	7	4	11	19	5	13	16
2	Water is available during the entire irrigation rotation.	20	7	3	7	19	8	4	17	13
3	The time of irrigation rotation is enough.	14	12	4	5	18	11	2	19	13
4	Irrigation is done by pumping.	30	0	0	34	0	0	34	0	0
5	Irrigation is done by gravity.	0	0	30	0	0	34	0	0	34
6	The adjacent lands to the canal are drowned during the irrigation rotation.	4	5	21	0	0	34	1	7	26
Axis (2) Performance of the irrigation canals										
7	Irrigation occurs during daylight only.	4	9	17	2	8	24	0	25	9
8	The water is available in the canal during daylight and at night.	26	3	1	28	6	0	22	12	0
9	Do you prefer irrigation during daylight?	7	21	2	8	26	0	26	8	0
10	The canal suffers from floating weeds or garbage.	18	10	2	29	4	1	25	5	4
11	The canal suffers from weeds on both sides.	23	7	0	30	4	0	31	3	0
Axis (3) Coordination between farmers and irrigation engineers/technicians										
12	Coordination is made with the technician for the canal periodically.	10	13	7	9	17	8	6	23	5
13	The irrigation engineer is in contact with you periodically.	7	10	13	6	10	18	11	18	5
14	The canal's periodical maintenance is done.	13	13	4	3	16	15	3	19	12
Axis (4) The need for lining										
15	Do you hope that the canal is lined?	30	0	0	32	1	1	34	0	0
Axis (5) Additional requirements										
16	Do you have any other things you wish to be added to the rehabilitation process?									
	Road Expansion	41								
	Trash box	20								
	Gate maintenance	23								

3. Characteristics of the study area

3.1. Site and location

The current research focuses on the El-Sont canal and its network, which serves as a representative canal for the Assiut countryside in Middle Egypt. The majority of this network is involved in a national canal lining and rehabilitation project. The canal originates at km 157 on the right bank of the Eastern Nag-Hamadi main canal, situated on the eastern side of the Nile. It extends approximately 40 km to the north and covers a total area of about 14,296.8 ha. This area is divided between Abnoub (9,891 ha) and Sahel-Seleem (4,405.8 ha), both of which fall under the jurisdiction of the Assiut Governorate's official irrigation engineering administration [19]. The combined length of the off-taking canals is approximately 149.16 km.

3.2. Soil classification

Soil samples were collected along the path of the canal to assess its characteristics. Sampling took place at intervals of five kilometers along the branch canal, specifically at km 2, 7, 12, 17, 23, 28, 33, and 38, as illustrated in Fig. 1. Additionally, one sample was taken for each off-taking canal. The collected samples were obtained from various depths, including 0.5, 1, and 1.5 m, both from the bed and side slopes of each canal location, as depicted in Figs. 2 and 3.

After conducting sieve analysis, the soil samples were classified according to the American Association of State Highway and Transportation Officials (AASHTO) [20]. The sieve analysis tests were carried out for all the soil samples, along with tests for liquid limit (L.L.), plastic limit (P.L.), and plasticity index (P.I.). Additionally, the group index (G.I.) was determined. Based on the results of these soil tests, the soil of the El-Sont branch canal and its off-takings can be classified according to the AASHTO system, as shown in Tables 1 and 2.

From Tables 1 and 2, it is clear that all of the soil samples from the El-Sont branch canal are classified as clayey soils, with a group index (G.I.) ranging between zero and 5. Additionally, the majority of the soil samples from the off-takings are also clayey soils, with a group index ranging from 0 to 4. Five off-takings pass through clayey sand soil, most of which are adjacent to the desert lands. In addition to analyzing the soil samples collected from the field, soil classification analysis is verified using remote sensing and the GIS technique. Mapping is performed using ArcGIS 9.2 software. In the study area, the upper soil texture is predominantly clay loam up to 30 cm, while the subsoil is clay (light), as illustrated in the map shown in Fig. 4.

The permeability of the soil depends on several factors, including fluid viscosity, pore size distribution, grain size distribution, roughness of mineral particles, void ratio, and degree of saturation. In the laboratory, there are two tests for determining soil permeability. The constant head permeability test is used for permeability measurement of granular soils, while the falling head permeability test is employed for fine-grained soils such as silts and clays. The results showed that the permeability coefficient of clayey soil ranges from 0.000085 to 0.000986 cm/s, whereas for sandy soil, it varies between 0.00013 and 0.0028 cm/s. Additionally, the study determined various parameters and coefficients used in the empirical equations relevant to the research.

3.3. Weather and humidity

The study area is characterized by an arid climate, with the elevation of the agricultural land being 48 m above mean sea level. Based on meteorological data obtained from the Arab-Alawamer official meteorological station, the recorded sheets indicate that the maximum

Table 5
Priority index weights for the different parameters of the rehabilitation project.

No	Canal condition	Basis for determining the risk factor (r)			Relative weight (w)[***]	Priority Index ($P_I = w \times r$)	Notes	Priority order
		Range	value					
1	Degree of cross – sections Deformations	Widening	Narrowing		3		Estimated by the percentage of deformation = (change in the existing wetted perimeter / original wetted perimeter)	First
		0—2.24◆	0–1.36◆	1				
		2.24–4.48	1.36–2.72	2				
		4.48–6.72[c]	2.72–4.08	3				
		6.72–8.69	4.08–5.44	4				
		8.69–11.2	5.44–6.8	5				
2	Degree of irrigation water to reach the canal end	0—0.51		1	3		Measured by the relative depth of water = (existing water depth at the end/design depth) compared to other canals in the same studied area	
		0.51–1.02		2				
		1.02–1.53		3				
		1.53–2.04		4				
		2.04–2.57		5				
3	Value of seepage losses/ canal unit length	0—0.82		1	3		According to soil type or (seepage amount/canal unit length) Compared to other canals in the same studied area	
		0.82–1.64		2				
		1.64–2.46		3				
		2.46–3.28		4				
		3.28–4.1		5				
4	Weeds length and its density along the canal stream	0—0.22		1	3		Measured by the percentage of (affected length/ canal length) compared to other canals in the same studied area	
		0.22–0.44		2				
		0.44–0.66		3				
		0.66–0.88		4				
		0.88–1.1		5				
5	Canal served area	0—0.51		1	3		Depending on the size of the area served (feddan), Compared to other canals in the same studied area	
		0.51–1.02		2				
		1.02–1.53		3				
		1.53–2.04		4				
		2.04–2.55		5				
6	Cost of rehabilitation process for the served area	1.42–1.58		1	2		According to type and Measured by the cost/km Compared to other canals in the same studied area	Second
		1.26–1.42		2				
		1.1–1.26		3				
		0.94–1.1		4				
		0.78–0.94		5				
7	Beneficiaries Documented complaints	**		1	2		Percentage of complaints from beneficiaries compared to other canals in the same studied area,	
		**		2				
		**		3				
		**		4				
		**		5				
8	Water quality (sewage)	**		1	2		It is measured by the amount of BOD in the water. Compared to other canals in the same studied area,	
		**		2				
		**		3				
		**		4				
		**		5				
9	Groundwater level	*		1	2		It is measured by the percentage of ground water depth above the bed or canal water depth compared to other canals in the same studied area,	
		*		2				
		*		3				
		*		4				
		*		5				
10	Length of the canal passing through housing of residential areas	**		1	1		It is measured by the percentage of (passing length/ canal length). Compared to other canals in the same studied area, Rehabilitation appropriate to the situation	Third
		**		2				
		**		3				
		**		4				
		**		5				
11	Agricultura drainage system performance and efficiency	*		1	1		Measured by the efficiency of the drainage system compared to other canals in the same studied area,	
		*		2				
		*		3				
		*		4				
		*		5				
12	Distance between canal intake, and the beginning of feeding canal	0—0.2		1	1		It is measured by the ratio of (the length from the head of the feeding canal to the intake/length of the feeding canal).	
		0.2–0.4		2				
		0.4–0.6		3				
		0.6–0.8		4				
		0.8–1		5				
13	Applied irrigation system	*		1	1		According to the used type (The mostly need water have the highest level) Compared to other canals in the same studied area,	
		*		2				
		*		3				
		*		4				
		*		5				
14	Irrigation works condition and efficiency (Intake, spillway, syphon, culvert…etc)	**		1	1		According to the performance conditions and compared to other works of canals in the same studied area,	
		**		2				
		**		3				
		**		4				
		**		5				

* All use the same irrigation system.

** Uncovered in the study.

*** According to the severity degree in the studied area.

◆ Calculated as: $\left(\frac{\text{level value}}{\text{Total number of assumed levels} = 5}\right) \times$ Max. value of change.

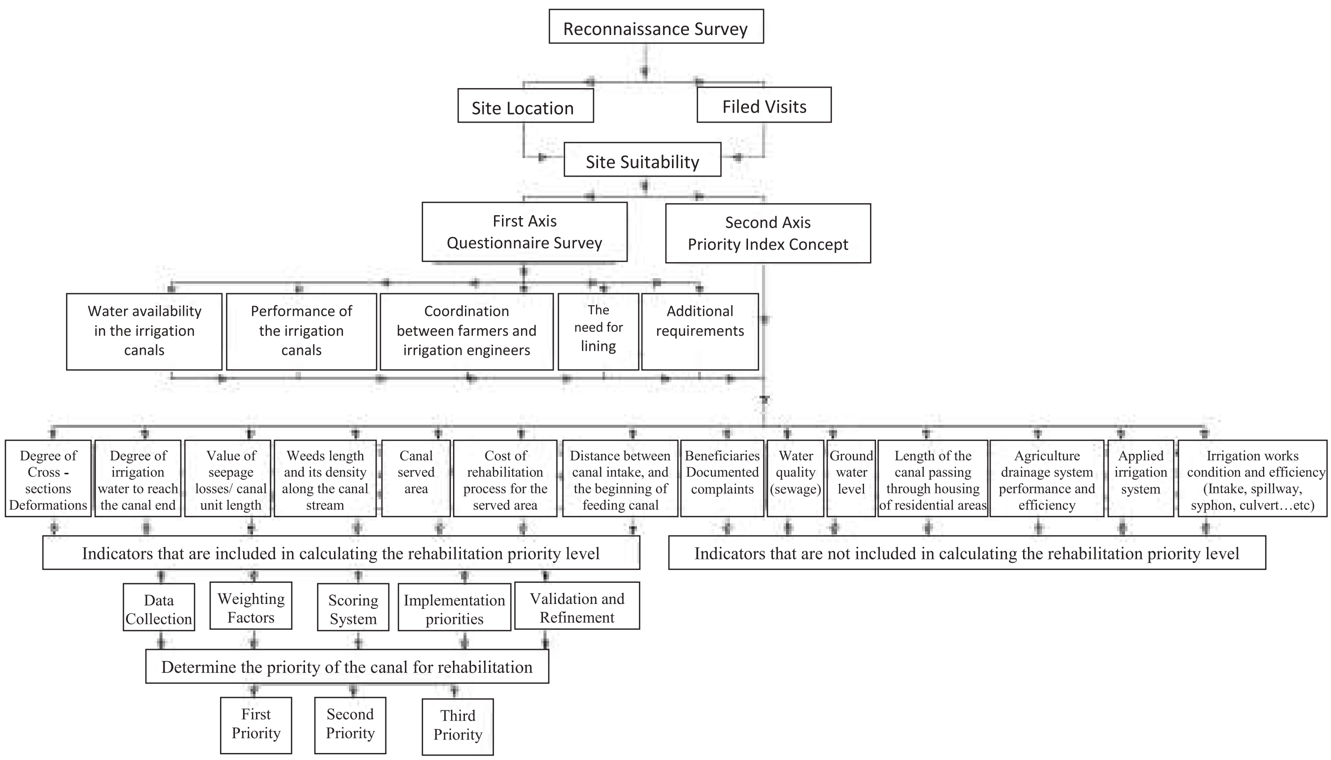


Fig. 5. Technical road map of research methodology.

temperature in the study area reaches 39.1 °C, while the minimum temperature is approximately 7.1 °C. The maximum humidity is 58.9 %, with the minimum being 27.9 % [21]. The weather data for the understudy canal area in the year 2021 are presented in Table 3.

3.4. Irrigation systems

The irrigation system utilized in the study area is the flood irrigation system. The network is divided into three irrigation rotations, with each rotation consisting of five days of work followed by ten days off. The first irrigation rotation (A) starts at the head and extends up to km 7.58. The second rotation (B) spans from km 7.58 to km 15.94. The third rotation (C) covers the distance from km 15.94 to the terminus of the canal [19]. The served area and the length of each irrigation rotation are illustrated in Fig. 1.

4. Methodology and used data

The research methodology will proceed along two main axes. The first axis involves exploring the satisfaction of the beneficiaries with the performance of their canals. This axis was chosen to identify the actual problems that hinder canal performance. The second axis utilizes collected and measured data from irrigation canals to apply the project execution priority index to the case study network. The objective is to maximize yield and optimize the use of available irrigation water.

4.1. Questionnaire survey

The current national lining and rehabilitation project for the distorted traditional irrigation system has had tangible impacts on the lives of millions of Egyptian farmers. These impacts primarily include: i) reduction of water losses after rehabilitation; ii) increased conveyance efficiency in the improved irrigation networks; and iii) improved environmental conditions. Identifying the extent of conviction and satisfaction among the beneficiaries of this national project is considered an essential part of its success and progress. To explore the extent of beneficiaries' satisfaction, a carefully designed questionnaire form has been developed to monitor their impressions of the situation before and after the project's implementation. The questionnaire also recorded the most significant defects or disadvantages that have negatively affected their daily lives. It also covers their level of satisfaction with the achievements made after completing the project in certain canals and whether it has met their aspirations. To illustrate the questions included in the prepared survey questionnaire, the following five specific axes are covered:

1) Water availability in the irrigation canals
2) Performance of the irrigation canals.
3) Coordination between farmers and irrigation engineers and technicians
4) The need for lining
5) Additional requirements.

Table 6
Geometric dimension for the water sections of El-Sont canal and its network and the calculated discharge.

No. of canal	Canal Name	Section		Bed Width (m)	Side Slope	Water Depth (m)	Discharge (m^3/S)		No. of canal	Canal Name	Section		Bed Width (m)	Side Slope	Water Depth (m)	Discharge (m^3/S)	
		From Km	To Km				Q_D	Q_{cal}			From Km	To Km				Q_D	Q_{cal}
1	El-Sont (sahel sleem)	0	7.6	12	3:2	2.6	21.8	15.37	9.5.1	Elakrad Branch	0	1.8	1	1:1	1	0.17	0.25
	El-Sont (abnoub)	7.6	15.94	11	3:2	2.6	17.62	13.73	9.5.2	Bani Zeid Branch	0	2	1.5	1:1	0.85	0.22	0.14
		15.94	23.2	9	3:2	2.6	17.62	12.76	9.5.3	Diab Branch	0	0.9	1	1:1	0.9	0.1	0.06
		23.2	26.4	8	3:2	2.35	15.33	9.54	9.5.4	Hablas Elgadida	0	4.8	2	1:1	1.58	1.02	1.3
		26.4	34.12	7	3:2	1.9	6.64	5.04	9.6	Hoshet Eltwabia	0	1.1	2	1:1	1.1	0.47	0.51
		34.12	39.9	5	3:2	1.4	5.76	4.11	9.6.1	Eltwabia Southern Branch	0	2.25	2	1:1	1	0.27	0.21
2	Sothern Elnabary	0	3.2	1	1:1	1	0.35	0.98	10	Kom Abo Shail Branch	0	1	1	1:1	0.9	0.4	0.55
3	Elmaasara	0	3.6	4	1:1	2.4	6.76	3.86	11	Right Southern Elsont Ganabiat	0	3	2	1:1	0.85	0.6	0
		3.6	6.98	3	1:1	1.75	3.98	3.86	12	Baheege	0	2.4	4	3:2	1.5	2.71	1.45
		6.98	8.8	2	1:1	1.5	1.64	3.86			2.4	4.5	3	3:2	0.9	2.1	1.25
3.1	Left Elmaana	0	5	3	1:1	1.85	2.7	1.92			4.5	6.3	2	3:2	0.75	0.4	0.55
	Ganabia	5	8.8	2	1:1	1.6	2.35	1.7	12.1	Abo Amera	0	1.9	2	1:1	1.4	0.55	0.42
		8.8	10.45	1	1:1	1.15	0.82	0.25	12.2	Elkhalifaa	0	1	1.5	1:1	1.2	0.35	0.56
3.1.1	Serage Banch	0	2	1	1:1	0.8	0.35	0.46	13	Bani Rezah	0	2.6	2	1:1	1.1	0.42	0.27
3.1.2	Elfaiama Branch	0	4	1	1:1	1	0.71	0.2	14	Abnoub Branh	0	2	1	1:1	0.75	0.47	1
3.2	Amro Branch	0	2.4	1	1:1	0.9	0.27	0.42	15	Elkadadeh Western Branch	0	2.2	1.5	1:1	1	0.93	0.31
3.3	Salebat Elmaasara Ganabia	0	1.3	4	1:1	1.4	1.52	1.02	16	Bani Ibrahem Western Branch	0	2.3	1	1:1	1.1	0.47	0.2
		1.3	4.34	3	1:1	1.18	1.25	1.02	17	Elsawalem Southern Branch	0	2	1	1:1	0.95	0.6	0.22
		4.34	5.4	2.5	1:1	1.1	0.85	0.8	18	Elrawateb Branch	0	1.25	1	1:1	0.85	0.38	0.2
		5.4	6.7	2	1:1	1	0.5	0.4	19	Right Northern Elsont	0	3.3	4	3:2	1.5	3.25	1.44
3.3.1	Elmanshia Branch	0	1.4	1	1:1	0.8	0.27	0.3		Ganabiat	3.3	5.7	2	3:2	1.15	1.7	0.95
3.3.2	Elgamasea Branch	0	2.1	1	1:1	0.9	0.39	0.5	19.1	Elsihabia Branch	0	2.05	1	3:2	1.3	1	1.44
3.4	Elqasr Branch	0	1.14	1	1:1	0.9	0.27	0.85	19.2	Asham Allah	0	1.6	1	3:2	1	0.5	0.64
3.5	Elquata Branch	0	1.36	1	1:1	0.75	0.26	0.28	20	Bani Mohamed	0	0.38	5	3:2	1.45	4.47	1.92
4	Elghwaish Branch	0	1.3	1	1:1	0.75	0.21	0.15			0.38	3.7	4	3:2	1.3	3.34	1.41
5	Elnabari Alwasta	0	2.45	1	2:1	1	0.35	0.98			3.7	6.4	3	3:2	1.2	2.09	1.3
6	Bani Mor	4.5	5.2	3	1:1	1.5	2.04	1.23	20.1	Left Northern Elsont Ganabiat	0	2.55	2	1:1	1	0.79	0.28
		5.2	6.3	2	1:1	1	1	0.83	20.2	Elmarwna	0	1.1	1.5	1:1	1	0.23	0.3
6.1	Quernaw Branch	0	1.42	2	1:1	0.75	0.27	0.2	20.3	Sahel Elaqab	0	1.3	1	3:2	1	0.31	0.16
7	Gazerat Bani Mor	0	1.6	1.5	3:2	1	0.4	0.64	20.4	Abo Diab Branch	0	1.7	1	1:1	1	0.63	0.21
8	Sahel Bani Mor	0	2.65	1.5	2:1	1	0.73	0.24	20.5	Elmansora Western Branh	0	1	1	1:1	0.85	0.4	0.32
8.1	Elbaharwa	0	1.3	1	1:1	0.75	0.15	0.1	20.6	Sahel Bani Mohammed	0	4.5	2.5	3:2	0.9	1.04	0.74
9	Elgharbia	0	2	4	3:2	1.75	4.62	4.12	21	Shaqequel	0	2	2.5	1:1	1.1	0.88	0.5
		2	5.99	2.5	1:1	1	2.47	3.31	22	Elmaabda Sothern Branch	0	1.25	1	1:1	1	0.5	0.11
9.1	Hoshet Kom Aboshil	0	1.65	1	1:1	0.75	0.1	0.21	23	Elmaabda Northern Branch	0	2.8	2	1:1	1.25	1.5	0.52
9.2	Ali Bek	0	2.1	1	1:1	0.9	0.35	0.29	24	Elshikh Saed Branh	0	1.2	3	1:1	1.2	1.88	1.34
9.3	Western Elnasara	0	3.75	2	1:1	1.65	0.85	0.21	24.1	Abo Meshel	0	1.1	1	1:1	0.75	0.28	0.28
9.4	Eastern Elnasara	0	3	2	1:1	1.7	0.85	0.61	24.2	Sahel Elmaabda	0	2.3	2	1:1	0.75	0.76	0.37
9.5	Hablass	0	5	2	1:1	1.4	1	1.3	25	Emtedad Elsont	0	2	2	3:2	1.3	0.85	0.45

Fig. 6. Measurements of the velocity in El-Sont branch canal at km 1.00.

Fig. 7. The used current meter type G269.

On the other hand, only a few studies have relied on statistical methods to select a sample for survey questionnaires. For example, Rahi et al. [22] and Marzouk [23] recommend utilizing the following Tomas Simson equation (1) to calculate the appropriate size of a random sample from a homogeneous study community with a high degree of accuracy.

$$n_o = \frac{\left[\left(\frac{Z_\infty}{2}\right)^2 * r * (1 - r_1)\right]}{{d_r}^2} \tag{1}$$

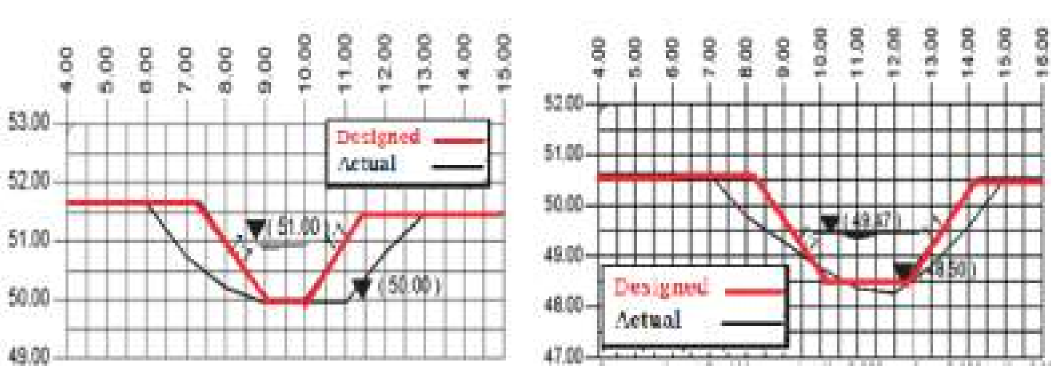
Where;	
n_o	The sample size (capita)
$Z_\infty/2$	The two-tailed area under the normal curve, where α = 0.05 and the value is 1.96
r_1	Ratio of the rural beneficiaries in the area under study (3.25 million in Assiut) to the total rural beneficiaries in Egypt (57.6 million) [24]
d_r	Accepted error rate (5–10 %)

By using the aforementioned equation for the El-Sont canal network (the area under study), the estimated appropriate sample size is 82 participants. The study involved a total of 123 participants, with 98 participants from unlined canals and 25 participants from lined canals within the study area. A summary of the sample results is presented in Table 4 for irrigation rotations (A, B, and C). The following section provides a separate analysis of each axis of the survey questionnaire.

4.2. Priority index concept

This section presents the step-by-step process of the proposed method for selecting irrigation canals for rehabilitation based on implementation priorities:

a. **Data Collection**: Gathering comprehensive data is the first step in the methodology. This includes information on canal conditions, such as sedimentation levels, structural integrity, and seepage losses. Additionally, data on water demand, crop types, environmental factors, and socioeconomic aspects should be collected.
b. **Weighting Factors**: Assigning weights to various factors is crucial to reflecting their relative importance. This step involves consulting experts and stakeholders to determine the significance of factors such as canal condition, water demand, environmental impacts, and socioeconomic considerations. A weighting system is developed to incorporate these different factors effectively.
c. **Scoring System**: A scoring system is developed to evaluate each canal based on the identified factors. This involves assigning scores to each canal for each factor, considering the collected data and the



a) Cross section of Kom AboShail canal at km 0.200 *b) Cross section of Gazrt BaniMor canal at km1.0*

Fig. 8. Widening in the cross sections of some canals.

Table 7
Calculation of the degree of risk factor for cross-section deformations (increase or decrease).

No. of canal	Canal Name	Wetted perimeter area (m^2)		Increase in existing wetted perimeter area		Index=	Degree	No. of canal	Canal Name	Wetted perimeter area (m^2)		Increase in existing wetted perimeter area		Index=	Degree
		Design	Existing	Value (m^2)	%	[(4)/average of (4)]				Design	Existing	Value (m^2)	%	[(4)/average of (4)]	
2	Southern Elnabry	12,251	21,120	8869	72.4	6.7	2	11	Southern Ganabia Elsont Right	13,212	0	0	0	0	1
3.1.1	Serage Branch	5475	83.9	5475	83.9	7.8	4	12.1	Aboamera	11,324	2901	−2186	−19.3	−1.8	2
3.1.2	Elfaiama Branch	914	96	−914	−6	−0.6	1	12.2	Elkhalifa	4894	5076	182	3.7	0.3	1
3.2	Amro Branch	8509	3011	3011	35.4	3.3	2	13	Bani Rezah	13,289	14,288	999	7.5	0.7	1
3.3.1	Elmanshia Branch	4568	5880	1312	28.7	2.7	2	14	Abnoub	6243	12,222	5979	95.8	8.9	4
3.3.2	Elgamsia Branch	7446	12,600	5154	69.2	6.4	3	15	Western Elkadadeeh	9523	10,772	1249	13.1	1.2	1
3.4	Elqasr Branch	4042	6840	2798	69.2	6.4	3	16	Bani Ibraheem	9456	9730	274	2.9	0.3	1
3.5	Elquata Branch	4245	6528	2283	53.8	5	3	17	Southern Elswalem	7374	7693	319	4.3	0.4	1
4	Elghawaish Branch	4058	3900	−158	−3.9	−0.4	1	18	Elrwateb	4255	4647	392	9.2	0.9	1
5	Elnabary Elwasta	13,407	21,120	7713	57.5	5.3	3	19.1	El Shihabiaa	11,659	10,833	−826	−7.1	−0.7	1
6.1	Qernaw Branch	5852	5112	−740	−12.6	−1.2	1		Ashamallah	6125	0	0	0	0	1
7	Gazerat Bani Mour	8169	8777	608	7.4	0.7	1	20.1	Left Northern Ganabiat Elsont	12,312	10,989	−1323	−10.7	−1	1
8.1	Elbaharwaa	4058	3617	−441	−10.9	−1	1	20.2	Al Marawna	4761	4244	−517	−10.9	−1	1
9.1	Hoshat Koumaboshail	5150	2972	−2178	−42.3	−3.9	2	20.3	Sahel Elakob	5987	8244	2257	37.7	3.5	2
9.2	Ali Beik	7446	8878	1432	19.2	1.8	1	20.4	Abo Diab	6508	6323	−185	−2.8	−0.3	1
9.3	Western Elnassara	25,001	16,582	−8419	–33.7	−3.1	2	20.5	Western Elmansoura	3404	4338	934	27.4	2.5	2
9.4	Estern Elnasaraa	20,425	16,782	−3643	−17.8	−1.7	1	20.6	Sahel Bani Mohammed	25,852	25,714	−138	−0.5	0	1
9.5.1	Elakraad	6891	6414	−477	−6.9	−0.6	1	21	Shakalkeel	11,223	9103	−2120	−18.9	−1.8	2
9.5.2	Bani Zeid	7808	10,950	3142	40.2	3.7	2	22	Southern Elmaabda	4786	3323	−1463	−30.6	−2.8	3
9.5.3	Diab Branch	3191	2000	−1191	−37.3	−3.5	2	23	Northen Elmaabda	15,499	16,289	790	5.1	0.5	1
9.5.4	New Hablass	31,051	31,770	719	2.3	0.2	1	24.1	Abo Meshel	3433	4185	752	21.9	2	1
9.6.1	Southern Etwabia	17,032	4492	−12540	−73.6	−6.8	5	24.2	Sahel Elmaabdaa	9479	11,166	1687	17.8	1.7	1
10	Koum Aboushail	3546	7811	4265	120.3	11.2	5	25	Emtdad Elsont	13,374	4752	−8622	−64.5	−6	5

Fig. 9. Infringement of the residential around the canals' stream.

Fig. 10. Weeds block the stream of Bani Mohamed canal.

assigned weights. The scoring system provides an objective measure to compare the canals and prioritize them accordingly.

d. **Implementation Priorities**: The next step involves ranking the canals based on their scores. Canals with higher scores indicate higher implementation priorities for rehabilitation. The ranking allows decision-makers to identify the channels that require immediate attention and allocate resources accordingly.
e. **Validation and Refinement**: The proposed method should be validated and refined through case studies or pilot projects. The results obtained from real-world applications can help improve the accuracy and reliability of the method, ensuring its practicality in different contexts.

4.3. Use of the collected and measured data of irrigation canals

The 'project execution priority index' sheet, as introduced in Table 5, is utilized to maximize the use of collected and measured data on the El-Sont canal and its network, covering all parameters related to its working efficiency and hydraulic performance. A survey and management interviews were conducted to analyze the damage to the irrigation canal, embankment, road, and discharge measurement structure. Secondary data, such as area and water availability, were collected from the Water Resources Department at Assiut.

Baker et al. [25] provided the principles of indexing and a mathematical explanation on which the basis for calculating the risk factor (r) in Table 5 is obtained in a dimensionless form using the following equation:

$$r = (\text{Measured variable for a canal}) / (\text{Average variable for all canals}) \quad (2)$$

Canals with a very low risk factor (r) indicate that they are less affected by this negative parameter compared to other canals. On the other hand, canals with the highest risk factor (r) indicate a high degree of impact due to this parameter. Each relative weight (w) assigned to the priority order is divided into 5 levels of condition severity (r). The difference between each sequential level is calculated as the largest risk factor for the under-study canal condition divided by the number of chosen levels, which in this case is five. As a result, each severity level is assigned a value from 1 to 5 based on the canal condition.

In Table 5, each priority order was assigned an assumed relative weight (w) from 1 to 3, based on the severity degree of the canal condition. The largest value of the assumed relative weight (w), 3, indicates the highest degree of distortion and the urgent need for rehabilitation, which is classified as the first priority. The lowest value of the assumed relative weight (w) is 1, indicating a less severe condition of the canal, and accordingly, it may be assigned the third (last) priority. The parameters involved in the first priority are: degree of canal cross-section distortion, degree of reaching irrigation water to the ends of the canals, value of seepage losses per unit length of the canal, length of weeds and their density along the canal, and canal-served area. Factors with the least effect and included in the third priority are: agricultural drainage system performance efficiency, distance between the canal intake and the beginning of the feeding canal, applied irrigation system, irrigation work conditions (intake, spillway, siphon, culvert, etc.), and length of the canal passing through residential areas.

The priority index (PI) of the canal can be determined by multiplying each corresponding risk factor (r) ranging from 1 to 5 by the total assigned weight of the item (w). As a result, the priority order of each effect parameter can be established. By adding up the values obtained for all the parameters associated with each canal, we can determine the sum, and the canal with the highest value of (PI) will be assigned the first priority order.

A guide chart has been prepared to show the sequence of procedures to be followed when studying the case of any canal, as depicted in Fig. 5. The priority degree for rehabilitation is determined using Table 5, taking into account the risk factor, relative weight, and priority index. Additionally, Fig. 5 was designed to serve as the main guide frame for irrigation engineers, experts, researchers, and decision-makers in order to determine priorities for lining irrigation canals when extending the study to other countries or regions.

4.3.1. Degree of canal cross- sections distortion

Table 6 provides a summary of the dimensions and engineering properties of the cross and longitudinal sections of the Branch Canal, as well as its off-takes. The flow meter, specifically an electromagnetic current meter, was utilized to measure the velocity of irrigation water in the exiting earthen canals, as depicted in Figs. 6 and 7. To obtain acceptable values for comparison with the official design discharges, actual running discharges were computed using measured dimensions, considering observed distortions in the existing network canal cross-

Table 8
Calculation of the degree of risk factor for water reaching the ends of the canals.

No. of canal	Canal Name	Water Depth (m) −1	Existing Depth(m) −2	D_d-D_e (3)= [(1)-(2)]	Index = [(3)/ average of (3)]	Degree	No. of canal	Canal Name	Water Depth (m) −1	Existing Depth(m) −2	D_d-D_e (3)= [(1)-(2)]	Index = [(3)/ average of (3)]	Degree
2	Sothern Elnabary	1	1.45	−0.45	0	1	11	Right Southern Elsont Ganabiat	0.85	0	0.85	1.85	4
3.1.1	Serage Banch	0.8	1.1	−0.3	0	1	12.1	Abo Amera	1.4	0.48	0.92	2	4
3.1.2	Elfaiama Branch	1	0.6	0.4	0.87	2	12.2	Elkhalifaa	1.2	0.89	0.31	0.67	2
3.2	Amro Branch	0.9	0.8	0.1	0.22	1	13	Bani Rezah	1.1	0.53	0.57	1.24	3
3.3.1	Elmanshia Branch	0.8	0.55	0.25	0.54	2	14	Abnoub Branh	0.75	0.99	−0.24	0	1
3.3.2	Elgamasea Branch	0.9	1.1	−0.2	0	1	15	Elkadadeh Western Branch	1	0.65	0.35	0.76	2
3.4	Elqasr Branch	0.9	1.2	−0.3	0	1	16	Bani Ibrahem Western Branch	1.1	0.5	0.6	1.3	3
3.5	Elquata Branch	0.75	0.7	0.05	0.11	1	17	Elsawalem Southern Branch	0.95	0.59	0.36	0.78	2
4	Elghwaish Branch	0.75	0.4	0.35	0.76	2	18	Elrawateb Branch	0.85	0.61	0.24	0.52	1
5	Elnabari Alwasta	1	1.45	−0.45	0	1	19.1	Elsihabia Branch	1.3	1	0.3	0.65	2
6.1	Quernaw Branch	0.75	0.6	0.15	0.33	1	19.2	Asham Allah	1	0	1	2.17	5
7	Gazerat Bani Mor	1	0.84	0.16	0.35	1	20.1	Left Northern Elsont Ganabiat	1	0.51	0.49	1.07	3
8.1	Elbaharwa	0.75	0.19	0.56	1.22	3	20.2	Elmarwna	1	0.73	0.27	0.59	2
9.1	Hoshet Kom Aboshil	0.75	0.86	−0.11	0	1	20.3	Sahel Elaqab	1	0.2	0.8	1.74	4
9.2	Ali Bek	0.9	0.82	0.08	0.17	1	20.4	Abo Diab Branch	1	0.63	0.37	0.8	2
9.3	Western Elnasara	1.65	0.47	1.18	2.57	5	20.5	Elmansora Western Branh	0.85	0.67	0.18	0.39	1
9.4	Eastern Elnasara	1.7	0.7	1	2.17	5	20.6	Sahel Bani Mohammed	0.9	0.6	0.3	0.65	2
9.5.1	Elakrad Branch	1	0.67	0.33	0.72	2	21	Shaqequel	1.1	0.69	0.41	0.89	2
9.5.2	Bani Zeid Branch	0.85	0.36	0.49	1.07	3	22	Elmaabda Sothern Branch	1	0.24	0.76	1.65	4
9.5.3	Diab Branch	0.9	0.22	0.68	1.48	3	23	Elmaabda Northern Branch	1.25	0.64	0.61	1.33	3
9.5.4	Hablas Elgadida	1.58	1.15	0.43	0.93	2	24.1	Abo Meshel	0.75	0.54	0.21	0.46	1
9.6.1	Eltwabia Southern Branch	1	0.46	0.54	1.17	3	24.2	Sahel Elmaabda	0.75	0.57	0.18	0.39	1
10	Kom Abo Shail Branch	0.9	0.15	0.75	1.63	4	25	Emtedad Elsont	1.3	0.83	0.47	1.02	2

sections. Discharges Q for the existing water sections were calculated using Manning's equation and field data, and these values are reported in Table 6.

From Table 6, it can be observed that approximately 33 % (19 canals) of the canals have actual discharge greater than the designed values, with half of them operating in rotation (B). Several factors contribute to this situation, including: (i) widening in the canal cross sections, as exemplified in Fig. 8; (ii) the canal inlet being located near the beginning of the feeder canal, or directly receiving water from El-Sont branch canal (8 out of the 19 canals), where weeds and distortions in the last part obstruct the water flow; (iii) inadequate maintenance of the intake gates, allowing water quantities exceeding the design parameters, leading to increased velocity and widening of water sections, as depicted at the start of the Kom Abo Shail canal in Fig. (8.a); and (iv) increased dredging in certain locations, resulting in a bed level lower than the designed specifications, as shown in Fig. (8.b). Based on the aforementioned factors, the risk factor degree for cross-section deformations was calculated, as presented in Table 7.

On the other hand, approximately 67 % (38 canals) of the canals have lower water levels than the designed values. This can be attributed to multiple reasons, including: (i) contractions in the canal cross-section resulting from collapses in the side slopes; (ii) encroachments by residents along the canal stream, as illustrated in Fig. 9; (iii) the presence of excessive weed growth in the canal cross-section, as demonstrated in Fig. 10; (iv) some canals have their inlets situated far from the beginning of the feeder canal, and the water flow in the feeder canal is impeded by

Table 9
Calculation of the degree of risk factor for seepage losses/unit length of the canal (m^3/day).

No. of canal	Canal Name	Egyptian	Indian	Davis& Wilson	Pakistani	Average	Index = [(5)/ average of (5)]	Degree	No. of canal	Canal Name	Egyptian	Indian	Davis& Wilson	Pakistani	Average	Index = [(5)/ average of (5)]	Degree
2	Southern Elnabry	4393	4763	7246	3505	4977	4.11	5	11	Southern Ganabia Elsont Right*	0	0	0	0	0	0	1
3.1.1	Serage Branch	1053	1255	1805	1907	1505	1.24	2	12.1	Aboamera	811	673	1217	1433	1033	0.85	2
3.1.2	Elfaiama Branch	1100	821	1770	2148	1460	1.2	2	12.2	Elkhalifa	486	416	704	812	604	0.5	1
3.2	Amro Branch	1022	876	1559	1809	1316	1.09	2	13	Bani Rezah	2096	1129	3435	2172	2208	1.82	3
3.3.1	Elmanshia Branch	492	307	702	904	601	0.5	1	14	Abnoub	2686	2003	3769	2043	2625	2.17	3
3.3.2	Elgamsia Branch	1106	1317	1896	2003	1580	1.3	2	15	Western Elkadadeeh	837	594	1309	1656	1099	0.91	2
3.4	Elqasr Branch	701	780	1059	1124	916	0.76	1	16	Bani Ibraheem	720	468	1126	1457	942	0.78	1
3.5	Elquata Branch	511	434	845	997	696	0.57	1	17	Southern Elswalem	1204	740	1986	1159	1272	1.05	2
4	Elghawaish Branch	206	148	419	531	326	0.27	1	18	Elrwateb	358	260	568	696	470	0.39	1
5	Elnabary Elwasta	2196	2911	3484	3505	3024	2.5	4	19.1	El Shihabiaa	1066	946	1533	1748	1323	1.09	2
6.1	Qernaw Branch	390	292	628	763	518	0.43	1	19.2	Ashamallah*	0	0	0		0	0	1
7	Gazerat Bani Mour	851	708	1210	1416	1046	0.86	2	20.1	Left Northen Ganabiat Alsont	876	749	1408	1675	1177	0.97	2
8.1	Elbaharwaa	350	134	675	479	409	0.34	1	20.2	Al Marawna	347	246	523	646	440	0.36	1
9.1	Hoshat Koumaboshail	196	135	323	428	270	0.22	1	20.3	Sahel Elakob	521	309	858	1187	718	0.59	1
9.2	Ali Beik	747	618	1165	1362	973	0.8	1	20.4	Abo Diab	491	364	779	949	645	0.53	1
9.3	Western Elnassara	1170	782	1902	2465	1579	1.3	2	20.5	Western Elmansoura Branch	369	282	557	671	469	0.39	1
9.4	Estern Elnasaraa	1584	1300	2282	2696	1965	1.62	2	20.6	Sahel Bani Mohammed	2408	1962	3434	4156	2990	2.47	4
9.5.1	Elakraad	522	377	795	967	665	0.55	1	21	Shakalkeel	1615	996	2430	1423	1616	1.33	2
9.5.2	Bani Zeid	1368	593	2334	1604	1474	1.22	2	22	Southern Elmaabda	211	108	338	467	281	0.23	1
9.5.3	Diab Branch	117	58	194	273	160	0.13	1	23	Northen Elmaabda	1444	1060	2085	2589	1794	1.48	2
9.5.4	New Hablass	3517	3833	4980	5348	4419	3.65	5	24.1	Abo Meshel	313	214	481	621	407	0.34	1
9.6.1	Southern Etwabia	324	211	516	664	428	0.35	1	24.2	Sahel Elmaabdaa	1863	1012	2819	1729	1855	1.53	2
10	Koum Aboushail	724	662	1074	1233	923	0.76	1	25	Emtdad Elsont	433	362	643	750	547	0.45	1

Table 10
Calculation of the degree of risk factor for density of weeds along the stream.

No. of canal	Canal Name	length	Weeds length		Index = [(3)/average of (3)]	degree	No. of canal	Canal Name	length Km	Weeds length		Index = [(3)/average of (3)]	degree
		(km)	**(km)**	**%**					**(km)**	**(km)**	**%**		
2	Sothern Elnabary	3.2	3	0.94	1.03	5	11	Right Southern Elsont Ganabiat*	3	0	0	0	1
3.1.1	Serage Banch	2	2	1	1.1	5	12.1	Abo Amera	1.9	1.9	1	1.1	5
3.1.2	Elfaiama Branch	4	4	1	1.1	5	12.2	Elkhalifaa	1	1	1	1.1	5
3.2	Amro Branch	2.4	2.4	1	1.1	5	13	Bani Rezah	2.6	2	0.77	0.85	4
3.3.1	Elmanshia Branch	1.4	1.4	1	1.1	5	14	Abnoub Branh	2	2	1	1.1	5
3.3.2	Elgamasea Branch	2.1	1.1	0.52	0.58	3	15	Elkadadeh Western Branch	2.2	2.2	1	1.1	5
3.4	Elqasr Branch	1.14	1.14	1	1.1	5	16	Bani Ibrahem Western Branch	2.3	2.3	1	1.1	5
3.5	Elquata Branch	1.36	1.36	1	1.1	5	17	Elsawalem Southern Branch	2	2	1	1.1	5
4	Elghwaish Branch	1.3	1.3	1	1.1	5	18	Elrawateb Branch	1.25	1.25	1	1.1	5
5	Elnabari Alwasta	2.45	2.45	1	1.1	5	19.1	Elsihabia Branch	2.05	2.05	1	1.1	5
6.1	Quernaw Branch	1.42	1.42	1	1.1	5	19.2	Asham Allah*	1.6	0	0	0	1
7	Gazerat Bani Mor	1.6	1.6	1	1.1	5	20.1	Left Northern Elsont Ganabiat	2.55	2.55	1	1.1	5
8.1	Elbaharwa	1.3	1.3	1	1.1	5	20.2	Elmarwna	1.1	1.1	1	1.1	5
9.1	Hoshet Kom Aboshil	1.65	1.65	1	1.1	5	20.3	Sahel Elaqab	1.3	0.5	0.38	0.42	2
9.2	Ali Bek	2.1	2.1	1	1.1	5	20.4	Abo Diab Branch	1.7	1.7	1	1.1	5
9.3	Western Elnasara	3.75	3.75	1	1.1	5	20.5	Elmansora Western Branh	1	0.5	0.5	0.55	3
9.4	Eastern Elnasara	3	3	1	1.1	5	20.6	Sahel Bani Mohammed	4.5	4.5	1	1.1	5
9.5.1	Elakrad Branch	1.8	1.8	1	1.1	1.1	21	Shaqequel	2	2	1	1.1	5
9.5.2	Bani Zeid Branch	2	2	1	1.1	5	22	Elmaabda Sothern Branch	1.25	1.25	1	1.1	5
9.5.3	Diab Branch	0.9	0.9	1	1.1	5	23	Elmaabda Northern Branch	2.8	2.8	1	1.1	5
9.5.4	Hablas Elgadida	4.8	4.8	1	1.1	5	24.1	Abo Meshel	1.1	1.1	1	1.1	5
9.6.1	Eltwabia Southern Branch	2.25	2.25	1	1.1	5	24.2	Sahel Elmaabda	2.3	2.3	1	1.1	5
10	Kom Abo Shail Branch	1	0.7	0.7	0.77	4	25	Emtedad Elsont	2	2	1	1.1	5

Table 11
Calculation of the degree of risk factor for served area.

No. of canal	Canal Name	Served area (Feddans)	Index =[(1)/average of (1)]	degree	No. of canal	Canal Name	Served area (Feddans)	Index =[(1)/average of (1)]	degree
2	Southern Elnabry	350	0.74269	2	11	Southern Ganabia Elsont Right*	650	1.379281	3
3.1.1	Serage Branch	380	0.806349	2	12.1	Aboamera	580	1.230743	3
3.1.2	Elfaiama Branch	800	1.697577	4	12.2	Elkhalifa	300	0.636591	2
3.2	Amro Branch	100	0.212197	1	13	Bani Rezah	450	0.954887	2
3.3.1	Elmanshia Branch	300	0.636591	2	14	Abnoub	500	1.060985	3
3.3.2	Elgamsia Branch	420	0.891228	2	15	Western Elkadadeeh	1000	2.121971	5
3.4	Elqasr Branch	300	0.636591	2	16	Bani Ibraheem	500	1.060985	3
3.5	Elquata Branch	280	0.594152	2	17	Southern Elswalem	650	1.379281	3
4	Elghawaish Branch	250	0.530493	2	18	Elrwateb	300	0.636591	2
5	Elnabary Elwasta	250	0.530493	2	19.1	El Shihabiaa	800	1.697577	4
6.1	Qernaw Branch	300	0.636591	2	19.2	Ashamallah*	450	0.954887	2
7	Gazerat Bani Mour	380	0.806349	2	20.1	Left Northen Ganabiat Alsont	628	1.332598	3
8.1	Elbaharwaa	150	0.318296	1	20.2	Al Marawna	220	0.466834	1
9.1	Hoshat Koumaboshail	100	0.212197	1	20.3	Sahel Elakob	300	0.636591	2
9.2	Ali Beik	380	0.806349	2	20.4	Abo Diab	500	1.060985	3
9.3	Western Elnassara	900	1.909774	4	20.5	Western Elmansoura Branch	320	0.679031	2
9.4	Estern Elnasaraa	920	1.952213	4	20.6	Sahel Bani Mohammed	1000	2.121971	5
9.5.1	Elakraad	180	0.381955	1	21	Shakalkeel	700	1.48538	3
9.5.2	Bani Zeid	210	0.445614	1	22	Southern Elmaabda	400	0.848788	2
9.5.3	Diab Branch	100	0.212197	1	23	Northen Elmaabda	1200	2.546365	5
9.5.4	New Hablass	1100	2.334168	5	24.1	Abo Meshel	180	0.381955	1
9.6.1	Southern Etwabia	230	0.488053	1	24.2	Sahel Elmaabdaa	800	1.697577	3
10	Koum Aboushail	420	0.891228	2	25	Emtdad Elsont	450	0.954887	2

weeds or collapses in its cross-section. This is particularly evident in the branch canal, specifically in the stretch from km 16 to the end, where only 2 out of 21 canals have surpassed the designed discharge.

4.3.2. Degree of irrigation water needed to reach the canal end

The design water depth that should be at the canal's end was determined, and the actual water depth at the canal's end was measured. The degree of risk factor for water reaching the canal's ends was then calculated based on these measurements, as presented in Table 8.

4.3.3. Value of seepage losses/canal unit length

It was expected that El-Sont branch canal and its off-takes would experience water loss through seepage. The equations listed in Table 9 were employed to calculate these losses, considering the average value obtained from all equations. Table 9 provides a summary of the estimated quantities of seepage water used to calculate the risk factor for seepage losses per unit length of each canal.

4.3.4. The length of the weeds and their density along the canal

The slope lengths, bank widths, and distances between grass and weeds in the canal network were measured using a measuring wheel. The analysis and summary of the risk factor for weed spread are presented in Table 10.

4.3.5. Other parameters

The study focuses on determining risk factors for various parameters, including the canal served area, rehabilitation cost, and distance between the canal intake and feeding canal, which are summarized in Tables 11, 12, and 13. However, it does not take into account factors such as the number of beneficiaries, documented complaints, water quality, groundwater level, canal length, and the condition and efficiency of the irrigation works. Furthermore, since all the canals utilize the same irrigation and drainage system, parameters related to the performance and efficiency of the agricultural drainage system and the applied irrigation system cannot be included in the study.

4.4. Application of priority index concept on the case study

The El-Sont branch canal, which is under study, supplies water to 46 off-taking canals. All of these canals were included in the designed priority index sheet provided in Table 5, along with their existing situation data. The measured and collected data for these canals were then utilized to calculate the risk factor (r) using equation (2). The results were summarized and presented in Tables 7, 8, 9, 10, 11, 12, and 13. By using these results, the priority index (PI) for all the studied canals in the Assiut region was determined and compiled in Table 14.

5. Results and discussion

5.1. The first Axis: Questionnaire survey

The first axis of the research focuses on exploring the satisfaction of beneficiaries with the performance of their canals. This axis was chosen to identify the actual problems that hinder the canals' performance. Regarding the sufficient quantity of water reaching the end of the canal, approximately 50 % of the samples in the irrigation rotation (A) agreed that water reaches the end of the canal in a sufficient amount, as depicted in Fig. 11. This finding is reasonable, considering that their canals are located near the branch canal intake and experience minimal losses.

Table 12
Calculation of the degree of risk factor for the cost of the rehabilitation process for the served area (L.E).

No. of canal	Canal Name	Length (Km)	Total Cost	Cost /Km	Index = [(3)/ average of (3)]	Degree	No. of canal	Canal Name	Length (Km)	Total Cost	Cost /Km	Index = [(3)/ average of (3)]	Degree
2	Southern Elnabry	3.2	4,057,900	1,268,094	0.903372	5	11	Southern Ganabia Elsont Right	3	4,215,440	1,405,147	1.001006	4
3.1.1	Serage Branch	2	2,267,680	1,133,840	0.807731	5	12.1	Aboamera	1.9	3,372,920	1,775,221	1.264642	3
3.1.2	Elfaiama Branch	4	5,072,240	1,268,060	0.903348	5	12.2	Elkhalifa	1	1,521,280	1,521,280	1.083738	4
3.2	Amro Branch	2.4	2,882,180	1,200,908	0.85551	5	13	Bani Rezah	2.6	4,091,220	1,573,546	1.120972	4
3.3.1	Elmanshia Branch	1.4	1,587,000	1,133,571	0.80754	5	14	Abnoub	2	2,199,580	1,099,790	0.783475	5
3.3.2	Elgamsia Branch	2.1	2,522,340	1,201,114	0.855657	5	15	Western Elkadadeeh	2.2	3,051,620	1,387,100	0.98815	4
3.4	Elqasr Branch	1.14	1,368,960	1,200,842	0.855463	5	16	Bani Ibraheem	2.3	3,072,120	1,335,704	0.951537	4
3.5	Elquata Branch	1.36	1,495,100	1,099,338	0.783153	5	17	Southern Elswalem	2	2,468,520	1,234,260	0.879269	4
4	Elghawaish Branch	1.3	1,429,920	1,099,938	0.78358	5	18	Elrwateb	1.25	1,458,940	1,167,152	0.831462	4
5	Elnabary Elwasta	2.45	4,065,500	1,659,388	1.182124	3	19.1	El Shihabiaa	2.05	3,506,200	1,710,341	1.218423	3
6.1	Qernaw Branch	1.42	1,899,700	1,337,817	0.953042	5	19.2	Ashamallah	1.6	2,029,680	1,268,550	0.903697	5
7	Gazerat Bani Mour	1.6	2,515,660	1,572,288	1.120075	3	20.1	Left Northern Ganabiat Elsont	2.55	3,840,860	1,506,220	1.073009	4
8.1	Elbaharwaa	1.3	1,429,920	1,099,938	0.78358	5	20.2	Al Marawna	1.1	1,525,580	1,386,891	0.988001	4
9.1	Hoshat Koumaboshail	1.65	1,815,480	1,100,291	0.783831	5	20.3	Sahel Elakob	1.3	1,889,260	1,453,277	1.035294	4
9.2	Ali Beik	2.1	2,522,340	1,201,114	0.855657	5	20.4	Abo Diab	1.7	2,155,820	1,268,129	0.903397	5
9.3	Western Elnassara	3.75	7,289,480	1,943,861	1.384779	2	20.5	Western Elmansoura Branch	1	1,166,660	1,166,660	0.831112	5
9.4	Estern Elnasaraa	3	5,931,420	1,977,140	1.408486	2	20.6	Sahel Bani Mohammed	4.5	7,759,260	1,724,280	1.228352	3
9.5.1	Elakraad	1.8	2,282,420	1,268,011	0.903313	5	21	Shakalkeel	2	3,384,820	1,692,410	1.205649	3
9.5.2	Bani Zeid	2	2,572,320	1,286,160	0.916242	5	22	Southern Elmaabda	1.25	1,585,080	1,268,064	0.903351	5
9.5.3	Diab Branch	0.9	1,080,520	1,200,578	0.855274	5	23	Northen Elmaabda	2.8	4,688,600	1,674,500	1.19289	3
9.5.4	New Hablass	4.8	9,103,500	1,896,563	1.351084	3	24.1	Abo Meshel	1.1	1,209,500	1,099,545	0.7833	5
9.6.1	Southern Etwabia	2.4	5,321,220	2,217,175	1.579484	1	24.2	Sahel Elmaabdaa	2.3	3,077,340	1,337,974	0.953153	4
10	Koum Aboushail	1	1,201,440	1,201,440	0.855889	5	25	Emtdad Elsont	2	3,896,520	1,948,260	1.387913	2

On the other hand, the majority of the sample participants or farmers in rotations (C and B) expressed disagreement regarding the sufficient quantity of water reaching the end of the canal, with ratios of 47 % and 56 %, respectively. It is worth mentioning that the earthen canals in the second and third rotations have high seepage rates, large and distorted sections, as well as weeds that hinder the delivery of sufficient water to the end of the canal.

Regarding the duration of irrigation rotation, approximately 47 % of the sample participants in the first rotation agreed that the irrigation time was sufficient for their needs, as shown in Fig. 12. However, in rotation (B), about 53 % of the sample mentioned that there is a fluctuation in the rotation time, which affects its effectiveness. The same pattern was observed in rotation (C), with a ratio of 56 %.

The performance of irrigation canals is significantly affected by two crucial factors: floating weeds or garbage and weeds present on both sides of the canal. As depicted in Fig. 13, approximately 60 %, 85 %, and 73 % of the sample participants in rotations A, B, and C, respectively, agreed that they experience issues with floating weeds or garbage.

Furthermore, nearly 77 %, 88 %, and 91 % of the sample participants agreed that the canals suffer from weeds on both sides, as shown in Fig. 14. These findings help explain why water fails to reach the end of the canal in sufficient quantities, which further supports the observations from the first and second questions on the first axis of the survey questionnaire.

Based on the aforementioned axis of the survey questionnaire, approximately 98 % of the sample participants expressed the need for lining the canals. This is to address the problems of irrigation water shortage, inequitable distribution, and the poor performance of the canals due to a lack of periodic maintenance.

5.2. The second Axis: Application of "Project execution priority Index" concept on the case study

The study utilizes collected and measured data from irrigation canals to apply the project execution priority index to the case study network. The objective is to maximize yield and optimize the utilization of available irrigation water. Equation (2) was employed to convert the measured and gathered data for those canals into the risk factor (r). Tables 7, 8, 9, 10, 11, 12, and 13 provide a summary of the findings obtained. These findings were utilized to generate and present the priority index (PI) for all the evaluated canals in the Assiut region under study, as illustrated in Table 14.

As a conclusion from Table 14, in the case of the El-Sont branch canal, the first execution priority must be given to the Hablass canal,

Table 13
Calculation of the degree of risk factor for the location of the intake from head of the feeding canal.

No. of canal	Canal Name	Head location	feeding canal length	Index = [(2)/average of (2)]	degree	No. of canal	Canal Name	Head location	feeding canal length	Index = [(2)/average of (2)]	degree
2	Southern Elnabry	0.25	40	0.00625	1	11	Southern Ganabia Elsont Right	12.3	40	0.3075	2
3.1.1	Serage Branch	4.1	10.45	0.392344	2	12.1	Aboamera	3.25	6.3	0.515873	3
3.1.2	Elfaiama Branch	4.4	10.45	0.421053	3	12.2	Elkhalifa	5.5	6.3	0.873016	5
3.2	Amro Branch	3.6	8.8	0.409091	3	13	Bani Rezah	16.2	40	0.405	3
3.3.1	Elmanshia Branch	1.3	6.7	0.19403	2	14	Abnoub	17.2	40	0.43	3
3.3.2	Elgamsia Branch	5.3	6.7	0.791045	4	15	Western Elkadadeeh	19.7	40	0.4925	3
3.4	Elqasr Branch	5.72	8.8	0.65	4	16	Bani Ibraheem	21.95	40	0.54875	3
3.5	Elquata Branch	6.4	8.8	0.727273	4	17	Southern Elswalem	23.5	40	0.5875	3
4	Elghawaish Branch	3.14	40	0.0785	1	18	Elrwateb	25.75	40	0.64375	4
5	Elnabary Elwasta	6.1	40	0.1525	1	19.1	El Shihabiaa	0.6	5.7	0.105263	1
6.1	Qernaw Branch		6.3	0	1	19.2	Ashamallah	2.1	5.7	0.368421	2
7	Gazerat Bani Mour	10.3	40	0.2575	2	20.1	Left Northern Ganabiat Elsont	0.25	6.4	0.039063	1
8.1	Elbaharwaa	1.2	2.65	0.45283	3	20.2	Al Marawna	2.25	6.4	0.351563	2
9.1	Hoshat Koumaboshail	0.5	6	0.083333	1	20.3	Sahel Elakob	3.5	6.4	0.546875	3
9.2	Ali Beik	0.75	6	0.125	1	20.4	Abo Diab	3.5	6.4	0.546875	3
9.3	Western Elnassara	1	6	0.166667	1	20.5	Western Elmansoura Branch	5.5	6.4	0.859375	5
9.4	Estern Elnasaraa	1.35	6	0.225	2	20.6	Sahel Bani Mohammed	5.25	6.4	0.820313	5
9.5.1	Elakraad	0.25	5	0.05	1	21	Shakalkeel	33.5	40	0.8375	5
9.5.2	Bani Zeid	0.25	5	0.05	1	22	Southern Elmaabda	35	40	0.875	5
9.5.3	Diab Branch	0.75	5	0.15	1	23	Northen Elmaabda	35.5	40	0.8875	5
9.5.4	New Hablass	3	5	0.6	3	24.1	Abo Meshel	0.75	2.5	0.3	2
9.6.1	Southern Etwabia	0.98	1.1	0.890909	5	24.2	Sahel Elmaabdaa	1.5	2.5	0.6	3
10	Koum Aboushail	12.25	40	0.30625	2	25	Emtdad Elsont	39.99	40	0.99975	5

which has the maximum priority index (PI) and is classified in the first execution priority order. The canal names indicated by an asterisk (*) in Table 14 are currently undergoing implementation as the research is being conducted. However, they may be included in the second or third priority order in Table 14. The El-Sont branch canal under study has 46 off-taking canals, categorized based on priority index: 11 are first priority, 16 are second priority, and 19 are third priority, respectively.

Also, according to Table 14, among the 11 canals with the first priority of implementation, only one (Abnoub) has been rehabilitated. On the other hand, five canals (Serage, Shakalkeel, Elqasr, Elquata, and Elghawaish) have been executed, despite being included in the second priority of implementation. Furthermore, three canals (Elgamsia, Elghawaish, and Western Elmansoura) have been implemented, and these canals deserve the third priority.

5.3. Potential benefits

This section discusses the potential benefits of the proposed method for selecting irrigation canals for rehabilitation based on implementation priorities:

a. **Resource Optimization**: By prioritizing canals based on their implementation priorities, the method helps optimize the allocation of limited resources, ensuring that the most critical canals receive immediate attention.
b. **Enhanced Efficiency**: The method enables decision-makers to focus on canals that have the greatest impact on water delivery and agricultural productivity, leading to improved overall system efficiency.
c. **Holistic Approach**: By considering multiple factors such as canal condition, water demand, environmental impacts, and socioeconomic aspects, the method promotes a holistic approach to canal rehabilitation, addressing both technical and non-technical considerations.
d. **Stakeholder Engagement**: The method encourages stakeholder involvement in the decision-making process, as their input is essential in determining the relative weights of different factors. This fosters transparency, accountability, and ownership of the rehabilitation process.

Table 14
Priority index for the distributary canals in the understudy area.

No. of canal	Canal name	Index degree *weight = r*w							Priority index (PI)	Order	Priority order
		Cross section Deformation	Water Reach End	Seepage losses	Dense Weeds	Served Area	Lining Cost	Head Location			
		W = 3	W = 3	W = 3	W = 3	W = 3	W = 2	W = 1			
9.5.4	New Hablass	3	6	15	15	15	6	3	63	1	First Priority
20.6	Sahel Bani Mohammed	3	6	12	15	15	6	5	62	2	
14	Abnoub*	12	3	9	15	9	10	3	61	3	
10	Koum Aboushail	15	12	3	12	6	10	2	60	4	
22	Southern Elmaabda	9	12	3	15	6	10	5	60	5	
9.3	Western Elnassara	6	15	6	15	12	4	1	59	6	
23	Northen Elmaabda	3	9	6	15	15	6	5	59	7	
9.4	Estern Elnasaraa	3	15	6	15	12	4	2	57	8	
12.1	Aboamera	6	12	6	15	9	6	3	57	9	
2	Southern Elnabry	6	3	15	15	6	10	1	56	10	
15	Western Elkadadeeh	3	6	6	15	15	8	3	56	11	
3.1.2	Elfaiama Branch	3	6	6	15	12	10	3	55	12	Second Priority
3.1.1	Serage Branch*	12	3	6	15	6	10	2	54	13	
25	Emtdad Elsont	15	6	3	15	6	4	5	54	14	
21	Shakalkeel*	6	6	6	15	9	6	5	53	15	
5	Elnabary Elwasta	9	3	12	15	6	6	1	52	16	
9.6.1	Southern Etwabia	15	9	3	15	3	2	5	52	17	
20.1	Left Northern Ganabiat Elsont	3	9	6	15	9	8	1	51	18	
3.4	Elqasr Branch*	9	3	3	15	6	10	4	50	19	
3.5	Elquata Branch*	9	3	3	15	6	10	4	50	20	
9.5.2	Bani Zeid	6	9	6	15	3	10	1	50	21	
13	Bani Rezah	3	9	9	12	6	8	3	50	22	
16	Bani Ibraheem	3	9	3	15	9	8	3	50	23	
17	Southern Elswalem	3	6	6	15	9	8	3	50	24	
19.1	El Shihabiaa	3	6	6	15	12	6	1	49	25	
20.4	Abo Diab	3	6	3	15	9	10	3	49	26	
3.3.1	Elmanshia Branch*	6	6	3	15	6	10	2	48	27	
3.3.2	Elgamsia Branch*	9	3	6	9	6	10	4	47	28	Third Priority
9.5.3	Diab Branch	6	9	3	15	3	10	1	47	29	
24.2	Sahel Elmaabdaa	3	3	6	15	9	8	3	47	30	
3.2	Amro Branch	6	3	6	15	3	10	3	46	31	
8.1	Elbaharwaa	3	9	3	15	3	10	3	46	32	
12.2	Elkhalifa	3	6	3	15	6	8	5	46	33	
4	Elghawaish Branch*	3	6	3	15	6	10	1	44	34	
20.3	Sahel Elakob	6	12	3	6	6	8	3	44	35	
18	Elrwateb	3	3	3	15	6	8	4	42	36	
19.2	Ashamallah	3	15	3	3	6	10	2	42	37	
20.5	Western Elmansoura *	6	3	3	9	6	10	5	42	38	
6.1	Qernaw Branch	3	3	3	15	6	10	1	41	39	
7	Gazerat Bani Mour	3	3	6	15	6	6	2	41	40	
9.1	Hoshat Koumaboshail	6	3	3	15	3	10	1	41	41	
9.2	Ali Beik	3	3	3	15	6	10	1	41	42	
9.5.1	Elakraad	3	6	3	15	3	10	1	41	43	
11	Southern Ganabia Elsont Right	3	12	3	3	9	8	2	40	44	
20.2	Al Marawna	3	6	3	15	3	8	2	40	45	
24.1	Abo Meshel	3	3	3	15	3	10	2	39	46	

* Canals are under the implementation process nowadays.

6. Conclusions

This study presents a novel method for selecting irrigation canals for rehabilitation based on implementation priorities. The method integrates various factors and employs a systematic approach, offering a comprehensive framework for decision-makers to identify canals that require immediate attention. The proposed method has the potential to optimize resource allocation, enhance efficiency, and foster stakeholder engagement in canal rehabilitation programs. Further validation and refinement through practical applications will strengthen its reliability and applicability in diverse irrigation contexts.

The study found that 98 % of the questionnaire sample expressed the need for canal lining to overcome irrigation water shortage and inequity in water distribution. The concept of the “Project Execution Priority Index” was successfully applied to the understudied canal network, resulting in great efficiency in arranging the priority order for the field implementation process.

For large-scale national development projects with limited timeframes and substantial budgets, comprehensive technical studies that document all relevant parameters and data are of great importance. Through the documentation of field data and parameters, an execution priority index can be prepared to determine where and with which component of the project to start, achieving maximum budget efficiency and completion within the specified timeframe.

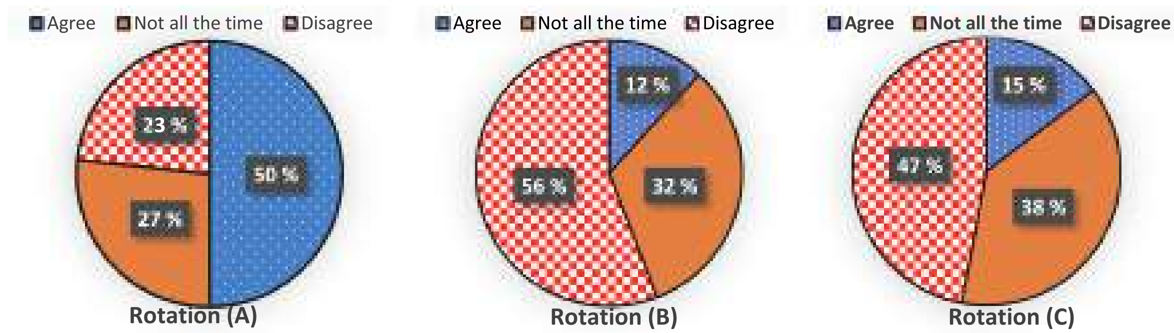


Fig. 11. Surveying results about question (Water reaches to the end of canal in a sufficient quantity?) for the three rotations.

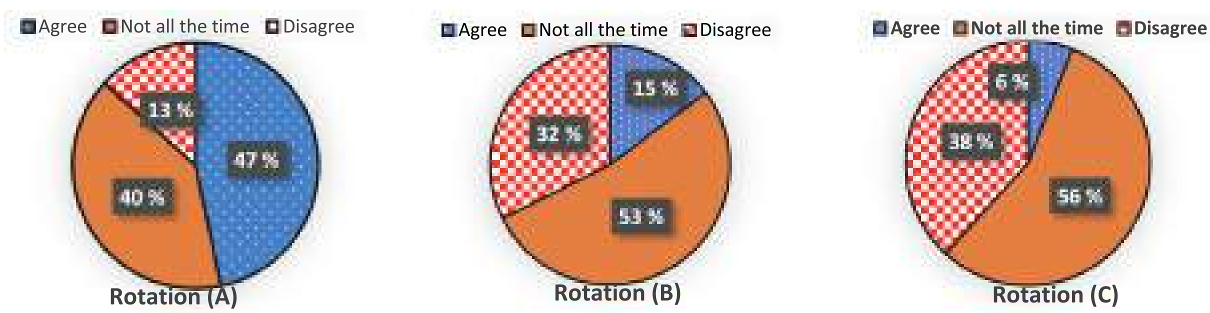


Fig. 12. Surveying results about question (The time of irrigation rotation is enough?) for the three rotations.

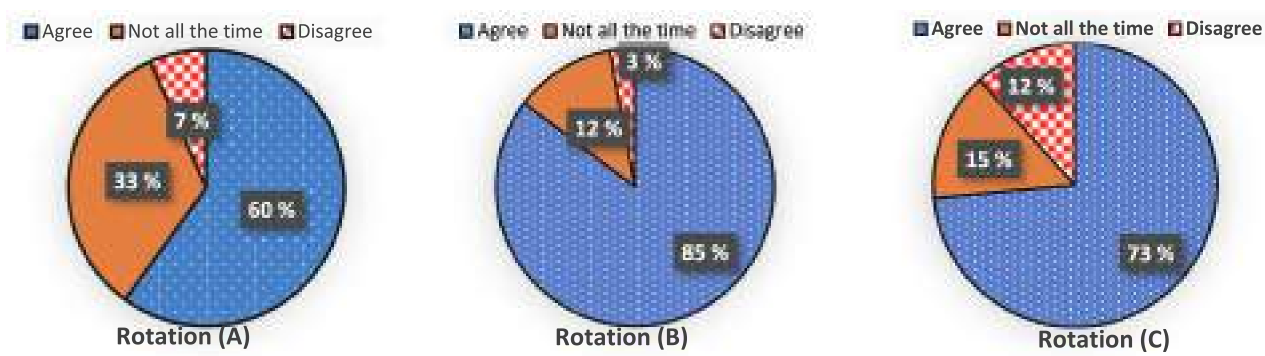


Fig. 13. Surveying results about question (The canal suffers from floating weeds or garbage?) for the three rotations.

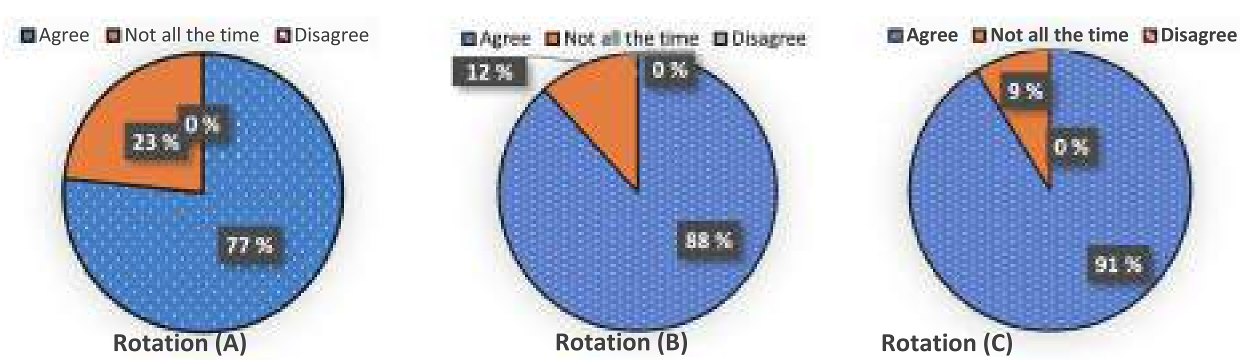


Fig. 14. Surveying results about question (The canal suffers from weeds on both sides?) for the three rotations.

Applying the new "Project Execution Priority Index" to the under-studied canal revealed that only one canal was rehabilitated among the 11 canals with the first priority of implementation. Five canals were executed despite being in the second priority, and three canals were implemented, earning the third priority.

CRediT authorship contribution statement

Mohamed A. Ashour: Conceptualization, Project administration, Supervision, Data curation, Investigation, Validation, Visualization. **Hassan I. Mohamed:** Data curation, Formal analysis, Supervision, Validation, Methodology, Software, Writing – review & editing. **Abdallah A. Abdou:** Investigation, Resources, Software, Writing – original draft, Data curation, Methodology. **Tarek S. Abu-Zaid:** Data curation, Formal analysis, Methodology, Supervision, Validation, Writing – review & editing, Investigation.

References

[1] El Gamal T, Zaki N. Egyptian irrigation after the Aswan high dam. Irrig Agri Egypt 2017:47–79. https://doi.org/10.1007/978-3-319-30216-4_4.
[2] Abu-zeid TS. Conveyance losses estimation for open channels in middle Egypt case study: almanna main canal, and its branches. J Eng Sci 2021;49(1):64–84. https://doi.org/10.21608/jesaun.2021.57454.1027.
[3] Mostafa SM, EL-Shorpagy GM, Mowafy MH, EL-Nashar WY. Rehabilitation the irrigation canals at end reaches. IOSR J Mech Civ Eng 2014;11(1):59–68.
[4] Donaldson M. Rehabilitation and modernization of irrigation schemes. Proc Inst Civ Eng: Water Mgmt 2013;166(5):242–53. https://doi.org/10.1680/wama.12.00054.
[5] Elkholy SM. Cases of slope failure of irrigation and drainage channels in Egypt and their rehabilitation. Tech J, Uni Eng Tech Taxila 2013;18(1):1.
[6] Wieland R, Olivares J. Economic analysis of irrigation rehabilitation projects. Agricultural and Food Sciences, Environmental Science: Economics; 1987.
[7] Davis R, Hirji R. Irrigation and drainage: rehabilitation (English). Water Resources and Environment Technical Note; No. E 2. Irrigation and Drainage series Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/725181468287747741/Irrigation-and-drainage-rehabilitation.
[8] Chauhan K, Ram S. Rehabilitation of canal irrigation schemes in India: a qualitative analysis. Water Policy 2023;25(1):59–68. https://doi.org/10.2166/wp.2022.237.
[9] Honggang Z, Yanqiong Li, Jianxin Yu. Design optimization of light metal irrigation channels. Proceedings of the 4th Annual International Conference on Material Engineering and Application (ICMEA 2017). doi: 10.2991/icmea-17.2018.32.
[10] Cuesta TS, Cancela JJ, Dafonte J, Valcárcel M, Neira XX. Social aspects influencing water management in the lemos valley irrigation district. Spain Irrig Drain 2005;2(5):125–33. https://doi.org/10.1002/ird.162.
[11] Amatya B, Khan F. Implementation of rehabilitation innovations: a global priority for a healthier society. J Int Soc Phys Rehabil Med 2022;5(2). https://doi.org/10.4103/jisprm.jisprm-000160.
[12] Casey AG, Soni DM, Saunderson PA. Method for selecting virtual channels based on address priority in an asynchronous transfer mode device. U.S. Patent No. 6,163,541. Washington, DC: U.S. Patent and Trademark Office, 1998.
[13] Cheng J, Zhu S, An D. Channel assignment based on priority borrowing. J of XiAn Jiaotong Uni 2001;12(35):1232–5.
[14] Syed S, ElwakilE. Project performance index for capital-intensive construction projects. Proceedings of International Structural Engineering and Construction, 2019. 10th International Structural Engineering and Construction Conference (ISEC-10) At: Chicago, Illinois, USA. doi:10.14455/ISEC.res.2019.129.
[15] Delos Reyes ML, David WP, Schultz B, Prasad K. Assessment of the process, nature and impact of rehabilitation for development of a modernization strategy for national irrigation systems in the Philippines. Irrig Drain 2015;64(4):464–78. https://doi.org/10.1002/ird.1910.
[16] Antol M, Dohnal V. Towards artificial priority queues for similarity query execution. 2018 IEEE 34th International Conference on Data Engineering Workshops (ICDEW), Paris, France, 2018: 78-83. doi: 10.1109/ICDEW.2018.00020.
[17] Falana OJ, Sodiya AS, Onashoga SA, Oyewole AT. PEDAM: Priority execution based approach for detecting android malware. in Lecture Notes in Networks and Systems, 2021. International Conference on Emerging Applications and Technologies for Industry 4.0 (EATI'2020). doi:10.1007/978-3-030-80216-5_12.
[18] Zhu Y, Chen S, Huang W, Ma G. Priority power generation allocation method for reservoir power stations based on the priority index. J Clean Prod 2021;322:129108. https://doi.org/10.1016/j.jclepro.2021.129108.
[19] Mwri. Ministry of Water Resources and Irrigation, Assiut Administration. Assiut Department. Assiut; 2021.
[20] Bello AA. Introductory soil mechanics I. Ist Edition, Tony Terry Prints, Lagos, Department of Civil Engineering, Faculty of Engineering. College of Science, Engineering and Technology, Osun State University, Osogbo; 2013.
[21] Ashour MA, Aly TE, Abu-Zaid TS, Abdou AA. A comparative technical study for estimating seeped water from irrigation canals in the Middle Egypt (Case study: El-Sont branch canal network). Ain Shams Eng J 2023;14(3):101875. https://doi.org/10.1016/j.asej.2022.101875.
[22] Rahi S, Alnaser FM, Abd GM. Designing survey research: recommendation for questionnaire development, calculating sample size and selecting research paradigms. Economic and Social Devel: Book of Proc 2019:1157–69.
[23] Marzouk M, Abdel Hamid S, El-Said M. A methodology for prioritizing water mains rehabilitation in Egypt. Housing and Building National Research Center (HBRC) Journal 2015;11(1):114–28.
[24] CAPMAS. Population and Housing Conditions - Governorates. The Central Agency for Public Mobilization and Statistics (CAPMAS), 2017.
[25] Baker A, Colyvan M. Indexing and mathematical explanation. Philos Math 2011;19(3):323–34. https://doi.org/10.1093/philmat/nkr026.