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Research Article

STRUCTURAL AND TECHNICAL EVALUATION OF PUMPED WATER SUPPLY SYSTEMS BY USING ANALYTICAL HIERARCHY PROCESS

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ABSTRACT

Factors such as physical characteristics of pumps, transmission lines and tanks play an important role in operating and managing water supply systems (WSS). Therefore, it is required that these systems are evaluated by taking into consideration their current status. The objective of this study is to carry out structural and technical performance evaluation for pumped-WSSs via Analytical Hierarchy Process (AHP). For this purpose, main factors such as pumping station, structural condition and transmission line, sub-factors such as pump physical, operational characteristics, pump and water tank building etc. were considered. Weights for each factor were calculated based on pairwise comparison matrices of factors composited by opinions of the experts. The AHP model was applied to 10 pumped-water supply systems that currently provide service. It is thought that the AHP model introduces significant innovations since it takes into consideration the variables to reflect and reveal the general state of the WSS.

Keywords: Water supply, decision support systems, urban water systems, performance indicators.

1. INTRODUCTION

Pumps and pumping stations have been used in water transmission lines and distribution systems depending on geographical conditions. Pumping stations and transmission lines as well as pump and water tanks are quite important in transmitting the desired amount of water in a timely and efficient manner. Especially, in old systems, pumps that already provide the service with high installation power directly increase energy consumption and operation cost of the system. In such systems, operating cost can increase depending on various factors such as the physical characteristics of transmission lines, physical conditions of water tanks and pump buildings, repair and maintenance frequency and cost, use of old pumps with high installation power, water losses due to leaks from transmission lines and water tanks thereby resulting in greater amount of flow to the system, especially in rural areas use of water for irrigation water demand from water supply systems. Therefore, evaluating structural and technical conditions of all components of such systems, determining the elements to be renewed in the system, calculating the renewal costs and cost-benefit analysis are quite important to operation in terms of system efficiency. Various

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studies have been carried out in literature for improving the operation conditions of pumped water supply syste ms and for decreasing the costs involved. Cabrera et. Al [1] analyzed the energy efficiency of water distribution systems and discussed the effect energy consumption of leakages occurred in pipelines on. Racoviceanu and Karney [2] investigated the effects of friction loss and water leakages at transmission lines on energy consumption and efficiency by measuring the water and energy losses. Xu et al. [3] carried out a study to determine the relationship between water and energy savings and pressure management and applied to a part of water distribution network in Being in China. Carriço et al. [4] used the energy balance method at water transmission line by using four energy indices in order to evaluate and manage the energy efficiency at water supply systems. Mamade et al. [5] examined the actualization of an energy audit plan in a water distribution system and determined by way of metric calculation method that the energy losses of system was 25 % by metric calculating method. Scanlan and Filion [6] aimed the revealing the energy indicators to determine the amount of energy wasted in recent years in pumps and water supply systems. On the other hand, Analytic Hierarchy Process (AHP) method has been applied for modeling the many problems in study area of hydraulic, environmental etc. [7, 8, 9, 10]. Al-Barqawi and Zayed [11] applied the AHP method in order to evaluate the renewal conditions of water supply systems in some cities in USA and Canada. Donevska et al. [12] presented a model based on AHP and GIS method for selection of non-hazardous landfill in Poland. Ennaouri and Fuamba [13] used the AHP method to assess both the hydraulic and structural aspects of sewerage systems. Mamo et al. [14] applied the Fuzzy Analytic Hierarchy Process (FAHP) method in order to analyze and evaluate the problems, which are frequently encountered by Municipalities and during the repairing and maintaining of infrastructure systems. Sargaonkar et al. [15] applied a model based on fuzzy multi-criteria evaluation approach in order to assess the condition of water supply network. The risk assessment model developed in their study combined all components of the infrastructure system in the study area. Xu et al. [16] proposed a methodology combining the AHP and TOPSIS methods in order to evaluate the condition of drinking water supply system in rural area.

The objective of this study is to evaluate the performance of the pumped water supply systems as structural and technical by using AHP method called multi-criteria decision analysis approach. For this aim, the main factors such as pumping station, structural conditions, transmission line etc. and sub-factors such as pump physical, pump operating, system technology and condition of pump and water tank buildings etc., which are thought to have an effect on structural and technical conditions of pumped water supply systems, were taken into account. The structural and technical evaluation system developed using AHP method based on the aforementioned factors has been applied the pumped water supply system that is already in service already at the city of Adıyaman, Turkey.

2. ANALYTIC HIERARCHY PROCESS (AHP)

AHP method also known as the multi-criteria decision analysis approach was first proposed by [17] and applied to problems in a wide range of fields. AHP method basically consists of the following steps; (i) defining the main and sub-factors which are effective variables on the problem, (ii) composing the pairwise comparison matrices for factors at each level, (iii) defining the degree of relationship between factors at each level, (iv) calculating the weights of each main and sub-factor, (v) consistency analysis etc. [17]. The flow chart developed for carrying out structural and technical evaluation of the pumped-water supply system via AHP method is presented in Figure 1. Moreover, the hierarchical structure including the main and sub-factors determined is given in Figure 2. Relative importance values proposed by [17] and given in Table 1 were used in the AHP method composing the pairwise comparison matrices of all factors given in Figure 2.

Table 1. Relative importa nce values proposed by Saaty (1980) [13]

Importance Intensity	Explanation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very Strong importance
9	Extreme importance
2, 4, 6 and 8	Intermediate values between adjacent scale values

The weight matrix for factors is calculated after creating the scoring matrix for each factor and sub-factor. The sum of pairwise comparison matrix and calculation of weights of the factors are given in equations (1) and (2), respectively [13].

$$S_j = \sum_{i=1}^{N} c_{ij} \tag{1}$$

$$w_i = \frac{\sum_{j=1}^{N} b_{ii}}{N} \tag{2}$$

N is number of the factors to be compared as pairwise and the term of b_{ii} can be written as $b_{ii} = \frac{a_{ij}}{c_j}$.

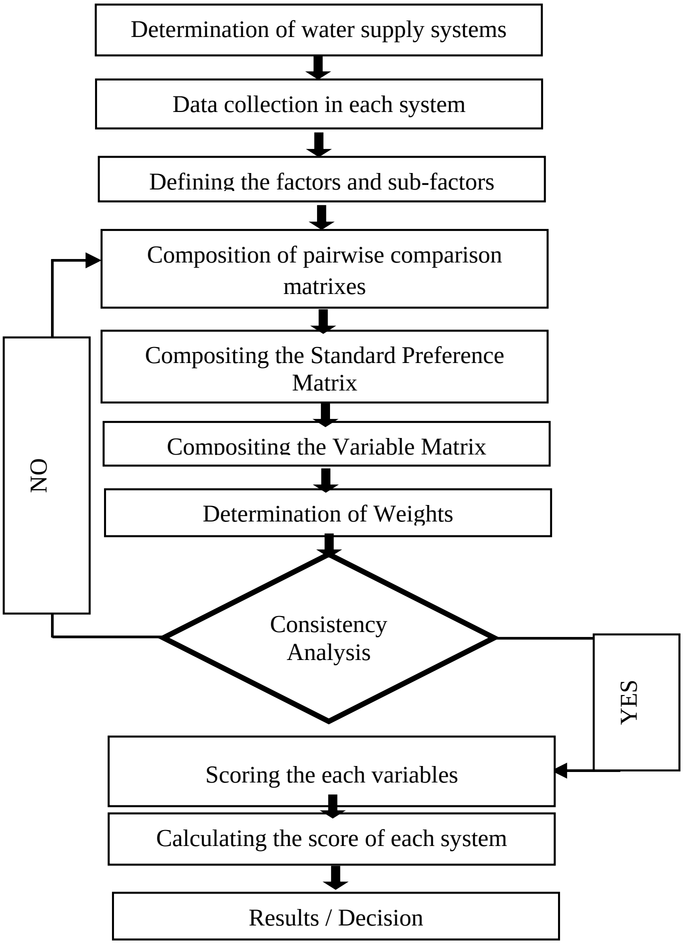

Figure 1. Flow chart for evaluating the pumped-water supply systems

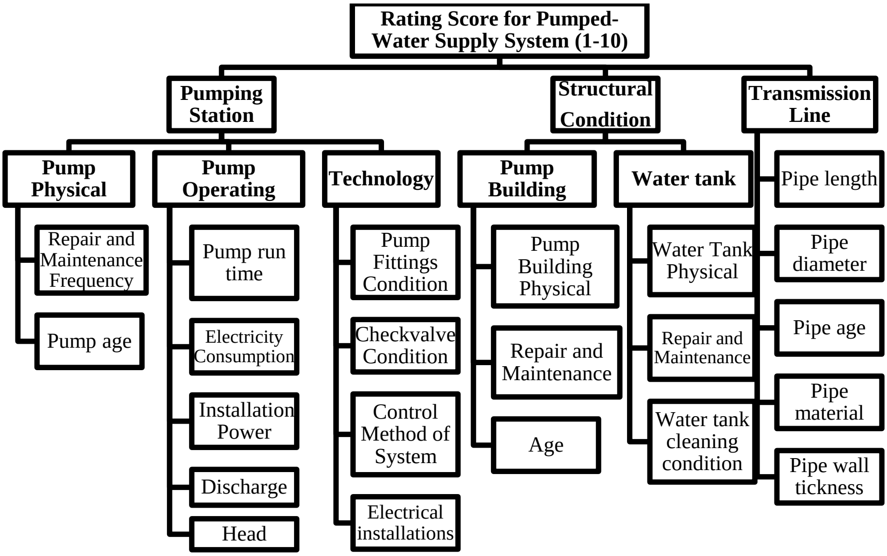

Figure 2. Hierarchical Structure for pumped-water supply systems

The consistency ratio is calculated in order to verify the consistency of weights After defining the weights of the factors in each level. Consistency Index (CI) in consistency analysis is determined based on the values of *average random index*, RI, calculated depending on the number of pairwise comparison matrices [11, 17].

$$CR = \frac{CI}{RI} \tag{3}$$

$$CI = \frac{\lambda_{max} - m}{m-1} \tag{4}$$

Where, CR is the consistency ratio, m is the dimension of matrix, λ_{max}; is the maximum Eigen value. The consistency of factor weights calculated in the previous level is verified via this analysis and the critical values of consistency ratio proposed by [17] can be given as; (i) If CR is greater than 0.10, pairwise comparison matrix and weights of factors are recalculated by reconsidering the opinions of experts and practitioners, (ii) If CR is equal or smaller than 0.10, then the results are assumed as valid. The scoring table for components of all factors is formed following the consistency analysis for weights was performed based on the opinions of the experts and practitioners working on the related problem. The total score (called rating score) of each pumped water supply systems are calculated in the last step based on scores and weights of each component of the factors defined in the previous level.

3. STUDY AREA

In this study, pumped water supply systems in service at city of Adıyaman shown in Figure 3, were selected as the study area to evaluate the systems by using AHP method based on several factors. Some characteristics of these systems such as installation power, service provided population, discharge and head, pump age, physical condition of pump and water tank buildings and transmission lines etc. were obtained by way of field observations. The pumping stations selected in this study were Adıyaman Kırkgöz, Kahta Çayı, Değirmenbaşı, Narince, Çadırkent, Gölbaşı Organize Sanayi, Pınaryayla, Durak, Olgunlar and Hasancık [18].

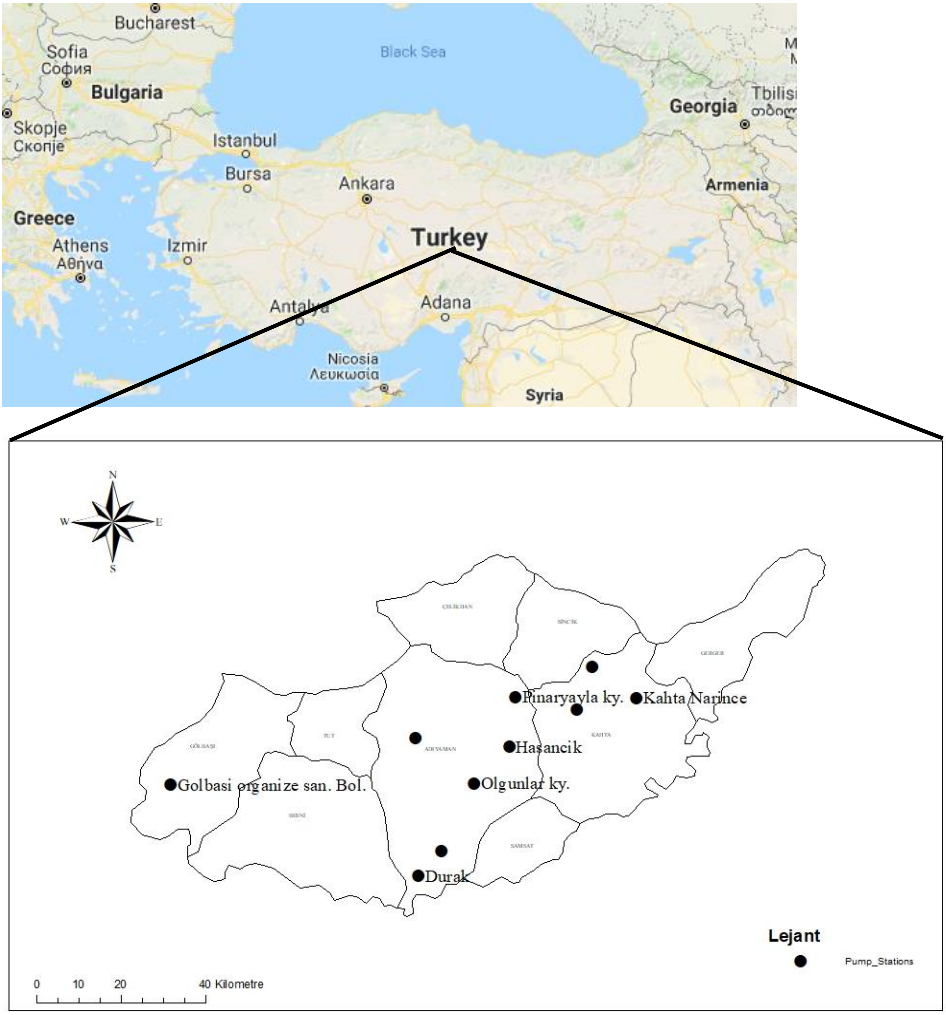

Figure 3. Study Area

4. STRUCTURAL AND TECHNICAL EVALUATION OF PUMPED WATER SUPPLY SYSTEMS

4.1. Composition of Pairwise Comparison Matrixes

The steps given in the flow chart in Figure 1 were followed and the main and sub-factors shown in hierarchical structure in Figure 2 were taken into account when evaluating the pumped water supply systems via AHP method. As explained in the previous section, relative importance values proposed by [17] and given in Table 1 were used for defining the importance level of the factors with regard to each other and for composing the pairwise comparison matrix of factors. For this purpose, opinions of experts and practitioners working in the field of water management who were already aware of field problems in Adıyaman, Malatya and Denizli Municipality, Adıyaman Provincial Administration and Adıyaman University Department of Construction and Technical Affairs were taken consideration. The opinions of experts were acquired for each main factors and sub-factors. The opinions were taken first for the main factors and pairwise comparison matrices were composed for the main factors after which, weight coefficients were calculated and consistency analyzes were made. Similar steps were then followed for each sub-factor. According to the hierarchical structure shown (Figure 2), Pumping Station, Structural Condition and Transmission Line were defined as main factors and pairwise comparison matrixes of these factors based on relative importance values were determined and given in Table 2 [18].

The Pumping Station main factor was determined to be more important than the Structural Condition and Transmission Line main factors (Table 2). It was observed according to the relative importance values of sub-factors of the Pumping Station main factor that the Pump Physical and Pump Operating factors are more important than the Technology factor. On the other hand, it was determined that the Water Tank factor was more important than the Pump Building factor. It was observed according to the results in Table 2 that the Installation Power factor was more important than the Pump Run Time, Electricity Consumption, Discharge and Head factors. Moreover, it was determined that the Check valve Condition and System Control Method factors were more important than other factors [18]. On the other hand, it was observed that Pump Building Physical and Water tank Physical factors are more important than the other factors. Moreover, it was determined according to Table 2 that pipe age factor is more important than other factors based on results of pairwise comparison of transmission line.

Table 2. Pairwise comparison matrixes of the factors

Factor	Pumping Station	Structural Condition	Transmission Line
Pumping Station	1	2	3
Structural Condition	1/2	1	2
Transmission Line	1/3	1/2	1

	Pump Physical	Pump Operating	Technology
Pump Physical	1	1	6
Pump Operating	1	1	4
Technology	1/6	1/4	1

	Pump Building	Water tank
Pump Building	1	1/4
Water tank	4	1

	Repair and maintenance Frequency	Pump Age
Repair and maintenance Frequency	1	1/2
Pump Age	2	1

Factor	Pump Run Time	Electricity Consumption	Installation Power	Discharge	Head
Pump Run Time	1	1/5	1/5	1/2	1/2
Electricity Consumption	5	1	1	3	3
Installation Power	5	1	1	5	5
Discharge	2	1/3	1/5	1	1
Head	2	1/3	1/5	1	1

	Pump Fittings	Check valve Condition	System Control Method	Electrical Installations

	Condition			
Pump Fittings Condition	1	1/3	1/3	1
Check valve Condition	3	1	1	3
System Control Method	3	1	1	3
Electrical Installations	1	1/3	1/3	1

Factor	Pump Building Physical	Repair and Maintenance	Age
Pump Building Physical	1	2	3
Repair and Maintenance	1/2	1	3
Age	1/3	1/3	1

	Water tank Physical	Repair and Maintenance	Water Tank Cleaning Condition
Water tank Physical	1	3	3
Repair and Maintenance	1/3	1	2
Water Tank Cleaning Condition	1/3	1/2	1

	Pipe Length	Pipe Diameter	Pipe Age	Pipe Material	Wall Thickness
Pipe Length	1	3	1	3	2
Pipe Diameter	1/3	1	1/3	1	2
Pipe Age	1	3	1	3	3
Pipe Material	1/3	1	1/3	1	1
Wall Thickness	1/2	1/2	1/3	1	1

4.2. Calculation of the Weight Coefficients

The weights of all factors were determined via AHP method based on the aforementioned pairwise comparison matrices. Moreover, the consistency index, CI, and consistency ratio, CR, for all factors were also calculated and shown in Table 3.

Table 3. Weights of sub-factors

Main Factor	Weight (w_i)	CI and CR	Sub-factor	Weight (w_i)	CI and CR	Attributes	Weight (w_i)	CI and CR
Pumping Station (PIFP)	0.54	0.0046 0.0079	Pump Physical (PFP)	0.48	0.0092 0.016	Repair and maintenance Frequency	0.33	0.00
						Pump Age	0.67	----
			Pump Operating (PIP)	0.42		Pump run time	0.07	0.0092
						Electricity Consumption	0.33	0.016
						Installation Power	0.40	
						Discharge	0.10	
						Head	0.10	
			Technology	0.10		Pump Fittings Condition	0.13	
						Check Valve Condition	0.37	0.00
						System Control Method	0.37	----
						Electrical Installations	0.13	
Structural Condition (YDFP)	0.30		Pump Building (PBNP)	0.20	0.00 -----	Pump Building Physical	0.53	0.026
						Repair and Maintenance	0.33	0.046
						Age	0.14	
			Water Tank (DBNP)	0.80		Water Tank Physical	0.59	0.026
						Repair and Maintenance	0.25	0.046
						Water Tank Cleaning Condition	0.16	
Transmission Line (THP)	0.16					Pipe Length	0.31	0.050
						Pipe Diameter	0.13	0.044
						Pipe Age	0.33	
						Pipe Material	0.11	
						Wall Thickness	0.11	

It was determined according to results that the weight of Pump Station main factor with 0.54 was greater than the weights of Structural Condition and Transmission Line main factors. The consistency ratio calculated for these main factors was found to be lower than the critical value of 0.10. Similarly, it was determined when the weight coefficients calculated for sub-factors of the Pumping Station main factor were evaluated that the highest value was obtained for the Pump Physical factor with 0.48, while the lowest value was calculated for the Technology sub-factor with 0.14. On the other hand, it was obtained for sub-factors of the Structural Condition main factor that the weight of Water Tank sub-factor with 0.80 was found to be higher than the weight of Pump Building.

According to the calculated weight coefficients, the efficiency of the pump station is considerably higher in terms of energy efficiency on pumped water supply system. Similarly, it can be evaluated that the physical state of the pump as well as the pump operating factor has a significant effect on the system efficiency. On the other hand, it is seen that the current condition of the water tank where the water is conveyed in terms of energy and water efficiency in the system seems to be an important influence. Leaks and water losses in the reservoir are indications that greater amounts of water is transported and water efficiency is reduced.

According to results in Table 3, it was observed upon an examination of the weights for sub-factors of Pump Physical factor that the weights for Pump Age and Repair and Maintenance Frequency sub-factors were obtained respectively, as 0.67 and 0.33. Moreover, while the highest coefficient of weight of was obtained for Installation Power sub-factor with a value of 0.40 according to results, the lowest weight values was obtained for Discharge and Head sub-factors. Similarly, when the results obtained for Pump Operating factor were evaluated, the highest weight was calculated for Check Valve and System Control Method sub-factors. Furthermore, it was observed according to results of sub-factors of Pump Building and Water Tank factors that the highest coefficient of weight were calculated for Pump Building Physical (with 0.50) and Water Tank Physical (with 0.59) sub-factors. As a result, when the weights calculated for the sub-factors of transmission line factor are evaluated, the highest weight was found for Pipe Age factor with 0.33 and the lowest weight was obtained for Pipe Material and Wall Thickness factors.

As is known, energy loss in transmission lines increases with roughness in the pipe and pipe length. Pipe age in water supply systems is known to have an important effect on the roughness. It was observed when the weight coefficients calculated by the AHP method are taken into consideration that the highest values are obtained for the pipe age and length factors. Therefore, it is thought that the results obtained by AHP method are representative of the physical structure of the problem.

4.3. Calculation of Rating Scores

The equations given below were used to calculate the rating scores for pumped-water supply systems following the calculation of the coefficients of weight for each main and sub-factor. Sub-components of each factor were scored the range of 1 to 10 according to the opinions of experts and practitioners (Table 4) for calculating the rating score of each system. In scoring each component, 1 indicates that the value has at least an effect on the structural and technical condition of the pumped-system, whereas 10 indicates that it is very effective on the system. The characteristics of water supply system selected for structural and technical evaluation are shown in Table 5.

Table 4. Scoring the components of factors

Factor	Sub-Factor	Range	Score
Pump Physical	Repair and Maintenance (number/year)	0-1	9
		1-2	8
		2-3	8
		3-4	7
		4-5	5
		>5	3
	Pump Age (Year)	>20	10
		15-20	8
		10-15	7
		5-10	4
		<5	2
Pump Operating	Pump run time (hour)	>14	10
		12-14	9
		10-12	9
		8-10	8
		6-8	7
		<8	7
	Electricity Consumption (Kwh/day)	>450	10
		350-450	8
		250-350	6
		150-250	4
		50-150	3
		<50	1
	Installation Power (Kwh)	>250	8
		200-250	6
		150-200	5
		100-150	4
		50-100	3
		<50	1
	Discharge (l/s)	>100	9
		75-100	7
		50-75	6
		25-50	5
		<25	2
	Head (m)	>200	8
		150-200	6
		100-150	5
		50-100	2
		<50	1
Technology	Pump Fittings Condition	Very Good	3
		Good	5
		Moderate	7
		Poor	10
	Check Valve Condition	Very Good	3
		Good	5
		Moderate	7
		Poor	10
	System Control Method	Automatic	4
		Manuel	6
	Electrical Installation	Very Good	3
		Good	5
		Moderate	6
		Poor	8
Water Tank	Water Tank Physical	Good	2
		Moderate	5
		Poor	8
	Repair and Maintenance (number/year)	>3	4
		2-3	6
		0-2	9
	Water Tank Cleaning Condition (number/year)	>3	4
		2-3	7
		0-2	9
Transmission Line	Pipe Length (km)	>7	8
		5-7	7
		3-5	5
		1-3	4
		<1	3
	Pipe Diameter (mm)	>400	3
		300-400	4
		200-300	4
		100-200	6
		<100	7
	Pipe Age (year)	>20	8
		15-20	7
		10-15	6
		5-10	5
		<5	3
	Pipe Material	Steel	4
		HDPE	4
		PVC	7
		ACP	9
	Wall Thickness	>20	3
		10-20	4
		<10	5

Factor	Sub-Factor	Range	Score
Pump Building	Pump Building Physical	Good	3
		Moderate	5
		Poor	7
	Repair and Maintenance (number/year)	>3	2
		2-3	7
		0-2	10
	Age	>20	8
		15-20	6
		10-15	6
		<10	2

Table 5. Pumping Stations selected for evaluation (reference year, 2016)

System ID	Pump Station										
	Pump Physical		Pump Operating					Technology			
	Repair and Maintenance (number/year)	Pump Age (Year)	Pump Run time hour)	Electricity Cons. (Kwh)	Install. Power (Kwh)	Discharge (l/s)	Head (m)	Pump Fittings Cond.	Check Valve Cond.	System Control Method	Electrical Installation
TS1	1	4	24	145416	166	30	220	Good	Good	Manuel	Good
TS2	2	5	24	19404	58,82	6	220	Good	Good	Manuel	Good
TS3	4	26	24	144000	160	112,5	90	Good	Moderate	Manuel	Poor
TS4	2	16	24	336000	350	125	54	Good	Moderate	Manuel	Poor
TS5	1	4	8	42840	40	15	180	Good	Good	Manuel	Good
TS6	4	22	24	414960	264	65	100	Poor	Poor	Manuel	Poor
TS7	1	2	8	15790	54	3	266	Good	Moderate	Manuel	Moderate
TS8	1	7	8	46620	37	4,7	200	Good	Moderate	Manuel	Moderate
TS9	1	15	8	28220	97	3	320	Moderate	Moderate	Manuel	Poor
TS10	1	16	8	24340	84	8	54	Moderate	Moderate	Manuel	Moderate

System ID	Structural Condition						Transmission Line				
	Pump Building			Water Tank							
	Pump Building Physical	Repair and Maintenance (number/year)	Age	Water Tank Physical	Repair and Maintenance (number/year)	Water Tank Cleaning Condition (number/year	Pipe Length (km))	Pipe Diameter (mm)	Pipe Age year)	Pipe Material	Wall Thickness (mm)
TS1	Good	1	4	Moderate	1	2	3452	280	4	HDPE	38.30
TS2	Moderate	2	10	Moderate	2	2	2100	200	5	HDPE	11.90
TS3	Moderate	4	26	Poor	4	4	8500	500	26	Steel	9.50
TS4	Moderate	2	16	Poor	2	4	3500	600	16	Steel	9.50
TS5	Good	1	2	Moderate	1	1	3400	180	4	HDPE	20.10
TS6	Poor	4	22	Poor	4	4	6373	250	22	ACP	7.50
TS7	Moderate	1	8	Moderate	1	1	1075	100	2	Steel	4.78
TS8	Moderate	1	19	Moderate	1	1	1492	125	20	Steel	4.00
TS9	Moderate	1	16	Moderate	1	1	207	76,2	15	Steel	4.78
TS10	Moderate	1	15	Moderate	1	1	3300	150	16	PVC	14.50

$$\mathrm{PSFS} = \mathrm{w_{pf}}.\mathrm{PFP} + \mathrm{w_{pi}}.\mathrm{PIP} + \mathrm{w_{te}}.\mathrm{TEP} \qquad (5)$$

$$\mathrm{PPS} = \textstyle\sum_{i=1}^{N} \mathrm{w_i}.\mathrm{c_i} \qquad (5a)$$

$$\mathrm{POS} = \textstyle\sum_{i=1}^{N} \mathrm{w_i}.\mathrm{c_i} \qquad (5b)$$

$$\mathrm{TES} = \textstyle\sum_{i=1}^{N} \mathrm{w_i}.\mathrm{c_i} \qquad (5c)$$

$$\mathrm{SCFS} = \mathrm{w_{pb}}.\mathrm{PBS} + \mathrm{w_{db}}.\mathrm{WTBS} \qquad (6)$$

$$\mathrm{PBS} = \textstyle\sum_{i=1}^{N} \mathrm{w_i}.\mathrm{c_i} \qquad (6a)$$

$$\mathrm{WTBS} = \textstyle\sum_{i=1}^{N} \mathrm{w_i}.\mathrm{c_i} \qquad (6b)$$

$$\mathrm{TLFS} = \textstyle\sum_{i=1}^{N} \mathrm{w_i}.\mathrm{c_i} \qquad (7)$$

$$RS = \mathrm{w_p}.\mathrm{PSFS} + \mathrm{w_y}.\mathrm{SCFS} + \mathrm{w_{th}}.\mathrm{TLFS} \qquad (8)$$

Where, PSFS is the Pump Station Factor Score, PPS is the Pump Physical Score, POS is the Pump Operating Score, TES is the Technology Score, SCFS is the Structural Condition Factor Score, PBS is the Pump Building Score, WTBS is the Water Tank Building Score, TLFS is the

Transmission Line Factor Score, RS is the Water Supply Rating Score, w_{pf} is the weight of pump physical factor, w_{pi} is the weight of the pump operating factor, w_{te} is the weight of the technology factor, w_i is the weights of the sub-factors, c_i is the score of the components of factors, w_{pb} is the weight of the pump building factor, w_{db} is the weight of the water tank building factor $w_p$is the weight of the pumping station main factor, w_y is the weight of the structural condition main factor and w_{th} is the weight of the transmission line main factor.

The rating scores for pumping stations selected for structural and technical evaluation were calculated based on the characteristics and the weights of factors given in the previous section (Table 6).

Table 6. The classes defined for evaluating the results of RS

Class	Score range	Structural and Technical State
A	[0-2]	Very Good
B	[2-4]	Good
C	[4-6]	Moderate
D	[6-8]	Poor
E	[8-10]	Very Poor

It was observed when the PPS calculated for the water supply systems were evaluated that the lowest value with 4.31 was obtained for TS5 and TS7 systems, while the highest value with 8.35 was calculated for TS3 and TS6 systems. On the other hand, it was determined according to results of Technology Score (TES) that while the systems of TS1, TS2 and TS5 had the lowest values with 5.37, the highest value of this score was obtained for the TS6 system. The highest value of POS with 8.35 was obtained for the TS4 and TS6 systems, while the lowest value of this score was calculated for the TS7 and TS8 systems. The PSFS rating score was calculated using scores of sub-factors, PPS, POS and TES, for each system in order to evaluate the performance of each system according to the Pumping system factor score. It was observed based on the results of PSFS calculated for each system that the system with the lowest score was TS6, while TS5 was the system which showed the best performance with a score of 3.82.

It can be observed that the TS3 system shown the best performance with a score of 4.43 based on PBS values, while the TS8 system had the lowest performance according to the results. Similarly, it was determined upon comparison of WTBS results that the lowest and highest values have been obtained for TS2 andTS4 systems, respectively. The SCFS rating score was calculated using scores of sub-factors, PBS and WTBS, for each system in order to evaluate their respective performance according to the Pumping system factor score. It was observed according to results of SCFS calculated for each system that TS4 had the lowest score, whereas TS2 system showed the best performance with a score of 5.82. The classes and score ranges were defined in order to evaluate the results of RS for each system which have been given in Table 7 for making a decision on the structural and technical condition of each system. The general rating score, denoted as RS was calculated for each system by using the PSFS, SCFS and TLFS values and their respective weights and the results have been given in Table 7.

Table 7. The PSFS and SCFS values for pumped water supply systems

ID	Scores of sub-factors of Pump Station main factor			**PSFS**	Scores of sub-factors of Structural Condition factor		**SCFS**	**TLFS**	**RS**	**Class**	**State**
	PPS	**POS**	**TES**		PBS	WTBS					
TS1	4.31	7.20	5.37	**5.63**	5.17	6.32	**6.09**	**3.83**	5.48	C	Moderate
TS2	5.32	4.10	5.37	**4.81**	5.80	5.82	**5.82**	**4.29**	5.03	C	Moderate
TS3	8.35	7.00	6.24	**7.57**	4.43	6.36	**5.97**	**6.50**	6.92	D	Poor
TS4	8.00	9.00	6.24	**8.24**	5.80	7.11	**6.85**	**5.24**	7.34	D	Poor
TS5	4.31	2.89	5.37	**3.82**	5.17	6.64	**6.35**	**4.09**	4.62	C	Moderate
TS6	8.35	9.00	8.26	**8.61**	5.49	6.36	**6.19**	**6.87**	7.60	D	Poor
TS7	4.31	3.09	6.24	**3.99**	6.23	6.64	**6.56**	**4 .0**	4.76	C	Moderate
TS8	5.65	3.09	6.24	**4.63**	7.07	6.64	**6.73**	**5.32**	5.37	C	Moderate
TS9	7.66	3.89	6.76	**5.99**	6.79	6.64	**6.67**	**4.81**	6.00	C	Moderate
TS10	8.33	3.29	6.50	**6.03**	6.79	6.64	**6.67**	**5.85**	6.19	C	Moderate

According to rating scores, while the classes of TS3, TS4 and TS6 systems were defined as class D (poor), other systems were included in class C (moderate). The pumped water supply systems of TS3, TS4 and TS6 were included in the "bad" class in comparison with other systems, which can be considered as an expected result due to the following reasons;

- The pump age of these systems was higher in comparison with those of the other systems,
- The pump operating characteristics (installed power, discharge, head etc.) were higher for these stations,
- Water tank physical conditions were in bad condition,
- The pipe age in the transmission line was higher than those of the other systems,
- The length of the transmission line was longer in comparison with those of the other systems,

It can be concluded that the model results developed based on the AHP method are compatible with these evaluations. As explained in detail above, the rating scores for each main factor can be calculated by using the structural and technical evaluation system developed in this study evaluating the pumped-water supply systems and an assessment about the structural and technical conditions of each supply system can be made.

5. CONCLUSIONS

AHP method was used in this study to carry out the structural and technical evaluation the pumped-supply systems which provide service based on various physical, hydraulics and technical variables or factors. The main factors such as Pumping station, Structural condition and transmission line as well as sub-factors such as pump physical, pump operating, pump and water tank building etc. were taken into consideration for constructing the AHP model. The weights and impact degrees of each factor on system evaluation were determined by AHP method based on relative importance of each factor. While the highest value of weight with 0.54 was obtained for Pumping Station main factor, the lowest value with 0.16 was calculated for Transmission Line main factor. It can be said that the physical structure of the problem is compatible with the weight coefficients obtained by the AHP method. For example, when looking at applications on the field, it is known that the pump station directly affects the energy efficiency of the system. The calculation of the high weighting coefficient for the pumping station within the main factors indicates that the problem is suitable for the physical structure. To give another example, the energy losses varying depend on pipe roughness and length in the piping are very important in terms of energy efficiency. It is seen that the calculated by AHP method for pipe length and roughness are higher than other factors. These results show that the weight coefficients determined by the AHP used in the evaluation of the system's performance overlap with the physical structure of the problem. The structural and technical system developed by AHP method was applied to 10 pumped-water supply systems providing service in Adıyaman city. According to rating scores given in Table 13, while the classes of TS3, TS4 and TS6 systems were defined as class D, other systems were taken part in class C. In application area, the systems defined in D class, it is seen that the pump age and the pump operating characteristics at these systems are higher than at other systems, water tank physical conditions are in bad condition, the pipe age and length in the transmission line are higher than other systems etc. It can be concluded that the model results developed based on the AHP method are compatible with these evaluations. The results showed that AHP method can be applied in successfully in evaluating the pumped-water supply systems as the structural and technical by practitioners and researchers.

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