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Use of AHP Method in Efficiency Analysis of Existing Water Treatment Plants

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Abstract *— The trend of urbanization in India is exerting stress on civic authorities to provide safe drinking water. It is very much necessary to evaluate the performance of the existing water treatment plant from time to time for the better understanding of design and operating difficulties in these water treatment plants. In this research work the aim is to set up the performance evaluation system for the existing water treatment plant. The conventional water treatment plants (WTPs) are designed using rule-of-thumb approaches developed with years of experience. The present study gives introduction to a Comprehensive Performance Evaluation (CPE) Technique to implement performance assessment of WTPs, by identifying performance indicators and corresponding evaluation items. A detailed list of such performance parameters has been prepared. An Analytical Hierarchy Process (AHP) method is used to assign relative weightages to these performance parameters and their major evaluation items. The case study for the Kotarpur WTP at Ahmedabad has been presented here.*

Keywords *—Water Treatment Plant (WTP), Performance Indicators, Analytical Hierarchy Process (AHP), Relative Weightages, Efficiency Analysis.*

I. INTRODUCTION

The unit processes in conventional water treatment plants include Coagulation, Flocculation, Sedimentation, Filtration and Disinfection. These individual units in the Treatment Plant are usually designed as recommended in the Manual. The design, when implemented, may give satisfactory level of performance but may not necessarily be optimal, functionally and cost wise[3].

The operation of the water treatment plant is a dynamic process. The performance of each treatment unit affects the efficiency of the subsequent units. Since most of the WTPs operate using rule-of-thumb approaches it becomes extremely important to carry out an efficiency analysis process based on several performance indicators. Such performance parameters have different impacts on the quality and efficiency of the processes. It becomes very difficult to decide the approximate importance of each of the parameters, if applied on ad-hoc basis. The method like Analytical Hierarchy Process (AHP) involves the views and feedback of the experts and technical personnel looking after the execution of the WTP.

There are usually many solutions proposed for each problem. Each of them would entail certain outcomes that are more or less desirable, more or less certain, in the short or long term, and would require different amounts and kinds of resources. There is a need to set priorities on these solutions according to their effectiveness by considering their benefits, costs, risks, and opportunities, and the resources they need. In the following study, an Analytical Hierarchy Process (AHP) method is used to assign relative weightages to the performance parameters and their major evaluation items. The case study for the Kotarpur WTP at Ahmedabad has been presented here.

II. STUDY AREA

The Kotarpur Water Works at Ahmedabad, in state of Gujarat, India, is the largest Conventional Water Treatment Plant in Asia with a capacity of treating 650 MLD and Over Loading Capacity of treating 715 MLD of surface water. Surface water from the Narmada Main canal is used for treatment at the Kotarpur Water Works. The Kotarpur Water Treatment Plant is owned by Ahmedabad Municipal Corporation but the Operation and Maintenance of the WTP is contracted to the Private Agency on yearly contractual basis [2].

III. METHODOLOGY

A. Identification of Process Performance Indicator Parameters

Based on the available information on various categories of the performance indicators around the world through literature study, significant and important 11 performance indicators were determined along with their major evaluation items. These proposed performance indicators and their major evaluation items were discussed with the high-level supervisors at the Kotarpur Water treatment plant. The outcome of technical recommendation for these 11 performance indicators is indicated in Table 1.

TABLE I: COMPREHENSIVE REVIEW OF PERFORMANCE INDICATORS SELECTED FOR WATER TREATMENT PLANT

Sr. No.	Performance Indicator	Technical Recommendation**
1	Water Quality Control	A
2	Chemical Cost Reduction	B
3	Water Production rate	A
4	Waste Minimization	B
5	Source Water Protection	B
6	In-plant Modification and Contingency Plans	B
7	Equipment Availability	B
8	No. of Employees	C
9	Reliability of Equipment	B
10	Maintenance of Equipment	B
11	Electricity Consumption	C

** A = Strongly recommended, B = Recommended, C = Not recommended

After the discussion those indicators which were not recommended (**C) were dropped and parameters pertaining to Equipment were merged as Equipment Availability/ Reliability/ Maintenance. Thus in all 7 performance indicators were identified. Assessment of these 7 performance indicators for priority ranking was carried out using Analytic Hierarchy Process (AHP). The flow diagram of the proposed Performance Evaluation System and the use of AHP in the process, for this WTP are shown in Fig. 1

B. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas L. Saaty (1980). It is a method to derive ratio scales from paired comparisons. The input can be obtained from actual measurement such as price, weight etc., or from subjective opinion such as satisfaction feelings and preference.

AHP allows some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

1) The AHP Theory: Consider n elements to be compared, $C_1 \ldots C_n$ and denote the relative 'weight' (or priority or significance) of C_i with respect to C_j by a_{ij} and form a square matrix $A=(a_{ij})$ of order n with the constraints that $a_{ij} = 1/a_{ji}$, for $i \neq j$, and $a_{ii} = 1$, all i. Such a matrix is said to be a reciprocal matrix. The weights are consistent if they are transitive, that is $a_{ik} = a_{ij}a_{jk}$ for all i, j, and k. Such a matrix might exist if the a_{ij} are calculated from exactly measured data. Then find a vector ω of order n such that $A\omega = \lambda\omega$. For such a matrix, ω is said to be an eigenvector (of order n) and λ is an eigenvalue. For a consistent matrix, $\lambda = n$. For matrices involving human judgement, the condition $a_{ik} = a_{ij}a_{jk}$ does not hold as human judgements are inconsistent to a greater or lesser degree. In such a case the ω vector satisfies the equation $A\omega= \lambda_{max}\omega$ and $\lambda_{max} \geq n$. The difference, if any, between λ_{max} and n is an indication of the inconsistency of the judgements. If $\lambda_{max} = n$ then the judgements have turned out to be consistent. Finally, a Consistency Index (CI) can be calculated from $CI = (\lambda_{max} - n)/(n-1)$.

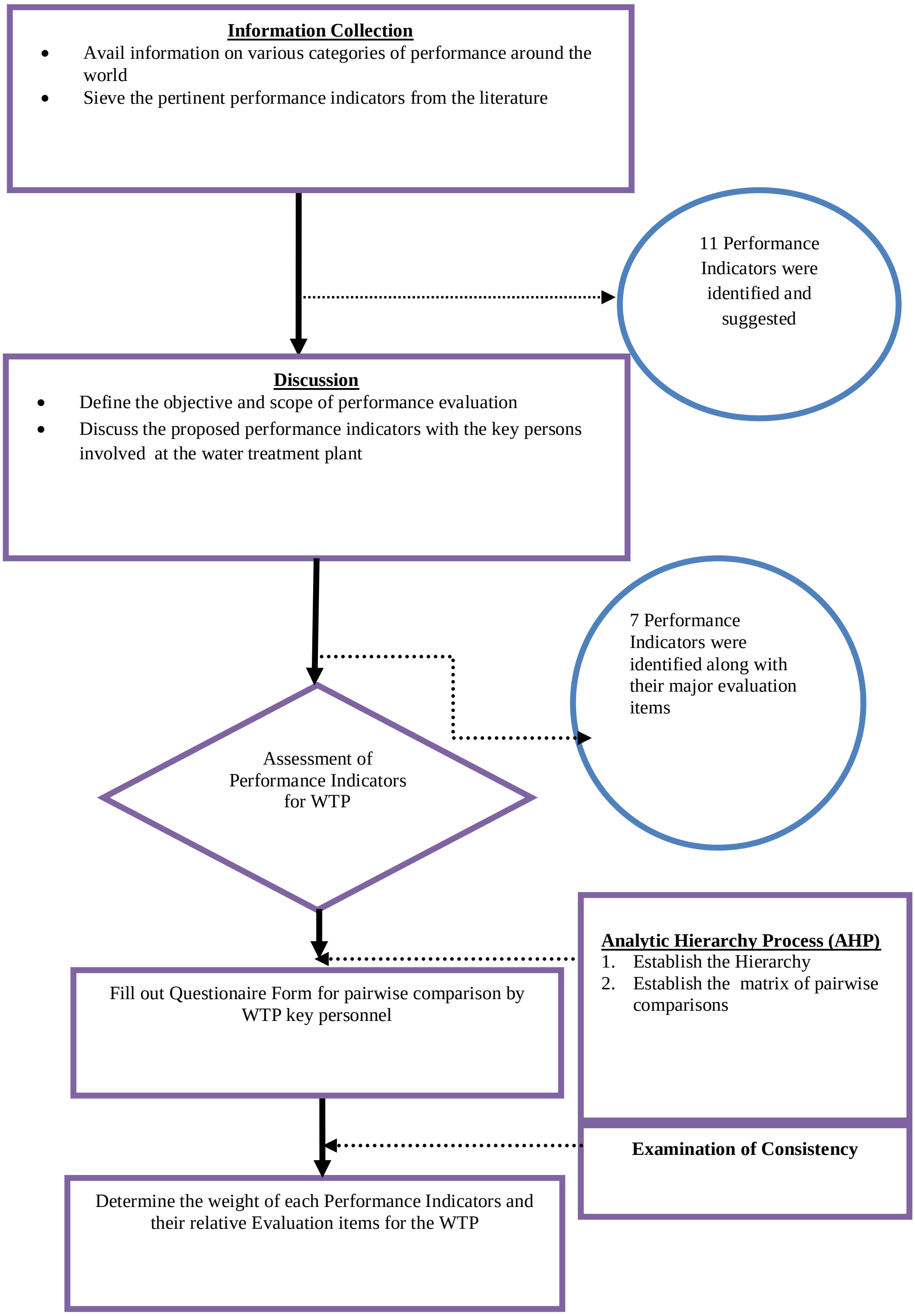


Fig. 1 Establishment of Performance Evaluation System for Kotarpur WTP[1]

That needs to be assessed against judgments made completely at random and Saaty has calculated large samples of random matrices of increasing order and the Consistency Indices of those matrices as shown in Table 2. A true Consistency Ratio (CR) is calculated by dividing the Consistency Index (CI) for the set of judgments by the Index for the corresponding random matrix (RI).

$$CR = CI / RI$$

Saaty[5] suggests that if that ratio exceeds 0.1 the set of judgments may be too inconsistent to be reliable. In practice, CRs of more than 0.1 sometimes have to be accepted. A CR of 0 means, that the judgments are perfectly consistent.

Table 2: Random Consistency Index (RI) [4]

n	1	2	3	4	5	6	7	8
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41
n	9	10	11	12	13	14	15	
RI	1.45	1.49	1.51	1.48	1.56	1.57	1.59	

2) The AHP Data Collection: Questionnaires for performance parameters, as shown in Table 5 were prepared for pairwise comparisons and a survey was conducted by involving experts and technical employees of the water treatment plant. For n parameters, no. of comparisons to be made is given in Table 3.

Table 3
Number of paired comparisons

Number of things	1	2	3	4	5	6	7	n
number of comparisons	0	1	3	6	10	15	21	$\frac{n(n-1)}{2}$

Table 4
AHP Evaluation Scale [4]

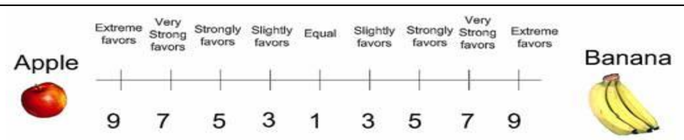
Extremely Important	9
Very Strongly Important	7
Strongly Important	5
Moderately Important	3
Equally Important	1

The evaluation scale[4] was divided into five categories as shown in Table 4. The scaling is not necessary 1 to 9 but for qualitative data such as preference, ranking and subjective opinions, it is suggested to use scale 1 to 9. Intermediate values such as 8,6,4,2 were also used to quantify the judgment of importance during pairwise comparison among the performance parameters.

In all 28 Questionnaires Survey Forms were circulated among the technical staff and operators of the Water Treatment Plant. Of 28 Survey Forms, 22 were received out of which 8 were not completely filled up and were thus discarded. Remaining 14 questionnaires were analysed using the Decision support model out of which 8 were found consistent.

Applying mathematics to decision-making, calls for ways to quantify or prioritize personal or group judgments that are mostly intangible and subjective. Decision-making requires doing what is traditionally thought to be impossible, comparing apples and bananas. But apples and bananas can be compared by decomposing preferences into the many properties that apples and bananas have, determining their importance, comparing and obtaining the relative preference of apples and bananas with respect to each property, and synthesizing the results to get the overall preference.

Table 5: Questionnaire Survey Form No. 2 for Performance Parameters filled up by the technical personnel at Kotarpur WTP.



Score	PERFORMANCE PARAMETER	PERFORMANCE PARAMETER	Score
2	Water Quality Control	Chemical Cost Reduction	
1	Water Quality Control	Water Production rate	
2	Water Quality Control	Waste Minimization	
3	Water Quality Control	Source Water Protection	
3	Water Quality Control	In-plant Modification and Contingency Plans	
2	Water Quality Control	Equipment Availability/ Reliability/ Maintenance	
	Chemical Cost Reduction	Water Production rate	**2**
2	Chemical Cost Reduction	Waste Minimization	
2	Chemical Cost Reduction	Source Water Protection	
	Chemical Cost Reduction	In-plant Modification and Contingency Plans	**2**
	Chemical Cost Reduction	Equipment Availability/ Reliability/ Maintenance	**2**

2	Water Production rate	Waste Minimization	
5	Water Production rate	Source Water Protection	
2	Water Production rate	In-plant Modification and Contingency Plans	
	Water Production rate	Equipment Availability /Reliability/ Maintenance	**2**
3	Waste Minimization	Source Water Protection	
1	Waste Minimization	In-plant Modification and Contingency Plans	
	Waste Minimization	Equipment Availability/ Reliability/ Maintenance	**2**
	Source Water Protection	In-plant Modification and Contingency Plans	**3**
	Source Water Protection	Equipment Availability/ Reliability/ Maintenance	**4**
1	In-plant Modification and Contingency Plans	Equipment Availability/ Reliability/ Maintenance	

IV. AHP DATA ANALYSIS

A matrix of pairwise comparison was analysed using the Decision Support Model, Software for Decision Making for each survey form to arrive at the consistency of views. Inputs from Questionnaire Survey Form 2 represented in Table 5 are shown in Fig. 3 and 4.

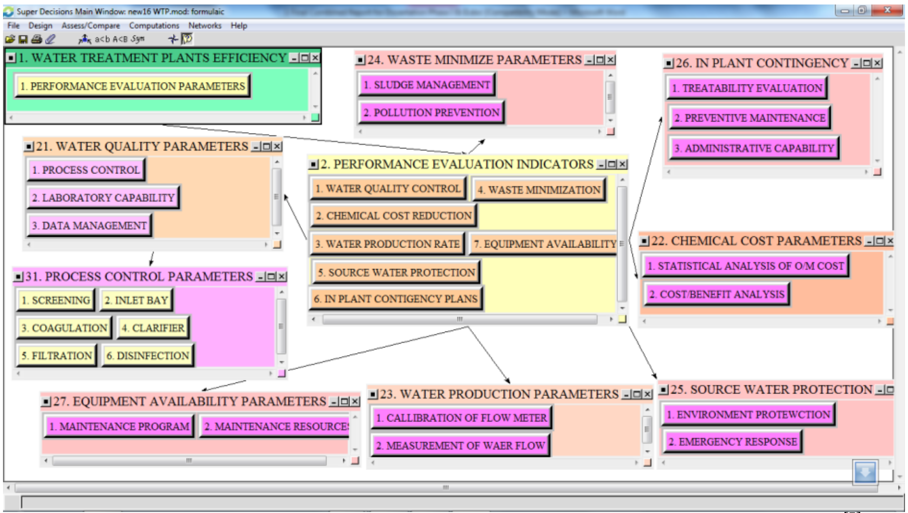


***Fig. 3 Super Decision Model showing Clusters and Nodes and their relationships*[5].**

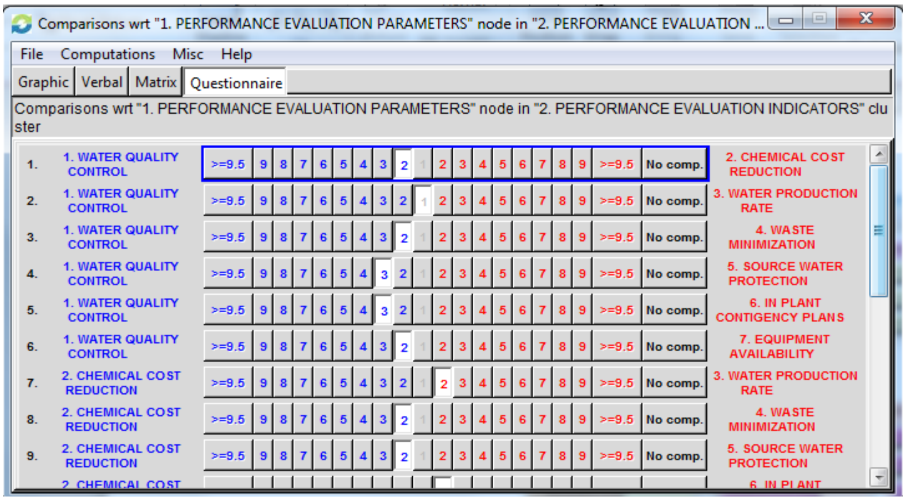


***Fig. 4 Super Decision Model showing pairwise comparison between parameters as per Questionnaires Survey Form*[5].**

1) The AHP Calculations: Table 6 shows the theoretical matrix representation of AHP. Data from Questionnaire survey Form No. 2 completed by the expert in the field was also used to determine the priority vectors as sample calculations using two methods described below. The theoretical results obtained from these two methods were compared with the priority vectors obtained for the same QSF analyzed through the mathematical model – i.e. The Super Decisions Software[5].

For 7 performance parameters, the matrix would be 7 * 7 matrix. The diagonal elements of the matrix would be always 1 for the paired comparison between the same parameter. There is a need to fill up only the upper triangular matrix using the following rules:

1. If the judgment value in the Questionnaire Survey Form is on the **left** side of 1, the **actual judgment** value is used.
2. If the judgment value in the Questionnaire Survey Form is on the **right** side of 1, the **reciprocal of judgment** value is used.

To fill the lower triangular matrix, the reciprocal values of the upper diagonal are used. If $\mathbf{a_{ij}}$ is the element of row **i** column **j** of the matrix, then the lower diagonal is filled using this formula

$$a_{ji} = \frac{1}{a_{ij}}$$

Thus the complete comparison matrix can be formed.

Table 6
Theoretical Matrix representation of Questionnaire Survey Form No. 2 for AHP method

Pairwise comparison	**Water Quality (1)**	**Chemical Cost (2)**	**Water Production (3)**	**Waste Minimization (4)**	**Source Water Protection (5)**	**In Plant Contingency Plans (6)**	**Equipment Availability (7)**
Water Quality	1	2	1	2	3	3	2
Chemical Cost	1/2	1	1/2	2	2	1/2	1/2
Water Production	1	2	1	2	5	2	1/2
Waste Minimization	1/2	1/2	1/2	1	3	1	1/2
Source Water Protection	1/3	1/2	1/5	1/3	1	1/3	1/4
In Plant Contingency Plans	1/3	2	1/2	1	3	1	1
Equipment Availability	1/2	2	2	2	4	1	1

2) Methods to determine priority vectors

Method I:

1. Multiplying together the entries in each row of the matrix and then taking the nth root of that product gives a very good approximation to the correct answer.
2. The nth roots are summed and that sum is used to normalize the eigenvector elements to add to 1.0. In the matrix the nth root for the first row is divided by the sum to give the first element in the eigenvector. Similarly other elements of eigenvectors (ω) are determined.
3. Determine the new vector ($A*\omega$) for each row. The first row element ($A*\omega$) is calculated by summation (Σ) of product (($A_{ij} * \omega_j$), i = 1, j = 1 to n), where A is n * n matrix). In the same manner for i = 2, 3 … n, j = 1 to n in each case, other elements of ($A*\omega$) can be obtained.
4. The next stage is to calculate λ_{max} so as to lead to the Consistency Index and the Consistency Ratio. The AHP theory says that $A\omega=\lambda_{max}\omega$ so the estimates of λ_{max} can be obtained by the simple expedient of dividing each component of ($A*\omega$) by the corresponding eigenvector element (ω) to get respective λ_{max} element.
5. The mean of these λ_{max} elements gives Avg λ_{max}. If any of the estimates for λ_{max} turns out to be less than n, or 7 in this case, there has been an error in the calculation, which is a useful sanity check.
6. The Consistency Index (CI) for a matrix is calculated from (λ_{max}-n) / (n-1)

7. The final step is to calculate the Consistency Ratio (CR) for this set of judgments using the CI for the corresponding value from large samples of matrices of purely random judgments (RI) using the Table 2, derived from Saaty's book. The CR should be less than 0.1 for the acceptable judgments.The Calculations using Method I are shown in Table No. 8

Method II:

1. For a n * n paired comparison matrix, first of all find the sum of each column.
2. Divide each element of the matrix with the sum of its column, to get the normalized relative weight. The sum of each column is 1.
3. The normalized principal Eigen vector (ω) can be obtained by averaging across the rows. The normalized principal Eigen vector is also called **priority vector.** Since it is normalized, the sum of all elements in priority vector is 1. The priority vector shows relative weights among the things to compare.
4. In order to check the consistency, Principal Eigen value (λ_{max}) is obtained from the summation of products between each element of Eigen vector and the sum of columns of the matrix. ($\lambda_{max} \geq n$)
5. Compute the Consistency Index as CI = (λ_{max}-n) / (n-1).
6. The final step is to calculate the Consistency Ratio (CR) for this set of judgments using the CI for the corresponding value from large samples of matrices of purely random judgments (RI) using the Table 2, as CR = CI / RI. If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable; otherwise there is a need to revise the subjective judgment. The Calculations are shown in Table No. 9

The Comparison between above two theoretical methods I and II, and the Super decision Software for the determination of priority vectors of Questionnaire Survey Form No. 2 is tabulated in Table 10 which is suggestive that the Super Decision software can be used for finding the relative weightages for the remaining Questionnaire Survey Forms.

Thereafter all the filled up Questionnaire Survey Forms for Performance Parameters were analysed using Super Decision Software and the mean of the survey was obtained to decide the relative weightages of each performance parameters. The adopted relative weightages in percentage is indicated in Table 11.

Table 8 Priority Vectors obtained from Theoretical Method I of AHP for Kotarpur WTP

Pairwise comparison	Water Quality	Chemical Cost	Water Production	Waste Minimization	Source Water Protection	In Plant Contingency Plans	Equipment Availability	7^{th} root of product of values	Eigen Vector	A * ω	Eigen Value λ_{max}
Water Quality	1	2	1	2	3	3	2	**1.8422**	**0.2350**	1.74388	7.42034
Chemical Cost	1/2	1	1/2	2	2	1/2	1/2	**0.8203**	**0.1047**	0.77354	7.39145
Water Production	1	2	1	2	5	2	1/2	**1.5341**	**0.1957**	1.42602	7.28623
Waste Minimization	1/2	1/2	1/2	1	3	1	1/2	**0.7873**	**0.1004**	0.73159	7.28393
Source Water Protection	1/3	1/2	1/5	1/3	1	1/3	1/4	**0.3687**	**0.0470**	0.34024	7.23386
In Plant Contingency Plans	1/3	2	1/2	1	3	1	1	**1.0000**	**0.1276**	0.94419	7.40115
Equipment Availability	1/2	2	2	2	4	1	1	**1.4860**	**0.1896**	1.4244	7.51373
					Summation			**7.8386**	**1.0000**	**Avg λ_{max}=**	**7.36153**
C I = 0.06025				**C R = 0.04565 < 0.1**					**Avg. λ_{max} > n = 7**		

Then the Questionnaire Survey Form No. 2 for Major Evaluation Items as shown in Table 12 was used for evaluating the relative weightages of each major evaluation items using (AHP) methodology by the Super Decision Software. The other survey forms were also evaluated and the mean of the all the consistent Survey was determined to adopt the relative weightages in percentage for the major evaluation items is given in Table 13.

Table 9: Priority Vectors obtained from Theoretical Method II of AHP for Kotarpur WTP

STEP 1:

Pairwise comparison	Water Quality	Chemical Cost	Water Production	Waste Minimization	Source Water Protection	In Plant Contingency Plans	Equipment Availability
Water Quality	1	2	1	2	3	3	2
Chemical Cost	1/2	1	1/2	2	2	1/2	1/2
Water Production	1	2	1	2	5	2	1/2
Waste Minimization	1/2	1/2	1/2	1	3	1	1/2
Source Water Protection	1/3	1/2	1/5	1/3	1	1/3	1/4
In Plant Contingency Plans	1/3	2	1/2	1	3	1	1
Equipment Availability	1/2	2	2	2	4	1	1
Summation	**4 1/6**	**10**	**5 5/7**	**10 1/3**	**21**	**8 5/6**	**5 3/4**

STEP 2:

Pairwise comparison	Water Quality	Chemical Cost	Water Production	Waste Minimization	Source Water Protection	In Plant Contingency Plans	Equipment Availability	Eigen Vector ω
Water Quality	1/4	1/5	1/6	1/5	1/7	1/3	1/3	0.2342
Chemical Cost	1/8	0	0	1/5	0	0	0	0.1057
Water Production	1/4	1/5	1/6	1/5	1/4	2/9	0	0.1944
Waste Minimization	1/8	0	0	0	1/7	1/9	0	0.0996
Source Water Protection	0	0	0	0	0	0	0	0.0466
In Plant Contingency Plans	0	1/5	0	0	1/7	1/9	1/6	0.1278
Equipment Availability	1/8	1/5	1/3	1/5	1/5	1/9	1/6	0.1917
Summation	1	1	1	1	1	1	1	1
STEP 3:	**Eigen Value $\lambda_{max} = 7.3801$**				**STEP 4:**	**C I = 0.0634, C R = 0.0480 < 0.1**		

Table 10: Comparison between above two theoretical methods and the Super decision Software for the data analysis of Questionnaire Survey Form No. 2 for Kotarpur WTP

Performance Parameters	Method I	Method II	Super Decision Software
Water Quality	23.50%	23.42%	23.69%
Chemical Cost	10.47%	10.57%	10.45%
Water Production	19.57%	19.44%	19.28%
Waste Minimization	10.04%	9.96%	9.90%
Source Water Protection	4.70%	4.66%	4.61%
In Plant Contingency Plans	12.76%	12.78%	12.80%
Equipment Availability	18.96%	19.17%	19.24%

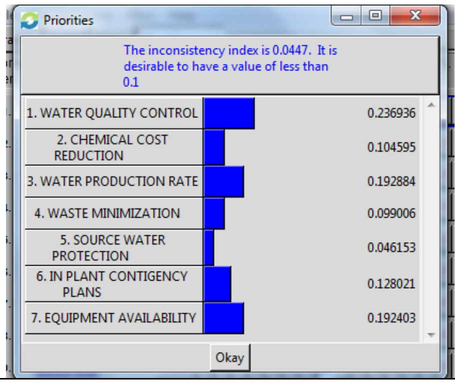
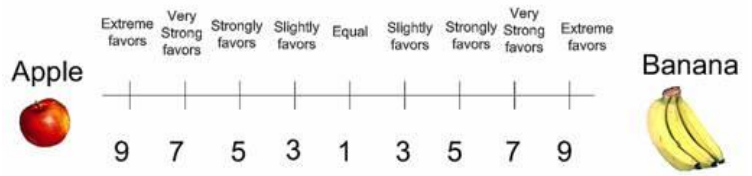


Table 11: Comparison of Priority Vectors of all the Consistent Questionnaires Survey Form for Performance Parameter and the Adopted Weightages

Performance Parmeters	Priority Vectors obtained from Decision Support Model								Mean	Assigned Weightages in (%)
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6	Survey 7	Survey 8		
Water Quality	0.1930	0.2369	0.2090	0.2140	0.2310	0.2350	0.2270	0.2260	**0.2215**	**23%**
Chemical Cost	0.1070	0.1046	0.1120	0.1120	0.0870	0.1610	0.1410	0.1390	**0.1204**	**12%**
Water Production	0.1930	0.1929	0.1830	0.2140	0.2320	0.1900	0.1910	0.1910	**0.1984**	**20%**
Waste Minimization	0.1070	0.0990	0.1110	0.1170	0.1020	0.1160	0.1290	0.1020	**0.1104**	**10%**
Source Water Protection	0.0500	0.0462	0.0510	0.0560	0.0470	0.0530	0.0470	0.0540	**0.0505**	**5%**
In Plant Contingency Plans	0.1560	0.1280	0.1590	0.1010	0.1140	0.0780	0.0960	0.1130	**0.1181**	**12%**
Equipment Availability	0.1930	0.1924	0.1740	0.1880	0.1850	0.1670	0.1680	0.1760	**0.1804**	**18%**
Inconsistency Ratio (< 0.1)	**0.0088**	**0.0447**	**0.0734**	**0.0760**	**0.0281**	**0.0532**	**0.0355**	**0.0635**	**0.0479**	**100%**

Table 12: Questionnaire Survey Form No. 2 for Major Evaluation Items under each Evaluation Items for Kotarpur WTP



Score	Major Evaluation Items	Major Evaluation Items	Score
	1. Water Quality Control		
3	Process Control (Coagulation, filtration, disinfection etc.)	Laboratory Capability (Sampling, testing, procedures)	
2	Process Control	Data Management (Data collection, application, monitoring)	
1	Laboratory Capability	Data Management	
	2. Water Production Rate		
3	Calibration of flow meter (Calibrated by instruments, Checked by pump efficiency etc.)	Measurement of water flow (flow during operation, Instantaneous peak flow, backwash water)	
	3. Chemical Cost Reduction		
4	Statistical analysis of operation and maintenance cost (Cost of energy consumption, chemicals, sludge treatment, training, transportation)	Cost- benefit analysis	
	4. Waste Minimization		
	Evaluation of sludge management system (amount of sludge production, waste water discharge, dewatering efficiency)	Implementation of pollution prevention program (reduction in waste quantity, disposal of sludge etc.)	**1**
	5. Equipment Availability/ Reliability/ Maintenance		
	Maintenance Program (Preventive, Corrective, Predictive maintenance)	Maintenance Resources (Equipment repair and parts, maintenance expertise, work space, tools etc.)	**2**
	6. Source Water Protection		
	Emergency Response plan	Environmental Protection program	**2**
	7. In-plant Modifications and Contingency plan		
2	Treatability Evaluation (performance objectives for each unit process, treated water in compliance with standards,	Preventive maintenance (warning system, tackle with breakdown system, chemical storage	

	documentation of standard operation procedures)	and transportation issues, timely maintenance etc.)	
2	Treatability Evaluation	Administrative capability (ability to upgrade treatment schemes, attempt to achieve objectives, ability to handle emergency, accountability, press release and media guidelines etc.)	
1	Administrative capability	Preventive maintenance	

Table 13: Category of Performance Assessment Indicators for Kotarpur WTP

Sr.	Performance Parameter	Weightage	Major evaluation Items	Weightage	Category
1	Water Quality	23%	Process Control (45%)	10%	Operation
			Laboratory Capability (20%)	5%	
			Data Management (35%)	8%	
2	Chemical Cost Reduction	12%	Statistical Analysis of Operation & Maintenance Cost (65%)	8%	
			Cost- Benefit analysis (35%)	4%	
3	Water Production Rate	20%	Calibration of flow meter (65%)	13%	
			Measurement of water flow (35%)	7%	
4	Waste Water Minimization	10%	Evaluation of sludge management system (50%)	5%	
			Implementation of pollution prevention program (50%)	5%	
5	Source Water Protection	5%	Environmental protection program (60%)	3%	Management
			Emergency response plan (40%)	2%	
6	In-plant Modification and Contingency Plans	12%	Treatability evaluation (30%)	3.5%	
			Preventive maintenance (40%)	5%	
			Administrative Capability (30%)	3.5%	
7	Equipment Availability/ Reliability/ Maintenance	18%	Maintenance program (40%)	7%	Maintenance
			Maintenance resources (60%)	11%	

V. CONCLUSION

The following Conclusions are derived:

1. All unit processes of the Kotarpur WTP are studied in detail and the performance indicators along with their major evaluation items have been identified.
2. The AHP method has been used to determine the relative weightages of the seven performance parameters along with their major evaluation. The AHP method is found to be quite useful and reliable.
3. These relative weightages as evaluated using AHP method are helpful in efficiency analysis by identifying those areas which need more attention based on priority.

VI. ACKNOWLEDGEMENT

The authors would like to acknowledge the kind help and cooperation provided by the experts and technical personnel associated with the Kotarpur Water Treatment Plant and other consultants operating in this field.

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