The Comparison of the Value Engineering Method and Hydraulic Method on Water Distribution Systems Performance Evaluation*

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ABSTRACT

Value engineering is an evaluation method to assess the matching degree on performance and its cost of water distribution systems from the point of function achievement characteristics, which had been published from 2006 in some journal. The scientific of Value engineering method had been confirmed by a large number of facts in other applications, but in the evaluation of water distribution systems is still a new topic. The correctness, accuracy of its evaluation results is very crucial taking into account the complexity of water distribution network; therefore, we should use another mature method for checking its correctness and accuracy. Hydraulic evaluation method of water distribution systems was built on the basis of hydraulic calculation; theory is relatively mature, which is one of achiever way of water distribution systems functional assessment. Therefore, it can be used to check the conclusions of value engineering evaluation. In this paper, hydraulic evaluation methods include two contents: first is the overall performance evaluation by using total performance index of water network, which includes selection of state variables associated with different evaluation system, rendering performance curve for the calibration standard service level performance element variation of state variables, select inductive element level performance evaluation function to expand the pipe network by the performance index. Second, component's performance evaluation which is based on the optimization calculation of water distribution systems, and use the hydraulic parameters ad the basic evaluation indicators. Last, pointed out the advantages and disadvantages of the hydraulic evaluation method and value engineering method by compare and analyze their respective results, drew the conclusion that value engineering method is better than hydraulic evaluation method.

KEYWORS: water distribution systems; performance; evaluation; value engineering; hydraulic; comparison

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1. INTRODUCTION

Since 2005, we agreed on the value engineering method to evaluate water supply network, not only want to establish a suitable method to evaluate the status of water supply network, also hope to compare the previous evaluation, correct value engineering method by the comparing. In this paper, introduce the process of evaluation method of water distribution network by hydraulic method.

2. HYDRAULIC METHOD ON WATER DISTRIBUTION SYSTEMS PERFORMANCE EVALUATION

The quantitative evaluation methods are mainly on the state variable, focus on the performance of the water supply system. First, select the relevant evaluation system for different state variables, and then draw the curve of the standard service performance which element-level performance indicators for the calibration of the changes of state variables. Finally, select the sum function and expand the element level performance evaluation, drew the entire pipe network performance index value.

2.1 State Variables

This is the first step in quantitative method for evaluating the performance of water supply network, selected different relevant state variables for evaluation system. For example: for water quality analysis system, the amount of chlorine of nodes' could reflect the water quality status of water supply network, should be chosen as the evaluation system of the state variables; Hydraulic Evaluation system, selected node pressure as one of the state variables. Usually we know the water supply network topology, after the selected state variables, need simulation and numerical calculation to determine the value of state variables.

2.2 Service Performance Curve

The second step of water supply network performance evaluation is drawn service performance standard curve for the corresponding state variables in the different evaluation system. Service performance is the service state of the network, such as: optimal state, acceptable service status and unacceptable service status, etc.

State variable is the value of the quantitative element level on pipe or pipe network nodes, service performance is represented by state variables. Service curve usually reflects the performance of water supply network element-level performance indicators of changes of state variables. According to the drawn service performance curve, can be obtained the performance index value corresponding to elements of the network, so can evaluate the performance of the network elements.

Performance index value of each node and the node pressure is a piecewise function, node in a different range of pressure changes; performance index value corresponding to the variation is different, function as following:

$$p_i = w(H_i) \qquad (1)$$

p_i: The performance values of the different network element i, $p_i = 0 \sim 4$;

H_i: Node's i pressure.

As the performance of water distribution network is closely related to their service

levels, therefore, when drawing the performance curves, establish a performance scale from 0 to 4, specific meaning: 4 - optimization service status; 3 - full service state; 2 - acceptable service status; 1 - unacceptable service status; 0 - no service status. With the change of state variable values, performance changes from “optimization service status” to “no service status”. For example: in the hydraulic evaluation system of water supply network, node pressure is an important state variable, on the one hand, in order to meet the user water demand, must meet the node’s minimum pressure head(h_{min}); On the other hand, in order to reduce leakage in the pipe network, must also control the node’s maximum pressure head(h_{max}). When a node’s actual pressure is just equal to the minimum pressure head that required (h_{min}), not only can meet the water supply, but also could lowest operating costs of pumps and leakage control. Therefore, the node with the performance of the pressure was set at 4, and mean the service performance is optimize. When a node’s pressure is below the maximum pressure(h_{max}), the network will not cause damage or burst pipes, so its on the acceptable service status; When the node’s pressure is greater than the given value of the maximum pressure(h_{max}), easily lead to pipeline leakage, therefore, service performance curve is plummet, When the node’s pressure has exceeded 50% of the maximum value(h_{max}) , nodes can no longer provide a good water supply services. According to the above principles, we can draw the hydraulic evaluation of the performance curve of water supply pipelines, see in Figure 1.

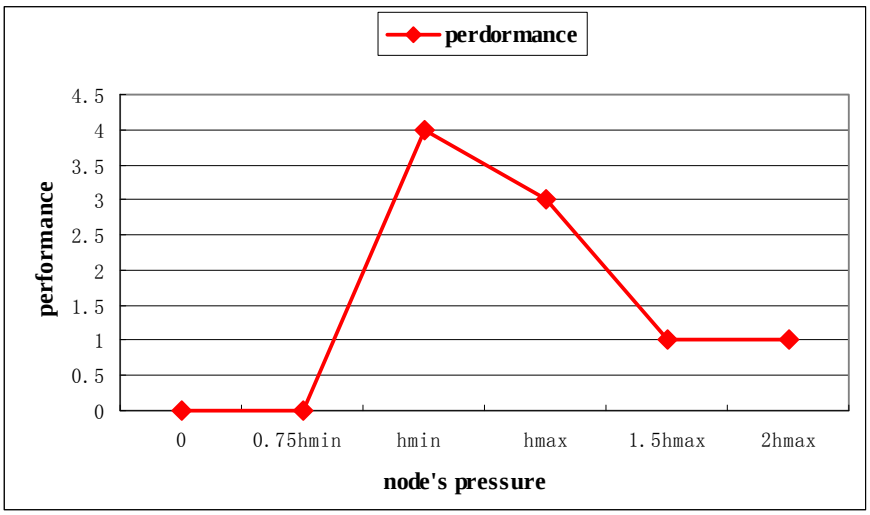

Fig.1 Service performance curve of water supply system

Service performance curve is to the benchmark curve of water supply network system performance evaluation, in the drawing process requires taking into account various water supply standards made by national, local or water companies, therefore, the curve will have different degrees of change over time and space.

2.3 Sum Function

This is the third step of water distribution network hydraulic evaluation. For the basic elements in the water distribution system, after the performance evaluation, such as nodes or pipes, we could get relative performance index value of each element, induction by a similar function to establish the elements of the correlation between performances, to be relative to the entire water distribution system's total performance index.

Here, "sum function" means an operator, in the water supply network, the operator is expanded the elements performance evaluation, resulting the entire total performance index of water supply network. The form of sum function is as following:

$$P = W(p_i) \qquad (2)$$

Here: P The total performance index of water supply network;

p_i The performance values of water network element (nodes or pipes), according to formula (1) calculated;

W The operator which is expanded the same form of performance index of all elements.

2.4 Case Study

We choose the Suzhou city as our case study whose water distribution systems is in Fig.2.

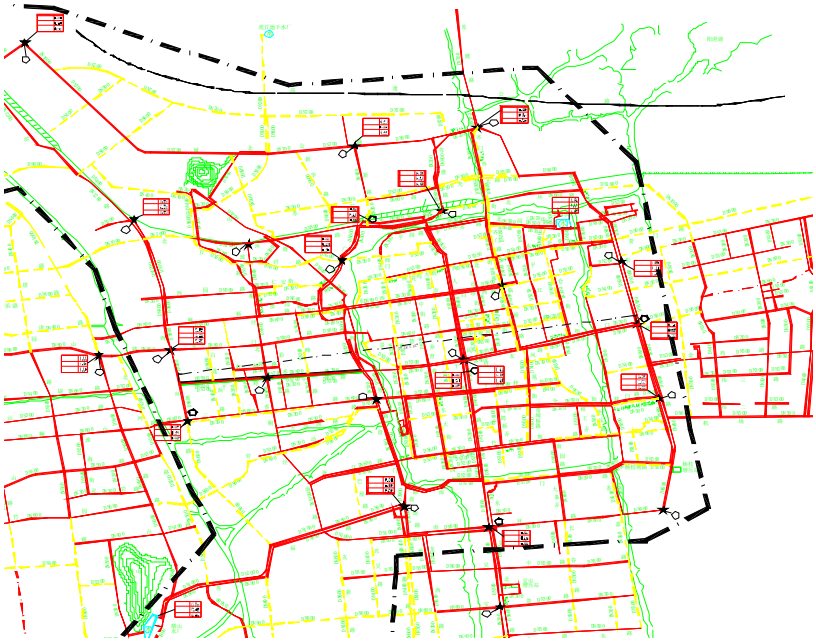

Fig.2 the water distribution systems of case study

Establishment of water distribution network hydraulic performance evaluation system is as follows: first, determine the state variables. Regular water supply in pipeline burst pipe, not only affect the industrial and agricultural production and living, resulting in waste of water resources and threaten the safe operation of water supply network to increase the operating costs of water supply enterprises. Therefore, in the present situation analysis of water supply pipe network should account the pipe,

pressure, etc., maybe proactive in preventing burst pipe incidents.

Suzhou area is flat, most of the water supply network is gray cast iron pipe, have been used a longer time, according to Suzhou City Water Company water supply planning and scheduling information on actual water supply for many years, determine the minimum service pressure $h_{\min} = 20mH_2O$, and the maximum pressure $h_{\max} = 28mH_2O$.

The second part is the rendering of the standard performance curve after the selected state variables, Suzhou water supply network service performance curve shown in Figure 3. By the hydraulic calculation of water supply network, pressure head value (h_i) of each node obtained, according to the drawn standard service performance curve, obtain the corresponding performance index value for each node (p_i), the results are listed in Table 1.

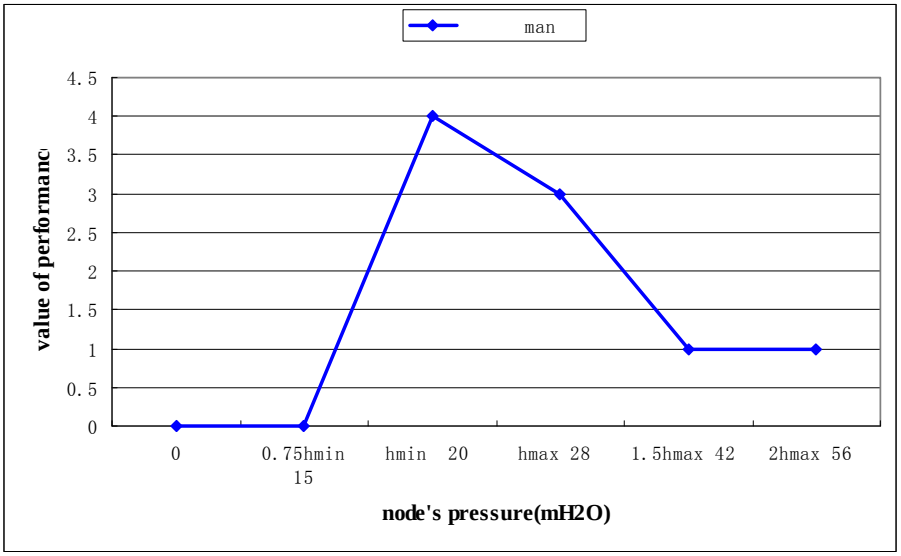

Fig. 3 Suzhou water supply network service performance curve

Table.1 Hydraulic performance evaluation of water distribution in Suzhou city

NODES	Q_i L/S	h_i M	p_i	w_i	$w_i * p_i$
1	46.51	37.71	1.513	0.00893	0.01351
2	202.35	24.31	3.492	0.03885	0.13566
3	268.15	22.89	3.673	0.05148	0.18909
4	473.98	21.83	3.794	0.09100	0.34525
5	114.87	22.36	3.684	0.02205	0.08123
6	114.86	22.45	3.682	0.02205	0.08119
7	256.29	26.01	3.235	0.04930	0.15949
8	45.28	35.07	1.765	0.00869	0.01534
9	55.49	28.47	2.745	0.01065	0.02923

10	284.34	25.53	3.298	0.05459	0.18004
11	604.54	21.92	3.792	0.11607	0.44014
12	553.38	22.23	3.696	0.10624	0.39266
13	45.89	27.80	2.785	0.00881	0.02454
14	347.73	27.09	2.815	0.06676	0.18793
15	342.25	22.17	3.690	0.06571	0.24247
16	352.74	21.64	3.796	0.06772	0.25707
17	619.72	32.10	2.415	0.1190	0.28739
18	179.03	26.01	3.235	0.03437	0.11119
19	300.66	21.55	3.755	0.05772	0.21674
total	5208.56	-------	-------	-------	**3.3902**

The third step is to choose the sum function, since water distribution assumed by each node in different water supply, making the nodes in the network system with different status, therefore, take the water supply to each node Q_i L/S as the weight coefficient, calculated weighted average of each node's performance value, summarized functional form as the following:

$$P = \sum_{i=1}^{n} w_i p_i \qquad (3)$$

$$w_i = \frac{Q_i}{\sum_{k=1}^{n} Q_k} \qquad (4)$$

Here, P the total performance index of water supply network;

p_i Node's performance value on pressure-related;

n The number of nodes in the water supply network;

w_i Weights;

Q_i Water quantum of each node.

After the weighted average all nodes performance values, we could reach conclusion that the total performance index of water supply network $P = 3.3902$, evaluation from hydraulic performance evaluation showed that the water supply network in a full service state to an optimize service state, the results are listed in Table 1.

3. WATER DISTRIBUTION SYSTEMS PERFORMANCE EVALUATION BASED ON VALUE ENGINEERING METHOD (VE)

The method has already undergone detailed analysis by the Cuimei Li [3] and will not therefore be discussed in this present article. The paper chiefly deal with the function structure and the value structure of the water distribution system, and formulated the Value Engineering method to evaluate the performance of the water distribution system. In the paper, we calculated the value index is equal to 1.754 of

the water supply in Suzhou city which in the Fig.2, corresponding evaluation concluded that the network is in excess of the full service state.

From the above data analysis, can be drawn that evaluation of these two indicators reflected the same overall performance of water supply network and the same service state.

4. ADVANTAGES AND DISADVANTAGES OF THE HYDRAULIC EVALIATION METHOD AND VALUE ENGINEERING METHOD

Evaluation of water networks is based on the hydraulic analysis and hydraulic calculate; on this basis also use some economic, mathematical model and methods. Water distribution system evaluated by value engineering methods and hydraulic evaluation method, what could evaluate the current situation of water supply network separately from the technical and economic parameters and hydraulic point of view, and that could also drew the design and operation principles of water supply network by the evaluation indicators.

4.1 Advantages of Value Engineering Method

(1)The study objects of value engineering methods are representative, caught the key small number of water distribution system. Value engineering methods was not took the whole water networks as the study objects, but through a scientific screening, only the core component of water supply network as evaluation objects.

(2)Value engineering methods is based on the extensive information, which could help establish the status information database of water supply network to provide comprehensive, systematic approach.

(3)Value engineering methods pioneered the use of hydraulic calculation of water supply network in new area. The hydraulic calculations are combined with the value engineering for evaluating the water distribution system by VE, hydraulic calculations, such as: pipe flow, flow velocity, flow node, the node pressure and etc. are all taken into the VE, is the basement for the function quantified and value index calculated in the VE. VE for water distribution system is a new binding site to hydraulic calculation and systems engineering.

4.2 Disadvantages of Value Engineering Method

(1)Value engineering study is part of the water supply network; subjects choose a direct impact on the scientific evaluation findings.

(2) The whole life cycle of water supply network is still need to study in depth.

(3) The creation of function quantify mathematical model based on VE of Water supply network is only just begun, mathematical model which we used is still not perfect, maybe lead to a certain degree of deviation.

4.3 Advantages of Hydraulic Evaluation Method

(1) The hydraulic evaluation method took the hydraulic operating parameters for the evaluation indicators, can be better reflect the hydraulic state of water distribution network.

(2) The hydraulic evaluation method has a good foundation for the hydraulic calculation method has been very mature for a long time. Calculated only from the perspective of hydraulic compared, the hydraulic evaluation method is more accurate than VE.

4.4 Disadvantages of Hydraulic Evaluation Method

(1)Standard service performance curve which drawn in the hydraulic evaluation method has strong subjective.

(2) Single state variable can only be one aspect of the performance evaluation of water supply network, should not be used as indicators of overall performance in water network.

(3) Lack of correlation between indexes.

5. CONCLUSION

Value engineering is an evaluation method to assess the matching degree on performance and its cost of water distribution systems from the point of function achievement characteristics, which had been published from 2006 in some journal. The scientific of Value engineering method had been confirmed by a large number of facts in other applications, but in the evaluation of water distribution systems is still a new topic. The correctness, accuracy of its evaluation results is very crucial taking into account the complexity of water distribution network; therefore, we should use another mature method for checking its correctness and accuracy. Hydraulic evaluation method of water distribution systems was built on the basis of hydraulic calculation; theory is relatively mature, which is one of achiever way of water distribution systems functional assessment. Therefore, it can be used to check the conclusions of value engineering evaluation.

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