How to monitor and adjust in real time the total water consumption and water use efficiency: Earned value method

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Abstract. The evaluation indexes of total water consumption and water use efficiency have the characteristics of post feedback. In this paper we introduce the basic concept and specific theory of Earned value method (EVM) from project management, and reconstruct parameters in the method to adapt to water resources monitoring. The case of Dandong was studied, by analyzing the industry and irrigation water utilization. Although the total water consumption of two aspects reaches standards, the industrial added value and water use efficiency of irrigation are not up to standard. The results show that PV can be used as a baseline for real-time monitoring and adjustment, and the advantage of the EVM is that it can be an organic unity of water consumption and efficiency, so we can analyze comprehensively water utilization process.

1 Introduction

Water is essential for human being, economic activities, ecology and environment. In recent years, because of the over-exploitation and low efficiency use of water resources, water resources shortage has become a major social, environmental and ecological problem [1].

In order to avoid further deterioration of water resources, the government of China introduced the most stringent water resources management system, and implemented “three red line” assessment indexes. But the shortage of controlling indexes, such as water consumption and water use efficiency, are only post feedback at the end of the year.

How to monitor and adjust in real time the total water consumption and water use efficiency? By foreign experience, this paper introduces the basic concept and specific theory of Earned value management (EVM) from project management.

The goals of this study are: (1) to design suitable earned value method of water resources; and (2) to monitor and adjust the index of water consumption and water use efficiency, and to evaluate the performance.

2 Materials and methods

2.1 Earned value method

Earned value method (EVM) as a systematic technical measure, plays an important role in project investment and schedule management. It integrates project scope, cost, and schedule measures to help

the project management team to assess in real time and measure project performance and progress [4-6].

EVM develops and monitors three key dimensions for each work package and control account as follows:

Plan value (PV) is the authorized budget for the work to be accomplished, and the total planned value for the project is also known as budget at completion.

$$PV=BC*WS \quad (1)$$

Earned value is the authorized work that has been completed, plus the approved budget for such completed work. Managers monitor EV, both incrementally determine current status and cumulatively determine the trends of long-term performance.

$$EV=BC*WP \quad (2)$$

Actual cost is the total cost actually incurred and recorded in accomplishing work which the EV measured.

$$AC=RC*WP \quad (3)$$

Where, there are four indexes in the Formulas: BC is the value of budgeted cost; WS is the value of work scheduled; RC is the value of real cost; WP is the value of work performed.

Variances from the approved baseline will also be monitored. Scheduled variance (SV) is a measure of schedule performance of a project, as an useful metric which can indicate whether a project falls behind its baseline schedule or not. If the value of SV is less than 0, it's indicated that the work we completed was less than we planted. On the contrary, if the value of SV is greater than 0, it's indicated that the work we completed was more than we planted.

$$SV=EV-PV \quad (4)$$

Cost variance is also a measure of cost performance of a project. If the value of CV is less than 0, the cost overrun for work completed is indicated. On the contrary, if the value of CV is greater than 0, the cost under-run of performance to date is indicated.

$$CV=EV-AC \quad (5)$$

2.2 Water consumption earned value

The principles of EVM can be applied to all projects, in any industry. In this paper, the purpose of introducing earned value method is to use the functions of dynamic monitoring and pertinent adjustment.

Water consumption earned value is a water resources management technique. The three key dimensions and four indexes were endowed with new meaning. PV is the water consumption which is planned monthly or annually; EV is the work, such as industry, irrigation, service and domestic, which has been completed, plus the authorized water quota or water use efficiency for completed work; AC is the actual monthly or annually water consumption. Moreover, in the next section, the work of WS, WP is per ten thousand RMB Yuan industrial added value and mu of irrigation farmland. The quota of the BC, RC is water consumption of per ten thousand RMB Yuan industrial added value and irrigation consumption of water per mu of farmland.

2.3 Study region and data

Dandong is located in the southeast of Liaoning Province, where the average annual precipitation is 1000mm, and the water resources quantity is 8.9 billion. The GDP is 98.5 billion RMB yuan (2015), rising by -3%, and the industrial added value is 40.2 billion RMB yuan, rising by -8.8%, (current price) [7].

The basic data for PV was referred to through "Dandong city water resources bulletin" and "Dandong national economic and social development statistical bulletin", and the real-time data for EV and AC is statistic in bureau of statistic and water resources of Dandong.

3 Results

In this paper we focus on two aspects of industrial added value and irrigation farmland with the Earned value model. Industry and irrigation water use efficiency are important constraint indexes of

the most stringent water resources management in china.

WS of industry is based on the average monthly data in the national economic bulletin of 2013-2014, plus the increase by 7%, which is listed in the Outline of 12th Five-Year Plan. BC (water consumption of per ten thousand RMB Yuan industrial added value) of 2014 is 24.7, decreased by 7%, so BC of 2015 is 22.97 as shown in Table 1. The actually data of 2015 is taken from statistics of bureau, but the data of RC is obtained by indirect calculation with AC and WP, and the price should be converted into the comparable price of the year of 2010.

Table 1. Earn value of water consumption of per ten thousand RMB Yuan industrial added value

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
WS	40	37	40	43	46	50	43	43	45	42	35	29
BC	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
PV	919	850	919	988	1057	1149	988	988	1034	965	804	666
WP	46	38	37	37	38	39	38	36	36	32	25	18
RC	22.83	22.11	22.43	22.43	22.11	22.18	22.11	22.22	21.67	22.19	22.00	22.22
EV	1057	873	850	850	873	896	873	827	827	735	574	413
AC	1050	840	830	830	840	865	840	800	780	710	550	400

Unit: WS, hundred million RMB yuan; BC,m^3/ten thousand RMB yuan; PV,ten thousand m^3; WP, hundred million RMB yuan; RC,m^3/ten thousand RMB yuan; EV, ten thousand m^3; AC, ten thousand m^3.

Table 2. Earn value of irrigation consumption of water per mu of farmland

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
WS				107	107	107	107	107	107			
BC				11	182	179	148	138	31			
PV				1177	19474	19153	15836	14766	3317			
WP				100	100	100	91	100	91			
RC				10	199	185	160	145	32			
EV				1100	18200	17900	13394	13800	2806			
AC				1000	19850	18500	14500	14500	2900			

Unit: WS, ten thousand mu; BC,m^3/mu; PV, ten thousand m^3; WP, ten thousand mu; RC,m^3/mu; EV, ten thousand m^3; AC, ten thousand m^3.

Table 2 shows the irrigation data from April to September during the irrigation period. The effective irrigation area is still 107 ten thousand mu. The BC of irrigation is the same as the industry, by the decrease of 5%, but the distribution of monthly value is average monthly data from the water resources bulletin of 2013-2014.

Monthly cumulative values of PV, EV, AC are shown as the thick solid line, dotted line and thin solid line in Figure 1 and Figure 2.

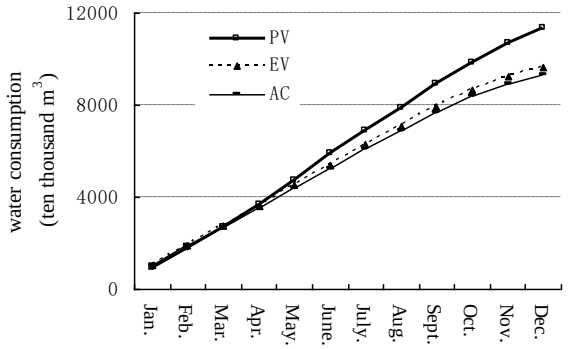

Figure 1. Earned value, planned value, and actual costs of water consumption of per ten thousand RMB Yuan industrial added value.

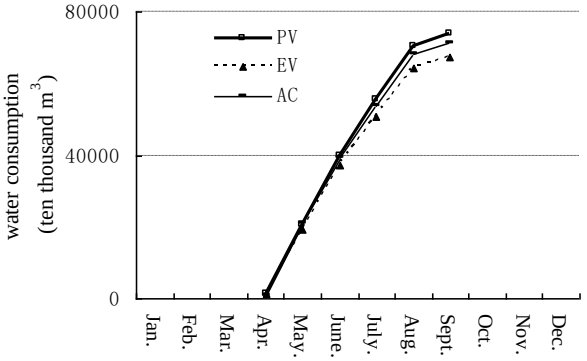

Figure 2. Earned value, planned value, and actual costs of irrigation consumption of water per mu of farmland.

4 Discussion

The expected performance of water managers in theory is the relationship of PV≈EV> AC, which indicates that both the total water consumption and the water use efficiency are better than the planned values. It shows the critical time of adjustment when the relationships were broken.

In this section, we focus on the application of the Earned value method to the industry. Table 1 shows that the unexpected result occurs in the first month (January), and lasts until February. The relation of EV>AC>PV indicates that not only the ten thousand RMB Yuan industrial added value is greater than the baseline, but also its efficiency is better than the planned value, but the total water consumption is beyond the critical value.

However, we must balance economic growth and water utilization, in order to promote economic and water resources sustainable development. In this paper, we suggest that the adjustment time may be in the midyear or the time the variance is greater than 10%-30% of total water consumption, at the same time, it is difficult to adjust the water utilization structure. So we don't adjust in February.

The accumulation of EV is greater than PV from January to March as shown in Figure 1, but from April to December, the relation of cumulative value is PV>EV>AC. The reason is that the industrial added value is less than the growth rate of 7%, but the efficiency is average 0.65m^3/ten thousand RMB yuan less than the planned value.

As shown in Table 2 and Figure 2, except for April, the rest months from May to September have the same monthly and cumulative trends, PV>AC>EV, and although the total water consumption reaches standards, the water use efficiency is not up to standard. By the supervision of irrigation process, it is found that drought weather leads to the reduction of available water supply and the increment of irrigation water requirement, so it's a feasible way to reduce irrigation area in order to control the total water consumption.

5 Conclusions

The shortage of water resources controlling index of the most stringent water resources management system is only post feedback. Water resources earned value management can monitor in real time and adjust in the procedure of water utilization.

Furthermore, PV can be used as a baseline or alert value. And according to the range of its variance, it can be a real-time warning and we can make adjustment for reaching standard of PV. The results of the case show that the water consumption of both industry and irrigation meet the requirement, but the efficiency of irrigation does not reach the standard during the whole process except April. Fortunately, we have not made a prediction, forewarning and adjustment scheme by the actual water resources and economic environment.

Finally, the advantage of the earned value method is that it can be an organic unity of water consumption and water use efficiency, so we can do comprehensive analysis of water resources utilization.

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