روش ارزش کسب شده بر اساس نظریه خاکستری برای پروژه های سرمایه‌گذاری

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چکیده

مدیریت ارزش کسب شده یک تکنیک شناخته شده در مدیریت پروژه با هدف ارزیابی و کنترل عملکرد و پیشرفت پروژه از طریق یکپارچه سازی سه عامل هزینه، زمان و محدوده پروژه می باشد. در این مقاله یک روش تحلیل ارزش کسب شده بر پایه تئوری خاکستری برای بهبود آنالیز شاخص های ارزش کسب شده و در ادامه تخمین زمان و هزینه اتمام پروژه تحت شرایط عدم قطعیت برای بهینه سازی زمان و هزینه پروژه ارائه می گردد. در نهایت، یک نمونه در پروژه های سرمایه گذاری برای نمایش کارایی مدل ارائه شده در شرایط دنیای واقعی بیان می شود.

واژگان کلیدی: آنالیز ارزش کسب شده، اعداد خاکستری، عدم قطعیت، پروژه های سرمایه گذاری.

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A Grey-based Earned Value Approach for Investment Projects

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Abstract: Earned value management (EVM) is a renowned project management technique in evaluating and controlling the performance and progress of the project by integrating time, cost and scope. In this paper, a new grey-based earned value analysis model has brought to develop the analysis of earned value indices and the cost and time estimates at completion under uncertainty to optimize the time and cost of the project. Finally, a case study in investment projects is presented to show the implication of the proposed model in real-life situations.

Keywords: Earned value analysis, grey numbers, uncertainty, investment projects.

۱. INTRODUCTION

Earned value project management is a valuable tool to be used in the management of projects. This technique is used to measure and communicate the real physical progress of a project and to integrate three critical elements of project management, i.e., scope, time and cost. It takes into account the work completed, the time taken and the cost incurred to complete the project, and it helps to evaluate and control project risks by measuring project progress in monetary terms [۱]. This paper discusses the EVM methodology under real-life uncertain conditions. Considering this uncertainty into interpretations and calculations helps not only in measuring the performance and progress of the investment project, but also in extending the applicability of the EV techniques. In this paper, a new grey-based EV technique is presented to measure the progress and performance of the investment projects under uncertainty circumstances.

As a different model for uncertain representations, grey systems were proposed by Deng in ۱۹۸۲ [۲،۳]. In grey systems, the information is classified into three categories: white with completely certain information, grey with insufficient information and black with totally unknown information. Interval grey numbers are the basic concepts in this paper. The following definition represents an interval grey number [۳].

$$\otimes \in [\underline{a}, \overline{a}], \ \underline{a} < \overline{a} \qquad (۱)$$

۲. EVM INDICES AND COMPUTATIONS

One of the EVM techniques to estimate the completion cost and time of a project is percent complete method that uses the experts' judgments for the estimation. Based on the percent complete method, the interval grey numbers for showing the progress of project by linguistic terms represents as follows:

[۰.۰,۲] as very low,

[۰,۲.۰,۴] as low,

[۰,۴.۰,۶] as half,

[۰,۶.۰,۸] as high

and

[۰,۸.۱] as very high.

In expressing the completion percent of each activity on the basis of a grey number, the interval grey earned value of each activity *i*, $\otimes EV_i$ can be calculated using the Eq. (۲).

$$\otimes EV_i = \otimes F_i * BAC_i \in \left[\underline{E_{۱i}}, \overline{E_{۲i}}\right] \in [a_{۱i} * BAC_i , a_{۲i} * BAC_i] \quad (۲)$$

where $\otimes F_i$ is the grey completion percent of the activity *i*.

$$\otimes F_i = [\underline{a_{۱i}}, \overline{a_{۲i}}] \quad (۳)$$

and BAC_i is the budget at completion of activity *i*. The total grey earned value is calculated as follows:

$$\otimes EV = \sum_{i=۱}^{n} \otimes EV_i \in [\sum_{i=۱}^{n} E_{۱i} , \sum_{i=۱}^{n} E_{۲i}] \in [\underline{E_۱} , \overline{E_۲}] \quad (۴)$$

The schedule performance index is a measure of the conformance of actual progress to schedule and calculate as follows:

$$\otimes SPI = {}^{\otimes EV}/_{PV} \in [\underline{{}^{E_۱}/_{PV}} , \overline{{}^{E_۲}/_{PV}}] \quad (۵)$$

where PV is the planned value.

The cost performance index is a measure of the budgetary conformance of the actual cost of work performed and is calculated as follows:

$$\otimes CPI = {}^{\otimes EV}/_{AC} \in [\underline{{}^{E_۱}/_{AC}} , \overline{{}^{E_۲}/_{AC}}] \quad (۶)$$

where AC is the actual cost.

Among several formulas available to calculate cost estimate at completion (EAC), a common formula assuming the future trend of the project cost performance remains intact, represented as follows:

$$\otimes EAC = \frac{BAC}{\otimes CPI} \in [\frac{AC*BAC}{E_۲}, \frac{AC*BAC}{E_۱}] \quad (۷)$$

Earned schedule (ES) is the time equivalent of the EV which measures schedule performance using time.

$$ES_i = N_i + \left(\frac{E_i - PV_N}{PV_{N+۱} - PV_N}\right), i = ۱,۲ \text{ so, } \otimes ES \in [\underline{ES_۱}, \overline{ES_۲}] \quad (۸)$$

where *N* is the longest time interval in which the PV_N (planned value at time *N*) is less than the EV. In contrast to SPI, the SPI_t is expressed in time units and represented as follows:

$$\otimes SPI_t = \frac{\otimes ES}{AD} \in [\frac{ES_۱}{AD}, \frac{ES_۲}{AD}] \quad (۹)$$

where AD is the actual duration of the project.

The generic ES-based equation to estimate the time at the completion of a project, or the project duration is:

$$\otimes EAC_t = AD + (\frac{PD-ES}{PF}) \quad (۱۰)$$

where the PD is the planned duration to complete the project and the PF is the performance factor which depends on the project status. Usually there are three cases considered for the PF, but the one with $PF = \otimes SPI_t$ is brought here as follows:

$$\otimes EAC_t = AD + \left(\frac{PD - \otimes ES}{\otimes SPI_t}\right) = AD + \left(\frac{[PD - ES_۲, PD - ES_۱]}{\left[\frac{ES_۱}{AD}, \frac{ES_۲}{AD}\right]}\right)$$
$$\in [AD + \min\left\{\frac{PD - ES_۲}{\frac{ES_۱}{AD}}, \frac{PD - ES_۲}{\frac{ES_۲}{AD}}, \frac{PD - ES_۱}{\frac{ES_۱}{AD}}, \frac{PD - ES_۱}{\frac{ES_۲}{AD}}\right\}, AD$$
$$+ \max\left\{\frac{PD - ES_۲}{\frac{ES_۱}{AD}}, \frac{PD - ES_۲}{\frac{ES_۲}{AD}}, \frac{PD - ES_۱}{\frac{ES_۱}{AD}}, \frac{PD - ES_۱}{\frac{ES_۲}{AD}}\right\}] \quad (۱۱)$$

In this section based on the case study that illustrated in the paper by Naeini et al. [۴], the new grey-based EV calculations are represented.

TABLE ۱: THE PERCENT COMPLETE AND THE EV OF ACTIVITIES.

Activity	BAC	Progress	$\otimes F_i$	$\otimes EV_i$
۱	۸۰۰	Very high	[۰.۸،۱]	[۶۴۰،۸۰۰]
۲	۱۰۰۰	High	[۰.۶۰،۰.۸]	[۶۰۰،۸۰۰]
۳	۵۰۰	High	[۰.۶۰،۰.۸]	[۳۰۰،۴۰۰]
۴	۱۲۰۰	Low	[۰.۲۰،۰.۴]	[۲۴۰،۴۸۰]
۵	۹۰۰	Very low	[۰.۰،۰.۲]	[۰،۱۸۰]
۶	۶۰۰	Not started	[۰،۰]	[۰،۰]

$\otimes EV \in [۱۷۸۰,۲۶۶۰]$
$\otimes CPI \in \left[\frac{۱۷۸۰}{۲۸۰۰}, \frac{۲۶۶۰}{۲۸۰۰}\right] = [۰.۶۴,۰.۹۵]$
$\otimes SPI \in \left[\frac{۱۷۸۰}{۲۳۰۰}, \frac{۲۶۶۰}{۲۳۰۰}\right] = [۰.۷۷,۱.۱۶]$

So, the kernel grey numbers of $\otimes CPI$ and $\otimes SPI$ [۵] are respectively $\otimes \widehat{CPI} = \frac{۱}{۲}(۰.۶۴ + ۰.۹۵) = ۰.۷۹$ and $\otimes \widehat{SPI} = \frac{۱}{۲}(۰.۷۷ + ۱.۱۶) = ۰.۹۷$ that shows they are on the planned cost and schedule.

TABLE ۲: THE ES CALCULATIONS.

I	E_i	N_i	$E_i - PV_{N_i}$	$PV_{N_{i+1}} - PV_{N_i}$	$ES_i = N_i + \frac{E_i - PV_{N_i}}{PV_{N_{i+1}} - PV_{N_i}}$
۱	۱۷۸۰	۵	۸۰	۶۰۰	۵,۱۳
۲	۲۶۶	۶	۳۶۰	۶۵۰	۶,۴۶

$$\otimes EAC_t \in \left[6 + \min \right.$$

$+$

$=$

$=$

۳. CONCLUSION

EV is a management technique that assissts project managers to have better control on their project. It evaluates project with indices related to cost and time of the project and estimates the final cost and time either. Here, considering the values of cost and time performance indices of the project shows that the project is doing well and is on the planned program in two categories of cost and schedule. The values of estimations of cost and time are predicted as well. Implementing grey theory in calculating EVM indices makes it more closer to the reality, according to the existance of uncertainty in real life projects.

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