The Project Duration Risk Analysis Based on Earned Value Measurement

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Abstract— **The project duration risk analysis has become more and more important with project management raised the duration requirement. Most of the existing analysis methods lack the linkage analysis of cost risk, aimed at this disadvantage, this paper proposes a new analysis method to project duration risk based on earned value measurement, discusses the different possible risk types under different earned value indexes, then divides the severity of duration risk into five different levels which will be convenient for project managers to take measures. Furthermore, an example is given behind in detail expressly illustrated the analysis process.**

Key words—Earned Value Measurement; Duration risk; Risk analysis

I. INTRODUCTION

Time, cost, quality and scope are the four main targets to be controlled in project management. Time has become an important target when project quality is fixed, project scope is certain and normal, the total investment is settled[1]. Nowadays most of engineering projects are very strict to the time limit of completion, indicated a strong rigid compulsory constraint. Such as Olympic Games venues projects, the earthquake resistance and disaster relieving projects, the Military Facilities construction items

etc, these projects all have the strict time limit, if the projects surpass the limit time, it will become worthless, and seriously affects the national prestige, brings harm to people's interests, even brings harm to the society's stability and security[2]. However, there are multitudinous uncertainties in the project implement process which may delay the duration frequently to lead the duration risk. The existing methods of project duration risk analysis and estimate are Critical Path Method(CPM), PERT, Random Network Planning Technique and so on. The representative literature: Liping[3] proposed a new method of PERT network duration risk calculation which has considered the influence of non-critical route to critical route. Fan Chengyu[4] proposed an estimate method of project duration risk based on Fuzzy Network, it can describe the uncertainty of schedule plan and the possible time of process(or route) in the influence of multitudinous uncertainties very well. Liujun[5] used Bayesian method to estimate project duration risk. Mao Jianping[6] used Fuzzy Comprehensive Evaluation to analyze project duration risk and evaluate the Fuzzy levels, which based on the basic principles of Fuzzy Comprehensive Evaluation and the factors that affected duration risk.

There are some disadvantages in the existing methods of project duration risk analysis and estimate, such as the lack of linkage analysis of cost risk. It is unscientific to analyze and estimate project duration risk without considering cost factor since there exists some correlativity and regularity between time and cost. Earned Value Management is an effective method to the integration and measurement of cost and time on a project, it can overcome the disadvantages of traditional risk analysis methods, make project managers find out actual schedule is behind or ahead of plan in the project implement process and predict the possible completion time according to this trend[7]. In this paper, we propose a new method of project duration risk analysis based on earned value measurement, which analyzes and estimates risk in an integrated approach from variant quality, variant state and variant size of cost and time indexes and the interaction between them.

II. THE BASIC PRINCIPLE OF EARNED VALUE MEASUREMENT ON PROJECT DURATION RISK ANALYSIS

At present, the Earned Value Management (EVM) mostly adopts the principle of "3222", including three Cost Indexes, two absolute variance indexes, two performance indexes and two prediction indexes[8—10] to check and measure the cost, schedule and their variances in the project implement process. We use the relationship of three cost indexes as start point, size and quality of absolute variance indexes and performance indexes as realistic basis, the trend of prediction indexes as judgment basis to analyze duration risk.

Three cost indexes in Earned Value Management are as follows: BCWS (Budgeted Cost of Work Scheduled), also called as "PV (Planed Value)", it is the value of all resources needed to do the work to meet the project's objective, which is a benchmark to estimate schedule and cost of project. BCWP (Budgeted Cost Work Performed), also called as "EV (Earned Value)", it is the amount of cost which should have taken to complete portions of the planned work according to the project plan. ACWP (Actual Cost of Work Performed), also called as "AC (Actual Cost)", it is the actual total cost of the work performed on some checkpoint. The cost index formula is: $PV=P0\times Q0$; $EV=P0\times Q1$; $AC=P1\times Q1$; where P0 is the budgeted price, Q0 is the budgeted quantity, P1 is the actual

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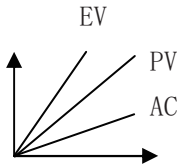
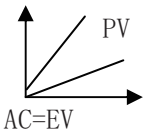
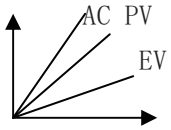
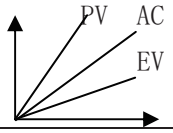
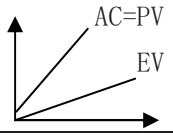
price on the checkpoint and Q1 is the actual quantity on the checkpoint[11—13].

There are two schedule variant indexes in earned value analysis index system, SV (Schedule Variance) and SPI (Schedule Performance Index). The formula is: SV=EV - PV= P0Q1 - P0Q0 = P0 (Q1 - Q0); SPI=EV/PV= P0Q1 / P0Q0 = Q1 / Q0. The principle of project duration risk measurement based on two schedule variant indexes is that when SV□0 and SPI□1 on the checkpoint, now Q1≧Q0. It indicates that a higher or same volume of work has been earned as planned and the schedule is normal or ahead of plan, there has no duration risk and the project can be completed on time or ahead of plan; When SV<0 and SPI<1 on the checkpoint, now Q1< Q0. It indicates that a lower volume of work has been earned as planned and the work is behind plan, there has some duration risk.

When we check the earned value management indexes in the project implement process, we discover that there are thirteen variant states of the relations among earned value analysis indexes since the number of all the possible qualitative combinations of PV, EV and AC is thirteen, which reflects different variance situations of cost and schedule[14]. According to the principle above, we can divide the thirteen variant states into two risk types. See table 1.

TABLE I. DURATION RISK TYPE

Risk type	Relation	Variance	Figure	Variance analysis
Duration risk only	PV>EV>AC P0Q0>P0Q1>P1Q1 Q0>Q1，P0>P1	SV<0,SPI<1 CV>0,CPI>1		The schedule is behind the plan, negative variance appeared, the budget under-run, duration risk only.
	AC=EV<PV P1Q1=P0Q1<P0Q0 Q1<Q0,P0=P1	SV<0,SPI<1 CV=0,CPI=1		The schedule is behind the plan, negative variance appeared, the earned price is exactly as budgeted, duration risk only.
Duration risk and cost risk both	AC>PV>EV P1Q1>P0Q0>P0Q1 Q0>Q1，P1>>P0	SV<0,SPI<1 CV<0,CPI<1		The schedule is behind the plan, the budget overrun, negative variance appeared both in schedule and cost, duration risk and cost risk both.
	PV>AC>EV P0Q0>P1Q1>P0Q1 Q0>>Q1，P1>P0	SV<0,SPI<1 CV<0,CPI<1		The schedule is far behind the plan, the budget overrun, negative variance appeared both in schedule and cost, duration risk and cost risk both.
	AC=PV>EV P1Q1=P0Q0>P0Q1 Q0>Q1 P0<P1	SV<0,SPI<1 CV<0,CPI<1		The schedule is behind the plan, the budget overrun, negative variance appeared both in schedule and cost, duration risk and cost risk both.

III. THE PROJECT DURATION RISK ESTIMATE BASED ON EARNED VALUE MEASUREMENT

We should not only regard earned value index as a record tool when we measure the duration risk, the more important thing is to estimate the possible duration risk. The concept of risk indicated that risk is a kind of uncertain loss which is described by the possibility (probability) and consequences of damage (loss) two parameters. So the project duration risk estimate based on earned value measurement is to analyze the possibility and the loss of duration risk. We can qualitative divide the risk degree into five different levels according to actual situations. They are very small(I), small(II), medium(III), serious(IV) and very serious(V).

The probability and loss of duration risk are affected by various factors, so we think that analyzing and estimating the size or severity of project duration risk should be combined with the following aspects to get an integrated estimate. Firstly, we should consider the size of variance indexes SV and SPI. The second aspect is the time we discovered the variance, it should be considered from the early stage, middle stage and late stage of the project implement process. The third aspect is

the state of variance, it should be considered from critical route and non-critical route or the work series which is divided into first and second series.

A. The analysis and estimate of duration risk only

We discuss the different situations of duration risk only in table 1. For example, if we measured SV is negative and the absolute value is large, SPI is less than 1 and the departure degree from 1 is large when we check the work in critical route at any time (whatever early stage, middle stage or late stage) in the project implement process, since there is no spare time in critical route, the project will be difficult to catch up with the protracted schedule through overtime work on the basis of no supplementary cost. In this situation, the probability of duration risk is very high and the level is V. The other situations of duration risk estimate is shown in table 2.

TABLE II. DURATION RISK ESTIMATE

SV、SPI	Check route	Check time	Risk level
SV<<0, 0<SPI<<1 (large variance)	Critical route	Early stage, middle stage, late stage	Very serious (V)
SV<<0, 0<SPI<<1 (large variance)	Non-critical route	Late stage	Serious (IV)
SV<<0, 0<SPI<<1 (large variance)	Non-critical route	Middle stage	Medium (III)
SV<<0, 0<SPI<<1 (large variance)	Non-critical route	Early stage	Small (II)
SV<0, 0<SPI<1 (middle variance)	Critical route	Early stage, middle stage, late stage	Serious (IV)
SV<0, 0<SPI<1 (middle variance)	Non-critical route	Late stage	Medium (III)
SV<0, 0<SPI<1 (middle variance)	Non-critical route	Middle stage	Small (II)
SV<0, 0<SPI<1 (middle variance)	Non-critical route	Early stage	Very small (I)
SV□0, 0<SPI□1 (small variance)	Critical route	Early stage, middle stage, late stage	Medium (III)
SV□0, 0<SPI□1 (small variance)	Non-critical route	Late stage	Small (II)
SV□0, 0<SPI□1 (small variance)	Non-critical route	Early stage, middle stage	Very small (I)

B. The linkage analysis of duration risk and cost risk both

We discuss the different situations of duration risk and cost risk both in table 1. For example, if we measured CV is negative and the absolute value is large, CPI is less than 1 and the departure degree from 1 is large when we check the first series work in the project implement process, the probability of cost risk is very high and it will affect duration risk, since the cost risk may make the late stage fare insufficient and delay the schedule, thus increase the probability of duration risk. The other situations of cost risk's influence to duration risk is shown in table 3.

TABLE III. THE INFLUENCE OF COST RISK TO DURATION RISK

CV、CPI	Work series	Check time	Influence to duration risk
CV<<0, 0<CPI<<1 (large variance)	first series	Early stage, middle stage, late stage	Very large
CV<<0, 0<CPI<<1 (large variance)	second series	Late stage	large
CV<<0, 0<CPI<<1 (large variance)	second series	Middle stage	Medium
CV<<0, 0<CPI<<1 (large variance)	second series	Early stage	Small
CV<0, 0<CPI<1 (middle variance)	first series	Early stage, middle stage, late stage	Very small
CV<0, 0<CPI<1 (middle variance)	second series	Late stage	Medium
CV<0, 0<CPI<1 (middle variance)	second series	Middle stage	small
CV<0, 0<CPI<1 (middle variance)	second series	Early stage	Very small
CV□0, 0<CPI□1 (small variance)	first series	Early stage, middle stage, late stage	Medium
CV□0, 0<CPI□1 (small variance)	second series	Late stage	small
CV□0, 0<CPI□1 (small variance)	second series	Early stage, middle stage	Very small

In order to take a farther trend estimate of completion risk, we use TAC (Time At Completion) to analyze when there exists duration risk. The time and cost have some linkage relation, so we should consider the influence of cost when we

predict the future schedule. There are three kinds of possible trend if there is no supplementary cost. Firstly, if the remainder work developed according to the original plan, there is no longer any new schedule variance. The Time At Completion Prediction formula is: TAC=PT+△T[15], where PT is the plan time, △T is the excess schedule prediction which caused by completion duration risk. Secondly, if the reminder work developed according to the actual schedule efficiency, take the actual schedule variance as the reference of latter work[8] [15]. Now the Time At Completion Prediction formula is: TAC=PT/SPI, the excess schedule prediction which caused by completion duration risk formula is: △ T=(PT/SPI-PT). Thirdly, if the reminder work developed according to the new uncertain efficiency, the completion duration risk is hard to predict.

IV. EXAMPLE ANALYSIS

Now there is an engineering project, including three work packages, the total budget is 760 thousand yuan, the planned schedule are ten weeks. We measured every earned value index at the sixth week of the project. See table 4.

TABLE IV. EARNED VALUE INDEXES AT THE SIXTH WEEK OF PROJECT UNIT: TEN THOUSAND RMB

Index	PV	EV	AC	Completion result (%)
Result	40	38	46	50%

Estimate Analysis:

CV=BCWP-ACWP=38-46=-8<0
CPI=BCWP/ACWP=38/46=0.83<1

Indicated the budget overrun

SV=BCWP-BCWS=38-40=-2<0
SPI=BCWP/BCWS=38/40=0.95<1

Indicated the schedule is behind the plan

Prediction Analysis:

(1)According t o the actual efficiency:

Estimate To Completion:

ETC=（BAC- EV）/CPI=(76-38)/0.83

=45.8(ten thousand RMB)

Time At Completion:

TAC=BAC/SPI=10/0.95

=10.5(week)

If the project developed according to the actual efficiency, the cost will overrun 78 thousand yuan and the schedule will overrun half of the week.

(2)According to the plan:

Estimate To Completion:

ETC=BAC-EV=76-38

=38(ten thousand RMB)

Time At Completion:

TAC=6+10-6×0.95

=10.3(week)

Through the analysis, it can be concluded that the negative variance appeared both in time and cost at the sixth week, but the variance is small. There are both duration risk and cost risk in the project. Although the probability is low, the schedule will overrun half of the week and the cost will overrun 78 thousand yuan by this trend. Therefore, we should find out the reasons to the variance and take some necessary measures.

V. CONCLUSIONS

Engineering project has continuously raised the duration requirement with the development of society, the loss caused by protracted duration has also become larger and larger which may make cost overrun and even lead the total value of the project to a sharp decline sometimes. So we should strengthen the analysis, estimate and control to project duration risk. Introduced the earned value management to project duration risk analysis can overcome the disadvantages of traditional risk analysis methods and make linkage analysis in duration/cost risk. First, we divide all the relations of earned value indexes into two risk types in the project implement process, then analyze and estimate the two risk types respectively. Through analyzing the influence of variance size, variance time and variance state to the probability and possible loss of project duration risk, we divide the severity of duration risk into five different levels which will be convenient for project managers to discover the risk situations, analyze reasons and take some necessary measures to ensure the project succeed.

REFERENCES

[1] Yu Xiaozhong. The Research of Decision-making Optimizing Method about T, Q, C in Project [J]. Value Engineering, 2004,(3):115—117.

[2]Liping. Gu Xinyi. The Research of PERT network Risk Method [J]. Theory Explore, 2004,(5):16—17.

[3]Fan Chengyu. Duration Risk Management of Engineering Project [J]. Engineering and Construction, 2006,(3):259—261.

[4]Liujun. Wang Jinyu. Tian Xilong. The Duration Risk Prediction of Project Based on Bayesian Method [J]. Technoeconomics and Management Research, 2006,(5):56—57.

[5]Mao Jianping. Zhang Wangbin. An Analysis of Period Risk Based on Fuzzy Synthetical Evaluation Method [J]. Construction Technology, 2009,(12):358−359.

[6] Abba, W.Y, "Earned Value Management - - Reconciling Government and Commercial Practices : For People Involved in Earned Value - - Government , Industry , Academic , or Consulting " [J].PM : Special Issue, 1997, (2) : 10-23.

[7]Alan Webb. Qi Anbang. Xiong Qinqin. Wu Qinyu translate. Project Management Guide---the application of earned value management [M]. Tianjin: Nankai University press, 2005.1:30−40.

[8]Yan Yongzhen. Baiming. Establishing Earned Value Management System Assembly Managing Project Time and Cost [J]. Optimization of Capital Construction, 2004,4:22−23,46.

[9]Luo Xinxing. Miao Weihua. Basic theory and Practical application of the Earned Value Measure [J]. Journal of Central South University(Social Science), 2003,6:369−372.

[10]Sun Xianwei. The Statistical Analysis Principle and the Development of the “Earned Value Management”in Project Management [J]. Modern Finance and Economics, 2002,(12):26−28,32.

[11]Yu Xiaozhong edit Principle of Statistics [M]. Haerbing: Haerbing press, 1996:181−21.

[12]Qi Anbang. On the Multi-factors Integration Management Method for Project Management [J]. Nankai Business Review, 2002,(6):70−75.

[13]Yu Xiaozhong. The Research of Duration Prediction Method Based on Earned Value Management [J]. Statistics and Decision-making, 2009,(2).

[14] Wafa Alsakini. Proactive schedule management of industrial turnkey projects in developing countriea [J].International Journal of Project Management,2004,22:75-87

[15] Xiaozhong Yu, Yuling Wang.The Variant States of the Relations among Earned Value Analysis Index System [J]. Chinese Journal of Management Science, 2006,(11)(Album):121−126.