UNIVERSITÉ DU QUÉBEC À RIMOUSKI

LE CHOIX D'ACTIONS CORRECTIVES EN SUIVI DE PROJET: UN MODÈLE MULTICRITÈRE D'AIDE À LA DÉCISION

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PAR

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A mes parents,

A mon épouse,

Je dédie ce mémoire.

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RÉSUMÉ

La gestion des risques, la gestion de qualité, la gestion de l'échéancier du projet comme la gestion des coûts sont généralement traitées comme des processus indépendants. Ces dernières années, quelques rares papiers se sont intéresses à l'intégration de ces approches afin de créer une synergie sur la performance des projets. Ces différents travaux se concentrent sur l'intégration de méthodes permettant d'évaluer la performance du projet tant dans la phase de planification que durant le suivi du projet lors de la phase d'exécution. Cependant, faire une bonne évaluation de la performance du projet n'est que la première étape vers un meilleur contrôle du projet. La seconde étape est celle visant à définir et mettre en œuvre, si nécessaire, un ensemble d'actions correctives. Cette dernière étape est énoncée dans le processus de suivi et contrôle de projet mais n'est pas supportée par une modélisation comme si cette gestion des actions correctives était trop contextuelle. De fait, on se base exclusivement sur la valeur des indicateurs de performance du projet (généralement le Schedule Performance Index et le Cost Performance Index) pour décider de prendre des actions correctives et l'évaluation de l'ampleur de ces actions relève du gestionnaire de projet. A notre connaissance, le seul travail qui propose une modélisation de ce processus de gestion des actions correctives est celui de Lipke (2003) qui suggère une approche basée sur un diagramme logique. Notre recherche, de nature instrumentale, va s'inscrire dans cette ligne de pensée et nous nous proposons de développer un modèle d'aide à la gestion des actions correctives. Pour y parvenir, une revue de littérature sur les indicateurs de performance des projets comme sur la gestion des actions correctives sera menée dans un premier temps. Une modélisation originale, permettant de faire un lien entre une analyse multidimensionnelle de la performance du projet et le type de stratégie d'actions correctives est alors proposé et discutée à partir d'un exemple didactique.

Mots clés : choix des actions correctives, méthode multicritère, temps, coût, qualité, suivi de projet, performance du projet.

ABSTRACT

Currently, risk management, quality management and time/cost management are managed as independent processes but recently, some exceptional papers focus on the integration of these approaches in order to create synergy on project performance. These works focus on the integration of methods to assess project performance in both planning phase and controlling phase or implementation phase. However, to make a proper assessment of project performance is only the first step towards a better control of the project. The second step is to define and implement, if necessary, a set of corrective actions. The last step is still adopted during the process of project monitor and control, but it is not supported by the model since the corrective actions of the project are depending on the whole project context. In fact, the choice of a corrective action is based on the classical project performance index values (schedule performance index, cost performance index) and the magnitude of the action is generally evaluated by the project manager. Other considerations should be taken into account and to our knowledge, the only work is the model mentioned by Lipke (2003) where he suggested an approach based on the logic diagram. While, this approach cannot provide the 'best' choice among a set of possible corrective actions, in our research, we propose a model to help the project manager in the choice of the corrective actions. To achieve this, a literature review on project performance indicators for the management of corrective actions will be conducted initially. An original model that makes a link between a multidimensional analysis of project performance and type of corrective action strategy will be proposed and discussed by a didactic example.

Key words : corrective actions choice, multicriteria method, time, cost, quality, project monitoring, project performance.

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INTRODUCTION GÉNÉRALE

Les organisations vivent une pression croissante pour améliorer la qualité, la valeur de leurs prises de décision à tous les niveaux et, en particulier, au niveau de leurs projets. En gestion de projet, une des principales approches développées pour répondre à cette préoccupation est la gestion des risques (Risk Management or RM). Une autre approche importante, utilisée dans l'analyse intégrée, a priori, du temps et du coût du projet, est celle de l'Analyse de la Valeur Acquise ou EVM (Earned Value Management). Plus récemment, et afin de contrôler la qualité tout au long du cycle de vie du projet, Paquin, Couillard et Ferrand (2000) ont proposé la méthode de la qualité acquise ou EQM (Earned Quality Method). Ces approches contribuent ensemble à la performance des projets et, en retour, à la performance des programmes, des portefeuilles de projets et finalement à l'organisation.

Généralement, la gestion des risques, la gestion de qualité, la gestion de l'échéancier du projet comme la gestion des coûts sont traitées en tant que processus indépendants mais récemment, quelques rares papiers (Hillson, 2000; Paquin, Couillard et Ferrand, 2000) se sont intéressés à l'intégration de ces approches afin de créer une synergie sur la performance des projets. Binbin (2007) a, quant à lui, proposé un cadre général qui peut être mis en application pour combiner EVM, EQM et RM de manière à maximiser l'atteinte des objectifs (temps/coût/qualité) durant la phase de planification des projets. Une recherche instrumentale menée par Xu (2009) a permis de développer un outil convivial d'aide à la planification et au suivi de projet, avec pour intention de développer une interface logicielle permettant au gestionnaire de projet d'avoir une vue, durant le suivi du projet, de la performance de son projet en terme de délai, de coût comme de qualité. Ces différents travaux se concentrent sur l'intégration de méthodes permettant d'évaluer la performance du projet tant dans la phase de planification que durant le suivi du projet lors de la phase d'exécution. Cependant, faire une bonne évaluation de la performance du projet n'est que la première étape vers un meilleur contrôle du projet. La seconde étape est celle visant à définir et à mettre en œuvre, si nécessaire, un ensemble d'actions correctives. Cette dernière étape est énoncée dans le processus de suivi et contrôle de projet mais n'est pas supportée par une modélisation comme si cette gestion des actions correctives était trop contextuelle. De fait, on se base exclusivement sur la valeur des indicateurs de performance du projet (le Schedule Performance Index et le Cost Performance Index) pour décider de prendre des actions correctives et l'évaluation de l'ampleur de ces actions relève du gestionnaire de projet. D'autres considérations devraient être prises en compte et à notre connaissance, le seul travail qui propose une modélisation de ce processus de gestion des actions correctives est celui précédemment cité de Lipke (2003) et qui suggère une approche basée sur un diagramme logique. Cependant, ce travail ne permet pas de choisir, parmi un ensemble d'actions correctives potentielles, celle qui apparait comme la 'meilleure'. Notre recherche, de nature instrumentale, va s'inscrire dans cette ligne de pensée et nous nous proposons de développer un modèle d'aide à la gestion des actions correctives. Pour y parvenir, une revue de littérature sur les indicateurs de performance des projets comme sur la gestion des actions correctives sera menée dans un premier temps. Une modélisation originale, permettant de faire un lien entre une analyse multidimensionnelle de la performance du projet comme d'autres considérations (possibilité d'avoir une stratégie de réaction, ..) et le type de stratégie d'actions correctives sera alors proposé. Finalement, cette modélisation sera illustrée et discutée à partir d'un exemple didactique.

INTRODUCTION

Currently, risk management, quality management and time/cost management are managed as independent processes but recently, some exceptional papers (Hillson, 2000; Paquin, Couillard and Ferrand, 2000) focus on the integration of these approaches in order to create synergy on project performance. Binbin (2007) proposed a general framework to combine EVM, EQM and RM to achieve the maximum objectives (time/cost/quality) during the phase of project planning. Another research was introduced by Xu (2009). He developed a tool which has the assistance in planning and monitoring project. This tool provides a vivid vision for project managers in terms of project performance like schedule delay, cost and quality monitoring during the process of project. These works focus on the integration of methods to assess project performance in both planning phase and controlling phase or implementation phase. However, to make a proper assessment of project performance is only the first step towards a better control of the project. The second step is to define and implement, if necessary, a set of corrective actions. The last step is still adopted during the process of project monitor and control, but it is not supported by the model since the corrective actions of the project are depending on the whole project context. In fact, to decide to take corrective actions and to assess the magnitude of the actions are based on the project performance index value (schedule performance index, cost performance index). Other considerations should be taken into account and to our knowledge, the only work is the model mentioned by Lipke (2003) and he suggested an approach, which is based on the logic diagram. While, this approach cannot provide which looks like the best choice among the set of corrective corrections, in our research, we continue this kind of train of thought and propose to develop a model to help manage the corrective actions. To achieve this, a literature review on project performance indicators for the management of corrective actions will be conducted initially. An original model that makes a link between a multidimensional analysis of project performance and type of corrective action strategy will be proposed. Finally, this model will be illustrated and discussed by a didactic example.

CHAPITRE 1 : Project performance indicators

1. INTRODUCTION

Currently, risk management, quality management and time/cost management are managed as independent processes but recently, some exceptional papers (Hillson, 2000; Paquin, Couillard and Ferrand, 2000) focus on the integration of these approaches in order to create synergy on project performance. Binbin (2007) proposed a general framework to combine EVM, EQM and RM to achieve the maximum objectives (time/cost/quality) during the phase of project planning. Another research was introduced by Xu (2009). He developed a tool which has the assistance in planning and monitoring project. This tool provides a vivid vision for project managers in terms of project performance like schedule delay, cost and quality monitoring during the process of project. These works focus on the integration of methods to assess project performance in both planning phase and controlling phase or implementation phase. However, to make a proper assessment of project performance is only the first step towards a better control of the project. The second step is to define and implement, if necessary, a set of corrective actions. The last step is still adopted during the process of project monitor and control, but it is not supported by the model since the corrective actions of the project are depending on the whole project context. In fact, to decide to take corrective actions and to assess the magnitude of the actions are based on the project performance index value (schedule performance index, cost performance index). Other considerations should be taken into account and to our knowledge, the only work is the model mentioned by Lipke (2003) and he suggested an approach, which is based on the logic diagram. While, this approach cannot provide which looks like the best choice among the set of corrective corrections, in our research, we continue this kind of train of thought and propose to develop a model to help manage the corrective actions. To achieve this, a literature review on project performance indicators for the management of corrective actions will be conducted initially. An original model that makes a link between a multidimensional analysis of project performance and type of corrective action strategy will be proposed. Finally, this model will be illustrated and discussed by a didactic example.

Earned Value (ES) systems have been set up to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery, total project budget and more recently, quality. Although EV systems have been proven to provide reliable estimates for the follow-up of cost performance within our project assumptions, they often fail to predict the total duration of the project. Earned Value management (EVM) measures schedule performance not in units of time but rather in units of cost. Moreover, at the completion of a project, which is behind or ahead schedule, the schedule performance index (SPI) is equal to 1 which corresponds to a perfect schedule performance. To tackle these problems, Lipke (2003) proposed the concept of Earned Schedule (ES). In this approach, schedule performance is measured in units of time and the associated indicators are appropriate measures throughout the entire period of project performance. In this section, EVM, EQM and ES are discussed and the associated performance indices are presented.

2. EARNED VALUE MANAGEMENT

2.1. INTRODUCTION OF EVM

Earned value has been used since the 1960's by the Department of Defence as a core part of the C/SCSC (Cost/Schedule Control System Criteria). Later the Department of Defence revised the criteria and result in that earned value management system was evolved from that criteria. Now, EVM is being used in various government contracts widely and is spreading through all kinds of works.

EVM, shortened form of Earned Value Management is an integrated management control system which combines schedule performance, scope and cost performance. This system integrates technical, cost, time, even risk management, which allows project manager's objective evaluation and quantification of current project performance to help project managers to predict and portray future performance based on trends. EVM is a systematic project management process used variance during the project process based on the cost and schedule control. Earned value management can provide objective, timely and quantitative data for effective decision making.

2.2. Project tracking without EVM

We list an example here to illustrate the EVM function clearly. We compare the project tracking with earned value and tracking without earned value. It is easy to find the difference between these two sceneries.

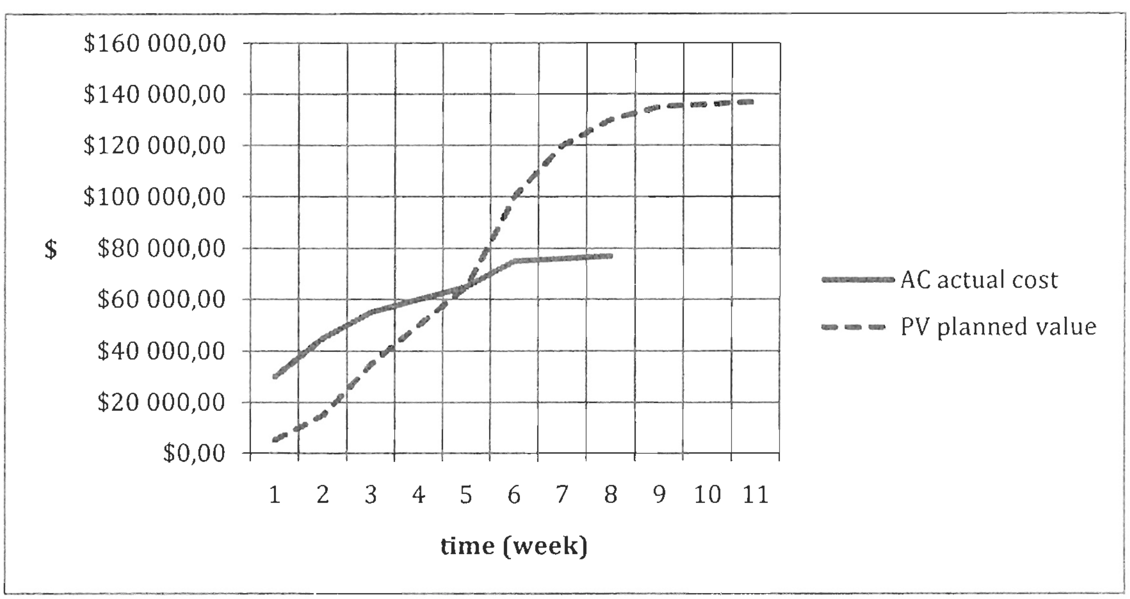

Figure 1. Project tracking without earned value

(source: http://en.wikipedia.org/wiki/Earned_value_management)

In figure 1, the solid line means the total of all expenditure on the project up to the reporting date, we called **actual cost (AC)** here; the dashed line means the sum of all the planned cost in the project up to the reporting date, we called the **planned value (PV)** here. We can find the following points obviously:

First, actual cost is higher than planned value before week 5, which means this project is over budget before week 5.

Second, actual cost is lower than planned value since week 5 until week 8, which means this project is under budget since week 5 until week 8.

However, what is still missing from figure 1 is how much work has been actually accomplished during the whole project. If the project is finished at week 8, the project would actually be under budget and ahead of schedule. But it also confused for decision making, if the project has actually been achieved around 5% of the whole project, which means the project is significantly over the budget and behind the schedule. Obviously, project tracking in this situation cannot explain anything and will be useless for decision making. Is this situation, we need a third variance to measure the project performance objectively, timely and quantitatively and convey the right project performance information for decision making. We will explain the principles of function of earned value management function in the next section.

2.3. PROJECT TRACKING WITH EVM

A third variance which we called earned value is the cost of all the progress achieved on the project up to reporting date. It is expressed in terms of the planned value from start to current. Earned value repents what has been earned, not simply what has been spent. It can be expressed as the following formula;

$$EV = \sum_{start}^{current} PV(completed)$$

We bring the earned value into the figure 1; figure 2 shows all three curves together, which is a typical earned value management line chart. The arrow line represents the earned value, which compare with the planned value and actual cost up to a given point in time.

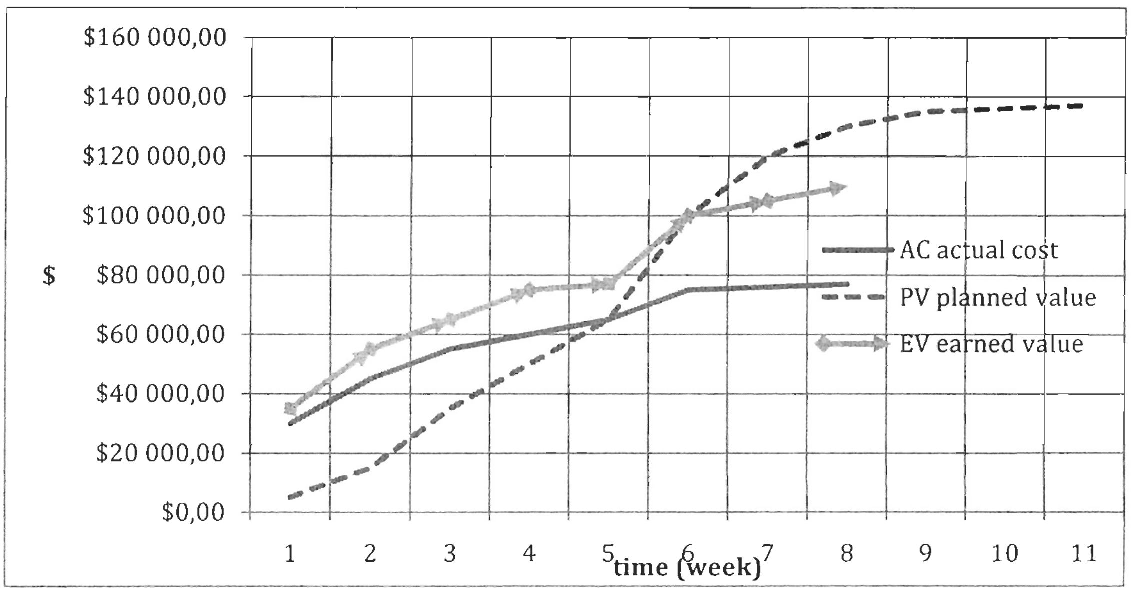

Figure 2. Project tracking with earned value

(source: http://en.wikipedia.org/wiki/Earned_value_management)

When we compare the earned value line with the planned value line, the difference was called schedule variance, marked as SV. While the result of comparison of earned value line and actual cost line was called cost variance, marked as CV. It can be seen from the illustration of figure 2 that a timely cost performance and schedule performance can be reflected the objective situation during the project control process up to a reporting time point.

2.4. BASIC EARNED VALUE TERMINOLOGY

In this section, we will introduce a series of terms which are involved in earned value management. These terms are standard terms and wildly used, which are described below:

Planned value (PV or BCWS), planned value is also called the budget cost for the worked schedule. This is the sum of all the planned costs in the project, or any given part of the project, up to the reporting date.[1] Generally speaking, planned value is the budget cost for the work schedule which is completed or finished on a certain activity or at the WBS level until a reporting time point.

Earned value (EV or BCWP), this is the cost of all the progress achieved on the project, or part of the project, up to the reporting date and expressed in terms of the planned value originally set out in the initial estimate; it is also 'Earned Value' as it represents what has been earned, not simply what has been spent.[2]

Actual cost (AC or ACWP), this is the total of all expenditure on the project, or part of the project , up to the reporting date; it is the sum of what has actually been spent irrespective of what has been planned or achieved.[3]

Cost variance (CV), CV is the numerical difference between the earned value and the actual cost at the reporting point. CV=BCWP-ACWP=EV-AC[4]

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[1] Kim, Y.& Ballard, G., 2002, *Earned Value Method and Customer Earned Value*, Journal of Construction Research, Vol. 3, Issue 1, pp. 55-56

[2] Anbari, F.T., 2003, *Risi-Adjusted Valuation of R&D Projects*, Research Technology Mangement, industrial Research Institute, Inc., September-October 2003

[3] Fleming, Q.W. & Koppelman, J.M., 2002, *Earned Value Management, Mitigating the Risks Associated with Construction Projects,* Project Management Institute

Schedule variance (SV), SV is the numerical difference between the earned value and the planned value expenditure at the reporting point. SV=BCWP-BCWS=EV-PV[5]

Work breakdown structure (WBS), according to PMBOK, WBS is defined the as "a deliverable-oriented grouping of project elements that organizes and defines the total work scope of the project. Each descending that organizes and defines the total work scope of the project. Each descending level represents an increasingly detailed definition of the project work".

2.5.EARNED VALUE MANAGEMENT INDICATORS

The two fundamental types of indexes which have the meaning for the earned value management are cost efficiency indicator and schedule efficiency index respectively. Those are basic cost performance and schedule performance index.

Cost performance index, CPI (cost efficiency), the ratio of the value to the amount spent at a point in time in project.

$$CPI = \frac{BCWP}{ACWP} = \frac{EV}{AC}$$

If the CPI>1, means the cost of completing the work is less than the planned, which stands for good normally.

If the CPI=1, means the cost of completing the work is equal the planned, which stands for good also.

[4] DODI 7000.2

[5] Branch, S.P., 2004, *The Basic of Earned Value Management,* Transactions of AACE International

If the CIP<1, means the cost of completing the work is higher than the planned, which stands for bad.

Schedule performance index, SPI (schedule efficiency), the ratio of the earned value created to the amount of value planned to be created at a point time in the project.

$$SPI = \frac{BCWP}{BCWS} = \frac{EV}{PV}$$

If the SPI>1, means the time elapsing of completing work is less than planned up to a report point, which stands for ahead of schedule.

If the SPI=1, means the time elapsing of completing work is equals to the planned up to a report point.

If the SPI<1, means the time elapsing of competing work is higher than planned up to a report time, which stands for behind of schedule.

There are another three significant forecasting indexes in the earned value management. The first is the estimated cost at completion; the second is the estimated time at completion; the third one to complete schedule performance indicator.

Estimated Cost AT Completion (EAC).

The estimated end cost when the project is completed. Through the previous literature review, we find that there are three situations to calculate EAC as below:

The first situation is occurred when the variance is occurred at the current stage and is not expected to happen during the rest stages of whole project lifecycle. The formula will be:

$$EAC=AC+ (BAC-EV)$$

The second status is happened when the past estimation assumptions are not valid and the new estimations are to be applied to the rest stage of project lifecycle. The formula will be:

EAC=AC+ETC (estimate to complete)

The last situation is happened that the assumptions are valid for the current variance and are to be continued to the rest project lifecycle. The formula will be:

$$EAC = ACWP + \frac{BAC - BCWP}{CPI} = AC + \frac{BAC - EV}{CPI},$$

where BAC is the budgeted cost at completion.

Webb (2003) pointed that the formula of the estimated cost at completion is made up of two parts, namely the cost, which is already spent, and the estimated of the future cost, under the assumption that nothing in the project is changed and it follows the existing trends.[6] Actually, these numbers are often calculated on a regular basis during the lifespan of the project, since the calculation for the EAC is full of many literatures. The most of important reason is the calculation of EAC depends on performance and trend as well as future assumptions.

Estimated Time to Completion (ETTC), the estimated duration of the project is completed. The formula is as follow:

$$ETTC = ATE + \frac{OD - ATE \times SPI}{SPI},$$

Where *ATE* is the actual time expended, and *OD* is the original duration.

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[6] Webb, A., 2003, Using Earned Value : A Project Manager's Guide, Abingdong, Oxon, GBM : Gower Publishing Limited, http://site.ebrary.com/lib/gubselibrary/Doc?id=10046806

From the above elaboration, we can develop the further the above equation as follow,

$$EAC = ACWP + \frac{BAC - BCWP}{CPI} = AC + \frac{BAC - EV}{CPI},$$

where $CPI = \frac{BCWP}{ACWP} = \frac{EV}{AC}$, so we can substitute as follow:

$$EAC = \frac{AC \times EV + BAC \times AC - EV \times AC}{EV} = \frac{BAC \times AC}{EV},$$

since $CPI = \frac{EV}{AC}$, we can obtain that: $EAC = \frac{BAC}{CPI}$

For the formula $ETTC = ATE + \frac{OD - ATE \times SPI}{SPI}$, it is consisted by two parts, the actual time spent and the estimated future time needed to finish the project. We bring the common denominator to simplify the above formula as follow;

$$ETTC = \frac{ATE \times SPI}{SPI} + \frac{OD - ATE \times SPI}{SPI} = \frac{ATE \times SPI + OD - ATE \times SPT}{SPI} = \frac{OD}{SPI},$$

We obtain $ETTC = \frac{OD}{SPI}$. In short, we can get the two important derived formulas as follow:

$EAC = \frac{BAC}{CPI}$ and $ETTC = \frac{OD}{SPI}$. To analysis the above two formulas, we can find that it has the limitation, since the EAC is the budgeted cost divided by the cost performance, errors could be happen when estimate the cost planned, or another situation is if there are any potential changes during the process of project, in that case it will no longer valid. Here for ETTC, it contains the same potential errors.

Therefore, Fleming and Koppleman (2000) disclose one additional method to monitor projects earned value performance, which is called **To Complete Performance Index**

(TCPI_EVM). This index is a comparative EVM index to determine if the independent estimated cost at completion is reasonable. To some extent, this index is a modification of the EAC index. The formula is as follow:

$$TCPI = \frac{BAC - BCWP}{BAC - ACWP} = \frac{BAC - EV}{BAC - AC},$$

If TCPI=1.0, which means that the remaining project will be on the tract and can be executed at the same cost performance level.

If TCPI>1.0, which means the remaining project work must be executed at a better cost performance level to bring the project on the original track.

If TCPI<1.0, which means the remaining project work can be executed at a lower cost performance level than the project completed work.

We can illustrate a simple example here to understand this index;

Project data as follow:

BAC=$125,000;

EV=60,000;

AC=$75,000

So, the TCPI= ($125,000-60,000)/ ($125,000-$75,000) =1.3, that means if the project manger wants to bring the project on the cost tract, the project must be executed with a 1.3 cost performance level than before.

For the nature of the above formula, TCPI index computes the future required cost efficiency needed to achieve a target EAC. This index is computed by dividing the budget remaining into the budget cost of work remaining.

To Complete Schedule Performance Indicator (TSPI_EVM), TSPI is an index which shows the efficiency of the remaining time on the project schedule that has been elapsed.

Generally speaking, this index is a comparative index of EVM system. The formula is as follow:

$$TSPI = \frac{BAC - BCWP}{BAC - BCWS} = \frac{BAC - EV}{BAC - PV}$$

If TSPI=1.0, which means the remaining project will be on the tract if followed by the previous.

If TSPI>1.0, which means the remaining project work must be executed at a better time level performance to bring the rest project to the planned track.

If TSPI<1.0, which means the remaining project work can be executed at a lower time performance level than the project completed work.

2.6. LIMITATIONS OF EVM

Earned value management is an excellent management method which integrates cost, schedule and requirements. This method facilitates scientific approach to project management. It also fosters project planning from historical performance to provide project status described by numerical evidence and predict project future trends. However, the EVM method has three major deficiencies which were pointed by Walt Lipke (2005)[7] as below:

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[7] Lipke, W. (2005). *Connecting Earned Value to the Schedule. CrossTalk—The Journal of Defense Software Engineering*. Retrieved September 20, 2005, http://www.stsc.hill.af.mil/crosstalk/2005/06/0506Lipke.html

1) The performance indicators are not directly connected to project output. For example, milestone completion or delivery of products may not meet the customer's expectation, yet EVM indicator values are acceptable.

2) The schedule indicators are flawed. For projects completing late, the indicator always show perfect schedule performance.

3) The performance indicators are not explicitly connected to appropriate management action. Even with EVM data, the project manager remains reliant upon his intuition as to any action needed.

Generally speaking, traditional schedule EVM metrics are good at beginning of project, it shows schedule performance trends. However, the metrics don not reflect real schedule performance at the end of project. Eventually, traditional schedule metrics lose their predictive ability over the last third of project. EVM metrics exist to the following questions;

First, the EVM schedule indicators are reflected in units of cost rather than time. Due to this flaw, it becomes difficult to make a comparison with time based network schedule indicators. In that case, it is hard for project managers to understand the schedule performance in terms of budget, since it is expressed by units of cost, not time.

Second, for the early finish projects the EVM index SV and SPI perform correctly for the whole process of project; while for the late finish project the EVM index SV and SPI behave erratically for projects behind schedule, they lose the predictive ability over the last third of the project, since SV improves and concludes at $0 variance and SPI improves and equals at 1.00 at the end of project, which are shown in Figure 3 and Figure 4.

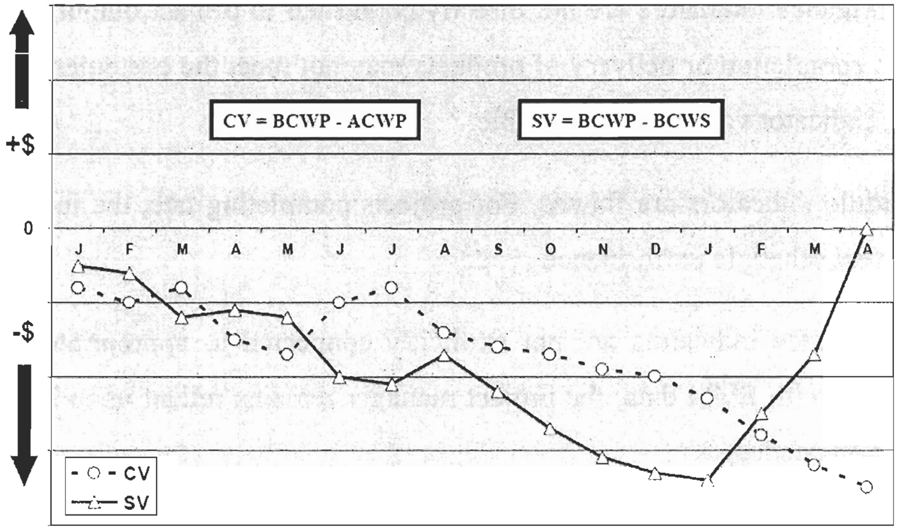

Figure 3. Cost and schedule variance (Source: Likpe, 2005)

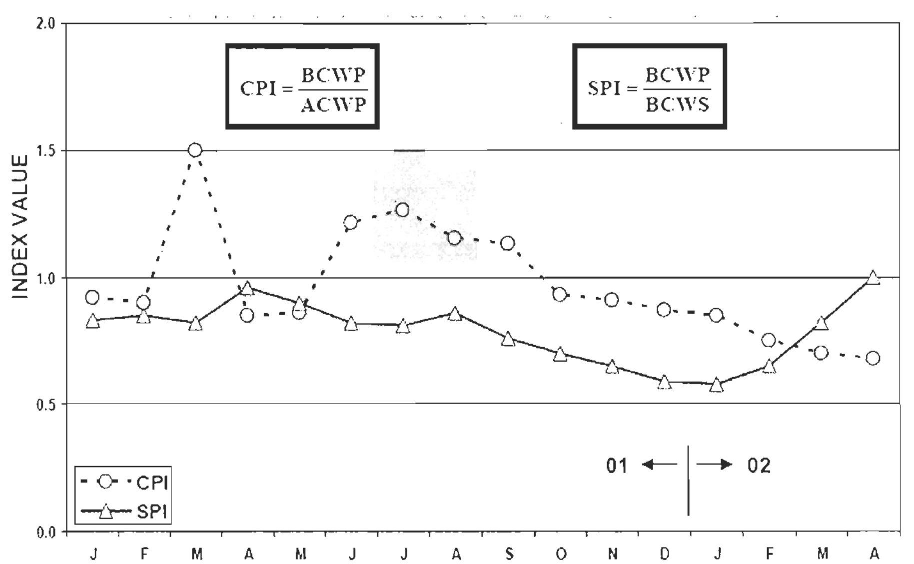

Figure 4. Cost and schedule performance indexes (source: Likpe, 2005)

The end point of the PV is the planned cost for the project at planned completion, budget at completion (BAC), which means PV=BAC, meanwhile at actual completion, the EV converges to the BAC, means EV=BAC, as far as all know, SV=EV-PV, when actual completion surpass the planned completion, SV=EV-PV=BAC-BAC=0, in this situation, SPI=EV/PV=BAC/BAC=1.00. From this explanation, it becomes easy to understand the behaviour of the schedule indexes which are shown in Figure 3 and Figure 4. It is not hard to understand that at some point during the process of project SV and SPI indicators will lose their management value. Project managers cannot rely on the schedule indexes in the EVM system.

3. EARNED SCHEDULE MANAGEMENT

3.1. EARNED SCHEDULE CONCEPT

Earned schedule (ES) is an extension to earned value management, which overcomes the flaw of earned value and was introduced by Walt Lipke in a seminal article "Schedule is Different" in 2003. It is a technique for calculating time-based estimated at completion using existing EV data. Since it was introduced by Walt Lipke, Kym Henderson extended its use to forecasting function. So far, earned schedule technique is better than using existing EV techniques to full potential. Both real and simulated data has shown the ES technique to be more accurate when compared to other predictive statistics.[8]

As described by Lipke in the seminal paper (2003)[9], the idea of Earned Schedule is analogous to Earned Value. However, instead of using cost for measuring schedule performance, we would use time. Earned Schedule is determined by comparing the cumulative BCWP earned to the performance baseline, BCWS. The time associated with BCWP, i.e. Earned Schedule, is found from the BCWS S-curve.

[8] Vanhoucke & Vandevoorde, *A Simulation and Evaluation of Earned Value Metrics to Forecast Project Duration*, Journal of Operations Research Society, October 2007, Vol 58: 1361-1374

[9] Walt Lipke, *Schedule is Different*, The Measurable News, 10-15, 2003

The Figure 5 showed the basic Earned Schedule model, like Lipke (2003) described, more explicitly, the cumulative value of ES is found by using BCWP (EV) to identify in which time increment of BCWS (PV) the cost value occurs. The value of ES then is equal to the cumulative time to the beginning of that increment plus a fraction of it. The fractional amount is equal to the portion of BCWP (EV) extending into the incomplete time increment divide by the total BCWS (PV) planned for that same time period.[10]

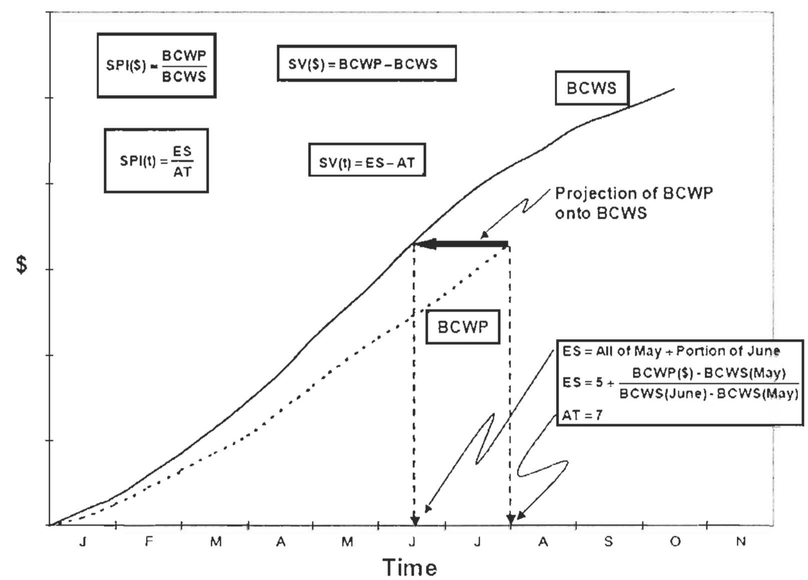

Figure 5. Earned Schedule Chart

According to Henderson and Lipke[10], the Earned schedule is expressed algebraically, ES_{cum} is the number of completed PV time increments EV exceeds PV plus the fraction of the incomplete PV increment in the unit of time being utilised. Therefore, in more mathematical terms,

$ES_{cum}=C+I$

[10] Henderson, K.,Earned Schedule :*A Breakthrough Extension to Earned Value Theory ?* A Retrospective Analysis of Real Project Data, The Measurable News, Summer, 2003, pp.1-10

Where: C=number of time increment where EV PV, and $I=(EV-PV_c)/(PV_{c+1}-PV_c)$

3.2. EARNED SCHEDULE INDEX

Using ES, the indicators can be described as follow:

Schedule Variance: $SV_{(cum)} = ES_{(cum)} - AT_{(cum)}$, where $AT_{(cum)}$ is cumulative actual time.

If the $SV_{(cum)} > 0$, which means $ES_{(cum)}$ exceeds $AT_{(cum)}$, it stands for ahead of schedule;

If the $SV_{(cum)} < 0$, which means $ES_{(cum)}$ is less than $AT_{(cum)}$, it stands for behind of schedule.

Schedule performance index: $SPI_{(cum)} = ES_{(cum)}/AT_{(cum)}$

If the $SPI_{(cum)}$ is greater than 1.00, when $ES_{(cum)}$ exceeds $AT_{(cum)}$, which means ahead of schedule.

If the $SPI_{(cum)}$ is less than 1.00, when $ES_{(cum)}$ is less than $AT_{(cum)}$, which means behind of schedule.

Henderson (2003)[11] suggested techniques which can be used to independently calculate estimates of project duration and the project completion date.

The first technique calculates an **Independent Estimate at Completion (time), IEAC $_{(t)}$** by using:

$$IEAC_{(t)} = PD / SPI_{(t)}$$

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[11] Henderson, Kym, *Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data*, The Measurable News, 2003

,where *PD* is the Planned Duration. Actually it is the short form of calculation of $IEAC_{(t)}$.

There is another long form of calculation of $IEAC_{(t)}$, which is shown as follow:

$$IEAC_{(t)} = AT + \frac{PD - ES_{(cum)}}{PF}$$

,where PF is a Performance Factor which is expressed as $P = \sum EV_j / \sum PV_j$, where PV_j is the planned value for tasks associated with ES, and EV_j is the earned value at AT (actual time) corresponding to and limited by the planned task, PV_j. Actually the above formula is the extension of short form. Henderson (2004)[12] pointed that this formula provides for the possibility of schedule performance factors other than $SPI_{(t)}$ to be developed and utilised.

The second technique calculates an **Independent Estimate of Completion Date (IECD)** for the project according to Henderson (2004)[9], the formula as follow:

$$IECD = ProjectStart\,Date + IEAC_{(t)}$$

In sum, the above two indicators are the predictive uses of earned schedule. There is another indicator as to future work, which is called **Planned Duration for Work Remaining (PDWR)**, the formula is as follow:

$PDWR = PD - ES_{(cum)}$, where PD is planned duration.

There is another index which is corresponding to TCPI in the EVM, is called **To Complete Schedule Performance Index (TSPI_ES)**. It was introduced by Walt Lipke (2009),[13] the formula is as follow:

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[12] Henderson, Kym, *Further Development in Earned Schedule*, The Measurable News, 2004

[13] Walt Lipke, *The TCPI Indicator Transforming Project Performance*, Projects & Profits, March 2009

$$TSPI = (PD - ES)/(TD - AT)$$

, where PD is the planned duration

ES is the Earned Schedule

TD is the total duration desired, we can understand it as estimated duration.

Generally: PD, the negotiated duration (ND), or estimated duration (ED), AT is the actual time or duration at the time of computation. Walt Lipke pointed that all of the preceding description for applications o TCPI can be made analogously for TSPI. That is, the use of TSPI is available for schedule management and control in a parallel manner to cost and TCPI. Both indexes are needed to have complete capability for the cost-schedule performance trade-off necessary for project recovery.

3.3. Earned schedule benefits

There are a number of benefits which are derived from Earned Schedule, the main benefits are;

First, Earned schedule was created as a simple solution to resolve the problem of schedule performance indicators failing for expressing in amount of money instead of time. Earned Schedule performance indexes can give a vivid vision to the project managers;

Second, Earned Schedule solves the problem of the EVM schedule indicator failing for late finishing projects. ES provides better schedule prediction using EVM data, and this kind of method is still valid from beginning to the end of the project.

Third, for the prediction of the project duration, using ES is also much easier to calculate. It provides an estimate of duration and completion dates, especially for late finishing projects.

Except the above main benefits, Alex Davis and Mick Higgins (2010)[14] listed the following benefits of Earned Schedule:

- It provides an estimate of duration and milestone completion dates—especially for late-running activities.
- The method provides forecast indicators much in the same way as EVM.
- Project and Programme Managers have another schedule analysis tool that potentially improves the confidence in statistically forecasting delivery dates—especially for projects and programmes that are behind schedule.
- As with standard EVM, ES facilitates drill-down to the areas of the schedule that need management attention.
- ES also provides early warning out of sequence activities by the use of the "P" factor.
- ES makes a contribution to trend analysis; it can be used to highlight trends in milestone slippage and be superimposed with contract delivery deadlines, risk confidence limits and benefit realisation data to provide a more comprehensive picture of project/programme performance.
- Last, and by no means least, you do not need any additional data to perform Earned Schedule calculation. The existing Earned Value date is all you need; you are just using it in a different dimension.

[14] Alex Davis & Mick Higgins, Earned Schedule An emerging Earned Value technique, the AMP Earned Value mangement SIG Working Group, January, 2010 http://www.apm5dimensions.com/news/earned-schedule-white-paper

4. Earned Quality Management

4.1. Introduction

According to the international standardization organization (ISO) has defined quality as the set of properties and characteristics of a product or a service required to meet the explicit and implicit needs of a client. Quality includes all the properties and characteristics that give a product or a service the capacity to satisfy fully the explicit and implicit client's needs. It is a complex task to measure the quality of a project, since it is involved multiple conflicting objectives as well as imprecise and qualitative attributes.

In the project management, lots of the quality control methods, like quality function deployment (QFD) and value analysis (VA), aim at achieving quality through improved product and process design. According to Jean Paul Paquin, 2000, these methods do not specifically address the fundamental issues relating to the periodic assessment and control of the quality of a project and product throughout its life cycle. [15]

The earned quality method (EQM) is a general method to help the project managers in evaluating and controlling the quality of the project through the whole project's life cycle. It was introduced by J.P Paquiln, 1996. The original intention is propose a multi attribute utility theory approach that enables project managers to measure and estimate the monetary value of a project's accumulated quality attributes. Earned quality is a tool for assessing and controlling quality through a project life cycle. The earned quality method is based on two fundamental assumptions:

a) The quality is a measurable concept

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15 Jean Paul Paquin, Jean Couillard, and Dominique J. Ferrand, *Assessing and Controlling the Quality of a Project End Product : The Earned Quality Method*, IEEE Transactions on Engineering Management, Vol. 47, No.1, Febuary 2000.

b) The quality is accrued progressively throughout the project's life cycle[16]

The earned quality method can allow project managers to assess and control the quality of the end products periodically through comparing earned quality and planned quality to detect quality deviations and initiate early corrective actions. EQM needs some steps as follow;

First, it must elucidate the client's needs, which means decomposing the overall quality objective into lower level objectives of more detail. Second, assessing and aggregating the client's preferences. Third, estimate the earned quality.

One point must be addressed, the project managers and the clients must select from a set of value functions, as shown in Figure 6 as follow;

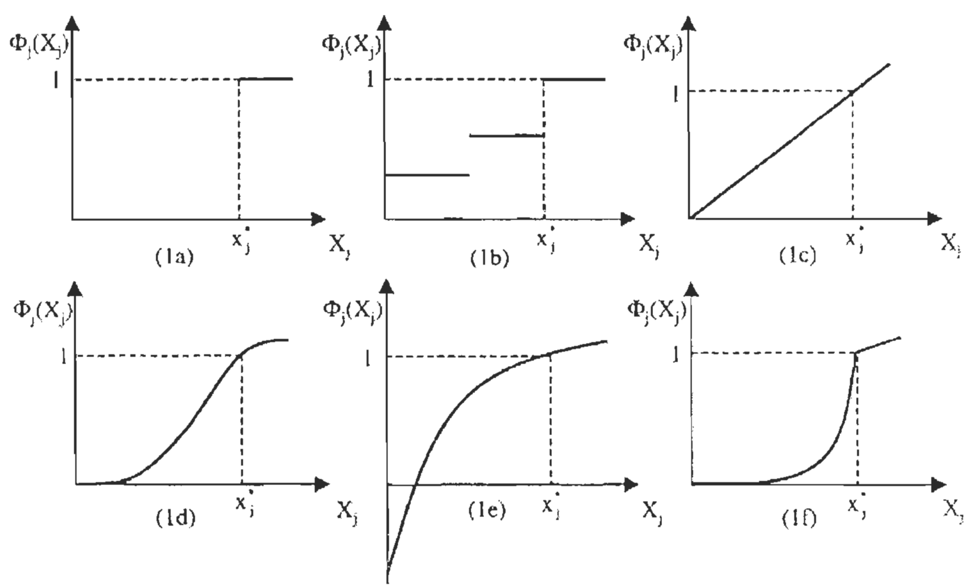

Figure 6. Value functions (Source: Paquin et al. 1996)

The project manager must obtain with regard to all J criteria estimates of the result X_j which will most likely be achieved upon project completion through the entire project's life

[16] J.P.Paquin, J.Couillard, R.Paquin, D.Godcharles, *Earned Quality : Improving Project Control*, 1996

cycle.[17] The overall quality Q of the project end product is equal to the weighted sum of the utility value of the results X_j achieved over all J criteria. Mathematically, we can express as:

$$Q = \sum_{j=1}^{J} w_j \Phi_j (x_j)$$

Which, Q is the overall quality of the project end product

w_j is the relative contribution of criterion to the overall quality objectiv, and $\sum_{j=1}^{J} w_j = 1$

J is the number of the criterions.

x_j is the result of the J criterion.

$\Phi_j (x_j)$ is the result of x_j achieved over all J criteria.

The EQM link the work breakdown structure (WBS) and quality breakdown structure (QBS), which have a relationship between WBS and QBS. See the Figure 7 as follow;

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[17] J.P.Paquin, J.Couillard, R.Paquin, D.Godcharles, Earned Quality : Improving Project Control, 1996

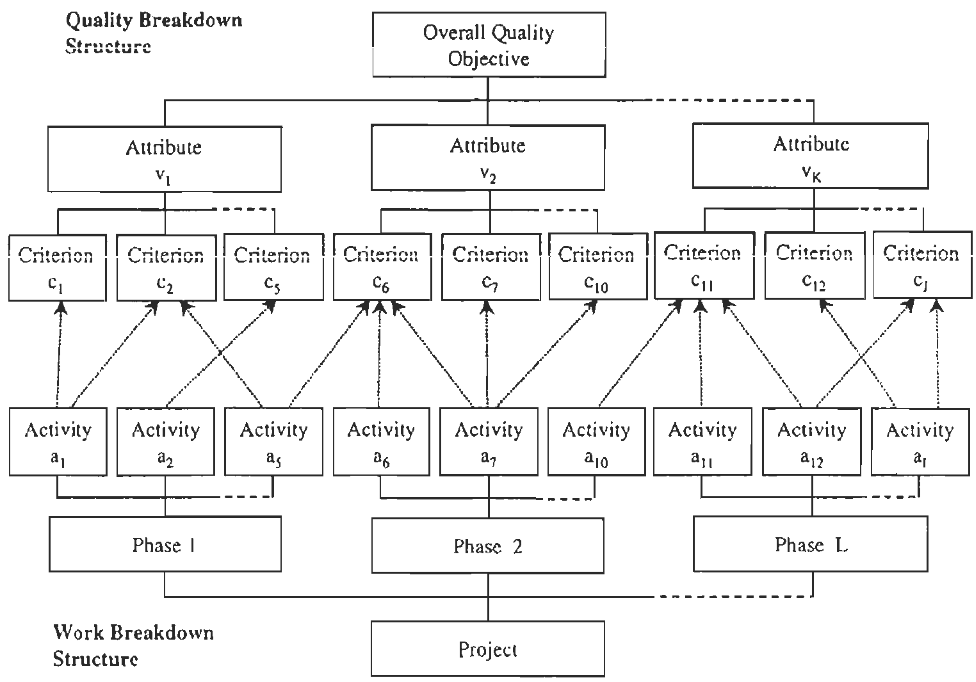

Figure 7. The WBS-QBS model (Source: Paquin et al. 1996)

The earned quality method link the activities to quality attributes, which enable the project manager to connect the WBS work element to the quality control through the entire the project life cycle. EQM uses the relationship between the WBS and QBS, which was shown in Table 1,

Table 1. Quality of work and quantity of work

Quantity of Work / Quality of Work	Work Scheduled	Work Performed
Planned Quality	Planned Quality of Work Scheduled (PQWS)	Planned Quality of Work Performed (PQWP)
Earned Quality		Earned Quality of Work Performed (EQWP)

(Source: Paquin et al. 1996)

Work scheduled stands for the planned rate of completion of the activities at the report time t, while work performed deal with the actual rate of completion of the activities at the reporting time point t.

Planned quality means the anticipated quality that should have accrued at the reporting time point t, while earned quality regards to the actual quality that accrued at the reporting time point t.

4.2. EXPLANATION OF EQM

According to the Paquin et al. (2000), **the planned quality of work schedule PQWS** measures the planned contribution to the overall quality objective attributable to the work scheduled for all activities. It is defined as follows until the reporting time point,

$$PQWS_t = \sum_{i=1}^{I}\sum_{j=1}^{J} w_j \Phi_j(x_j^*) r_{ij}^*(t)$$

Where

$r_{ij}^*(t)$, the planned contribution to the expected result x_j^* as measured by criterion C_j attribute to the work scheduled for activity a_j at time t, $0\,0 \le r_{ij}^*(t) \le r_{ij}$

The planned quality of work performed PQWP measures the planned contribution to the overall quality objective attributable to the work performed on all activities at reporting time point t, which is defined as following;

$$PQWP_t = \sum_{i=1}^{I}\sum_{j=1}^{J} w_j \Phi_j(x_j^*) r_{ij}(t)$$

Where

$r_{ij}(t)$, the planned contribution to the expected result x_j^* as measured by criterion C_j attributable to the work performed on activity a_j at time t, $0 \leq r_{ij}(t) \leq r_{ij}$

The earned quality of work performed EQWP measures the overall client satisfaction with the results achieved or the earned quality, attributable to the work performed on all activities at reporting time point. It can be expressed as follows;

$$EQWP = \sum_{i-1}^{I} \sum_{j=1}^{J} w_j \Phi_j (\hat{x}_j) \hat{r}_{ij}(t)$$

Where,

$\hat{x}_j(t)$ the actual result achieved with regard to criterion C_j of the work performed at time t

$\hat{r}_{ij}(t)$ the estimated contribution to the actual result $\hat{x}_j(t)$ as measured by criterion C_j attributable to the work performed on activity a_j at time t

By comparing the earned quality of work performed EQWP with the planned quality of work performed PQWP, the quality variance QV will be the following equation ;

QV=EQWP-PQWP

If QV<0, means the quality objective was underachieved.

If QV>0, means the quality objective is over achievement.

A quality performance index (QPI) is calculated as follow;

$$QPI = \frac{EQWP}{PQWP} * 100\%$$

This index standard may be initiated whenever preset threshold have been exceeded.

4.3. The modified EQM (Xu, 2009)

The EQM model is very original and interspersing. However, it has the limitations related to necessary information needed to get going. Specially, we state the limitations as follow:

- The choice of function that reflects the quality on a given criterion is subjective. This is not necessary, but it is a limit to the method because it requires managers to set up the functions first.
- By considering the relative contribution of a task to a given quality criterion is not only the liner relationship with time. However, in practice, it makes project managers to have a subjective information and hard to estimate the difference. And it would not be more convenient for using a linear relationship to consider the achieved percentage of the activity.
- The model considers a discrete approach based on benchmarks to evaluate the achieved percentage of the activity. But it would not be interesting to work with a continuous measure of the percentage of completion.

In response to these criticisms regarding to the applicability of EQM method in practice, Xu (2009) proposed a modification formulas that include the EQM calculations as follow:

$$PQWP = \sum_{i=1}^{I} \sum_{j=1}^{J} w_j r_{ij} \quad \%_i$$

$$EQWP = \sum_{i-1}^{I} \sum_{j=1}^{J} w_j \Phi_j r_{ij} \quad \%_i$$

$$QPI = \frac{EQWP}{PQWP}$$

5. PROJECT CONTROL AND DECISION MAKING

5.1. PROJECT CONTROL

Project management is the discipline of planning, controlling and managing resources to bring the success of completion of specific project goal or aim. One of the fundamental responsibilities of a project manager is to make sure that all kinds of administration behaviours are done as they are supposed to be done. In that case, it can bring the success of completion of specific project goal. In other words, this kind of responsibilities was called control. Control is the act of reducing the difference between plan and reality. It is also the last element in the implementation cycle of planning—monitoring—controlling. In essence, control is the act of reducing the difference between plan and reality.[18] In the world of project management, the term "control" is much more analogous to drive a coach to take a trip. The driver must keep making course adjustments with the original destination as promised in the beginning of the voyage. The driver must make sure bring the customers to the correct destination safely on time as promised in the beginning of the voyage. And the successful project voyage must include carefully charting a course to destination, driving to destination on time, distinguishing location on the map, paying attention to weather, and keeping a watchful eye on speed and so forth.

Project control, of course, is one of the most important areas in project management. First, it involves bringing actual performance into the congruence with the original plan. Project control is one of the fundamental components in the world of project management. In every project, project control that is defined as the behavior of reducing the difference between plan and reality is the necessary process which involves monitoring progress of the plan, analyzing the variances including cost, time and so forth, taking necessary corrective actions, even stop the project when it is necessary to accomplish the project according to

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[18] Project Management: A managerial approach Jack R.Meredith, Samuel J. Mantel, JR

given target. This kind of behavior is the fundament guarantee that can push the whole project forward to given destination.

Furthermore, project control can be used as an effective project method to make project move on the right track. Specifically speaking, good project control can significantly improve project performance and reflect the project situation precisely. It can provide more information for the administration level. Specifically speaking, it can make the project on the original routine and keep costs competitive and maintain schedule integrity. For example, effective project control not only can reduce the fixed costs, but also deal with the variable cost highly competently. While, in today's modern project management, except traditional cost and schedule control, scope control, risk control, quality control, and customer satisfaction control emerges. They are becoming the new focus for project managers. Generally speaking, good project control usually can be used as a strategic tool to enhanced competitive forces in the market.

Project control is not the only factor that can guarantee project success, but it is one of the most important factors. Generally, the regulation of results through the alteration of activities and the stewardship of organizational assets are two fundamental purposes of control. The final objective of project control is to reduce the difference between plan and reality. While, controlling the destiny of certain project is not simple for project managers. Maintaining control in terms of minimizing the distance between plan and reality is always the subject of controlling. That means project managers should keep an eye on the future, they must know clearly all kinds of variances and deal with these variances under a reasonable range.

In short, project control will address the following questions:

- When a manager should act,
- What action he should take.

These two questions are age-old questions, but there is a relationship between the project performance and management actions. Traditional management tools just give the behaviour of project performance and general actions, but they do give the details of how to measure this kind of relationship? In another words, how to decide when to take the appropriate actions is faced by the project managers.

5.2. PROJECT PERFORMANCE ANALYSIS AND DECISION MAKING

Project performance is the behaviour of project control. And project performance is also called project efficiency which is measured by the Earned Value Management (EVM) indicators, cost and schedule performance indexes, CPI and SPI, respectively. [19] Furthermore, it is also measure by Earned Schedule Indexes, like $SPI_{(cum)}$ and so on. Actually, project performance is measured by a set of indexes, like CPI, SPI, TCPI, and TSPI and so forth, which provide information concerning project progress. For a simple example, if the SPI is less than 1.0, which means the project is performing less than the planned performance as to the reporting time, project managers will put more labour resources on it to catch the schedule.

EVM is still the best effective project management tool to monitor the health of project for project managers so far. Even project managers hold this tool, but this kind of tool does not provide the corrective action tips. Furthermore, whatever project managers who do something wrong or right will buy time. If they do the corrective actions, and will get the project back on course, otherwise, project performance will go worse. All these situations are due to lack of relationship between the project performance and corrective

[19] Fleming, Q. Cost/Schedule Control System Criteria, The Management Guide to C/SCSC. Chicago : probus, 1988

actions. We cite part of the model that Walt Lipke developed in 2003.[20] Lipke indicated that expect the project performance, there are other considerations needed to make the management decision, which are sufficiency of data, possible strategy and sufficient time. He also pointed that there are four basic actions inside this model, they are as follows:

- No Action Required
- Investigate
- Adjust/Realign
- Negotiate [20]

Lipke also gave the explanation of these four actions, obviously, it is easy to understand the first two items, when the project is performing well, and the project managers would be wise to not make any changes. While, if the project has poor performance, but has insufficient data, the project managers would investigate for potential causes and data definitely.

The Adjust/Realign and Negotiate actions are not so simply connected to the analysis results. The project manager should negotiate additional cost and/or schedule, ore reduction of requirements, only when a recovery strategy is not possible, or there is insufficient time for the recovery to be effective.[14]

The figure 8 shows the relationship between project performance and actions as follow;

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[20] Walt Lipke, Deciding to Act, Cross Talk, The Journal of Defense Software Engineering, Dec., 2003 Issue

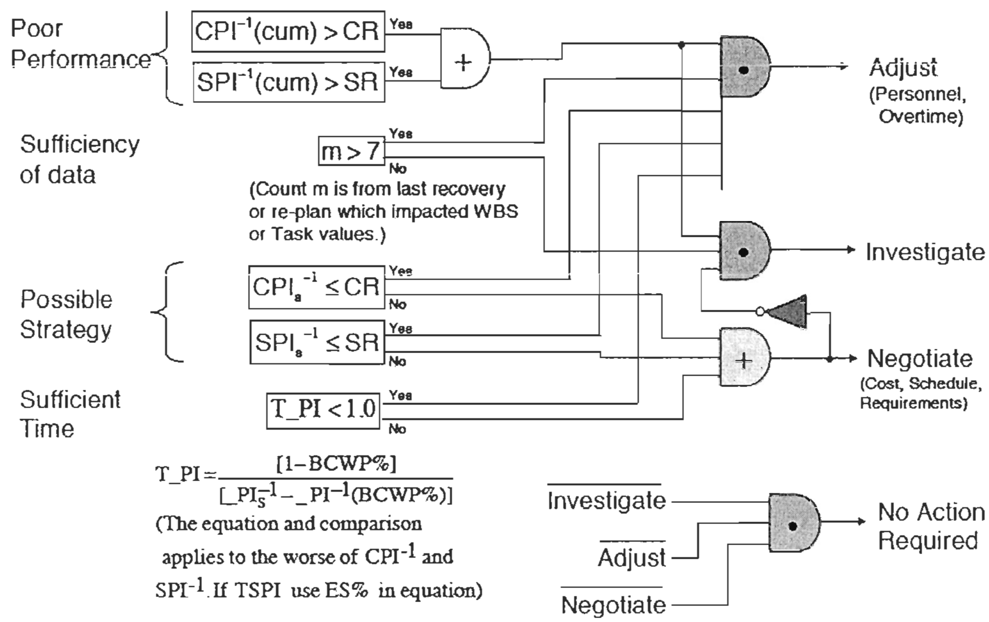


Figure 8. Decision Logic

Source: Lipke, 2003

In summary, this decision logic provides another management tool for project managers. Through this method, it can help me project managers to make decision wiser and avoid the mistake. Furthermore, the action recommended will be more rational than before. And it also provides a fundamental diagram for our following research in this paper. We will discuss the modified decision model and corrective actions management during the next chapter.

CHAPITRE 2 : The proposed methodology for corrective actions management

1. THE PROPOSED METHODOLOGY

Earned Value Method has been set up to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery, total project budget. It is a well-known and generally accepted method that integrates cost, schedule and technical performance. There are always three parameters present in EVM: Planned Value, Actual Cost and Earned Value. With these three parameters a series of indexes and ratios can be obtained (show CV, CPI, EAC, ETC, SV, SPI). Although the classic earned value metrics are designed to forecast both time and cost, these metrics are purely cost-based. In fact, it has been documented that CV, CPI, ETC, EAC (all these are indexes from the cost side of the project) are very accurate but there is a problem with the schedule side (SV and SPI). Recently, this problem has been tackled by researchers (Lipke, 2003 and Vandevoorde & Vanhoucke, 2006) and it leads to the Earned Schedule method (ESM). This technique has shown very interesting results, and can be considered as a new alternative for the more classic earned value metrics for the evaluation of the schedule performance of the projects. So, EVM indicators and ESM indicators can be considered as accurate to evaluate the cost and schedule performance of the project. For Assessing and Controlling the Quality of a Project End Product, a Quality Earned Method has been developed (Paquin, Couillard & Ferrand, 2000). These methods (EVM, ESM and EQM) provide early indications of project performance to highlight the need for eventual corrective actions. But, there is still another step, the choice of a good corrective or recovery action. To the best of our knowledge, no research has been done to tackle directly this aspect prior to this paper, may be excepted the the paper of Lipke (2003b) which proposes a decision logic coupling the decision data (performance indicators, sufficiency of data, of time) to the management of actions. However, the decision logic diagram doesn't propose a ranking of the different possible strategies but classify them into one of the following categories:

- Adjust or realign the project,
- Investigate if there is insufficient data,
- Negotiate, with the customer the cost, schedule or requirements
- No action required when the performance of the project is good.

Moreover, the quality side of the project is not considered in this decision logic diagram. Taking into account all these new developments, we propose the decision aid methodology for corrective actions management described in figure 9.

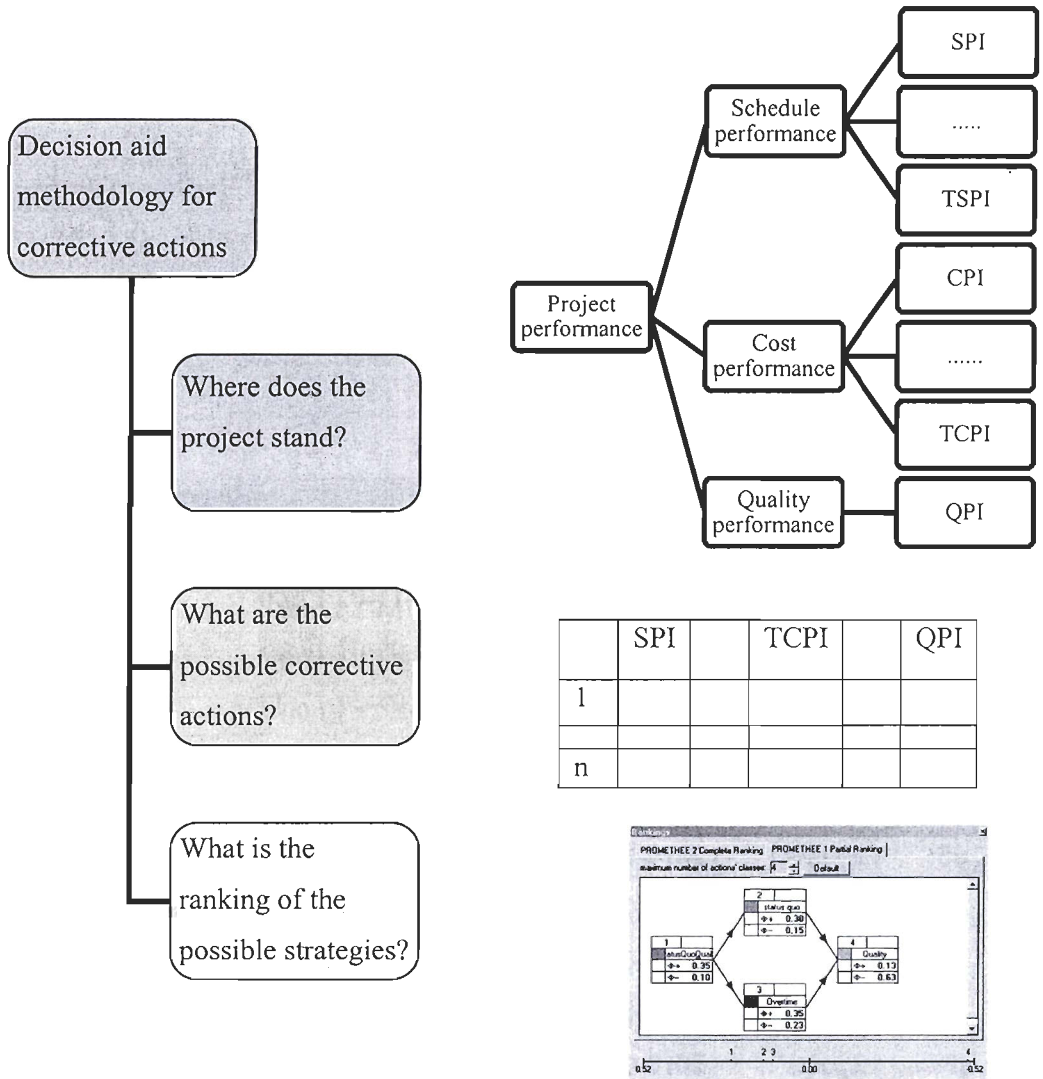


Figure 9. The proposed decision aid methodology for corrective actions management

This methodology involves three basic steps:

- Use of time index, cost index and quality index to evaluate where the project is, if it is necessary to realign the project and if there is time and sufficient data to do.
- Definition and evaluation for the criteria chosen and the used strategies previously.
- Arrange and use a multi criterion to provide different corrective actions and possible recommendations for project managers.

In the following section, we will use an example to illustrate the proposed methodology.

2. Didactical example

To illustrate our model, we'll use the following didactical example. The proposed project consists of 27 tasks (table 2) and 5 different resources (table 3).

Table 2. Project description

Nom de la tâche	Durée planifiée	Début planifié	Fin planifiée	Noms ressources	Prédécesseurs
timPlanif	**47 jours**	**2010-08-30 08:00**	**2010-11-02 17:00**		
a1	3 jours	2010-08-30 08:00	2010-09-01 17:00	r1	
a2	2 jours	2010-08-30 08:00	2010-08-31 17:00	r2	
a3	2 jours	2010-09-02 08:00	2010-09-03 17:00	r1	2;3
a4	4 jours	2010-09-06 08:00	2010-09-09 17:00	r2	4;6
a5	2 jours	2010-08-30 08:00	2010-08-31 17:00	r3	
a6	2 jours	2010-09-10 08:00	2010-09-13 17:00	r1	5
a7	1 jour	2010-09-14 08:00	2010-09-14 17:00	r5	7
a8	1 jour	2010-09-14 08:00	2010-09-14 17:00	r4	7
a9	2 jours	2010-09-14 08:00	2010-09-15 17:00	r3	7
b1	3 jours	2010-09-15 08:00	2010-09-17 17:00	r2	8
b2	2 jours	2010-09-16 08:00	2010-09-17 17:00	r1	10
b3	3 jours	2010-09-20 08:00	2010-09-22 17:00	r1	11
b4	2 jours	2010-09-20 08:00	2010-09-21 17:00	r2	12
b5	3 jours	2010-09-23 08:00	2010-09-27 17:00	r3	13;14
b6	4 jours	2010-09-15 08:00	2010-09-20 17:00	r5	9
b7	2 jours	2010-09-21 08:00	2010-09-22 17:00	r5	16
b8	2 jours	2010-09-23 08:00	2010-09-24 17:00	r5	17
b9	4 jours	2010-09-28 08:00	2010-10-01 17:00	r4	15;18

c1	3 jours	2010-09-27 08:00	2010-09-29 17:00	r1	18
c2	2 jours	2010-09-28 08:00	2010-09-29 17:00	r2	15
c3	3 jours	2010-09-30 08:00	2010-10-04 17:00	r5	20
c4	5 jours	2010-09-30 08:00	2010-10-06 17:00	r1	21
c5	4 jours	2010-10-07 08:00	2010-10-12 17:00	r1	19;22;2 3
c6	4 jours	2010-10-13 08:00	2010-10-18 17:00	r2	24
c7	3 jours	2010-10-13 08:00	2010-10-15 17:00	r3	24
c8	6 jours	2010-10-19 08:00	2010-10-26 17:00	r4	25;26
c9	5 jours	2010-10-27 08:00	2010-11-02 17:00	r5	27

Table 3. Resources table

Resource name	Standard Taux	Tx. hrs. sup.
r1	30,00 $/hr	40,00 $/hr
r2	40,00 $/hr	50,00 $/hr
r3	40,00 $/hr	50,00 $/hr
r4	50,00 $/hr	60,00 $/hr
r5	30,00 $/hr	40,00 $/hr

Moreover, the quality of the project is evaluated by 3 criteria (QC1 to QC3) and the contributions of the different activities to the different criteria are in Table 4.

Table 4. Contributions of the activities to the quality criteria

	QC1	QC2	QC3
a1	0,1	0	0
a2	0,05	0	0
a3	0,1	0	0
a4	0,1	0	0
a5	0,05	0	0
a6	0,1	0	0

a7	0,1	0	0
a8	0,05	0	0
a9	0,1	0	0
b1	0,1	0,1	0
b2	0,05	0,05	0
b3	0	0,1	0
b4	0	0,1	0
b5	0	0,1	0
b6	0	0,05	0
b7	0	0,1	0
b8	0	0,1	0
b9	0	0,05	0
c1	0	0,1	0
c2	0	0	0,1
c3	0,05	0	0,05
c4	0	0	0,05
c5	0	0	0,05
c6	0	0,05	0,2
c7	0	0	0,1
c8	0,05	0	0,2
c9	0	0,1	0,25

For this project (table 5), the planned duration is 47 days, from the 30-08-2010 to the 02-11-2010 and the BAC (budgeted at completion) is 22880$.

Table 5. Project statistics

Statistiques sur le projet pour 'timorigin.mpp'

	Début	Fin
En cours	10-08-30 08:00	10-11-02 17:00
Planifié	10-08-30 08:00	10-11-02 17:00
Réel	NC	NC
Variation	0j	0j

	Durée	Travail	Coût
En cours	47j	632h	22 880,00 $
Planifié	47j	632h	22 880,00 $
Réel	0j	0h	0,00 $
Restant	47j	632h	22 880,00 $

% achevé :

Durée : 0% Travail : 0%

Fermer

We simulated the project using protrack (www.protrack.be) and we generated 4 tracking periods, every 2 weeks. In annex 1, the reader can find the main results for each tracking period. For our didactical example, we consider that it is the 22-10-2010 and that the project manager uses our proposed decision aid methodology for project performance tracking and corrective actions management. So, in the next sections, we will illustrate, with this didactical example, the different steps of our approach.

Step1. Where does the project stand?

To resume the evolution of the project during these different tracking periods, we can visualize the values, in time, of different indices of the project performance (PV, EV, ES, CPI, SPI, SPI(t), EAC, EAC(t) and QPI). We can observe (figure 10 à figure 12) that the costs of the project are under control. For example, CPI vary from 1.11 to 1.01 and the EAC from 22700$ to 23100$, which is quite the planned value of 22880$. Finally, the value of the TCPI is .96. The index value describes the cost performance efficiency required for the remainder of the project to achieve the desired final cost and when TCPI is equal to or less than 1.00, there is confidence that the EAC can be achieved.

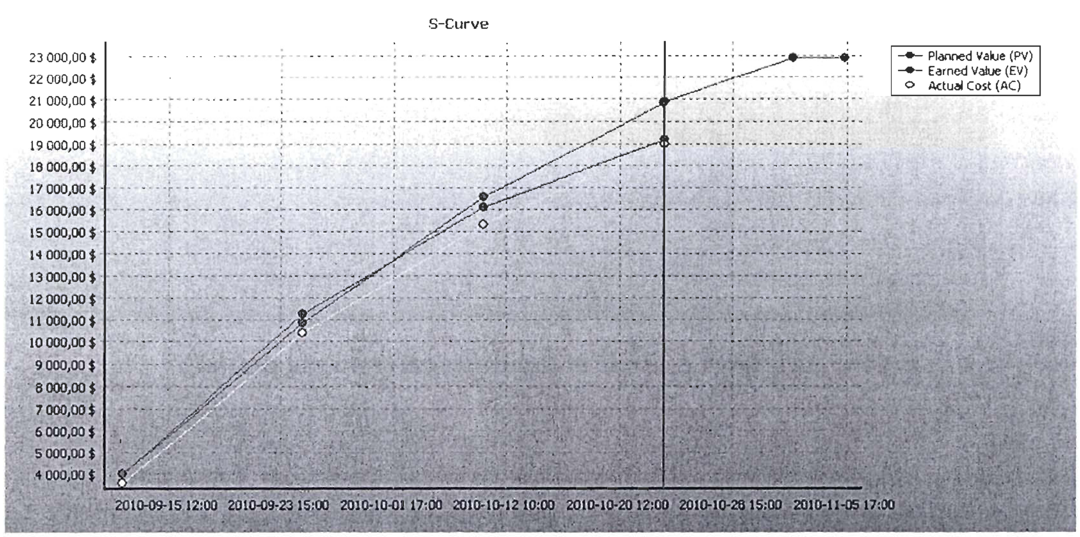


Figure 10. S curve at the different tracking periods

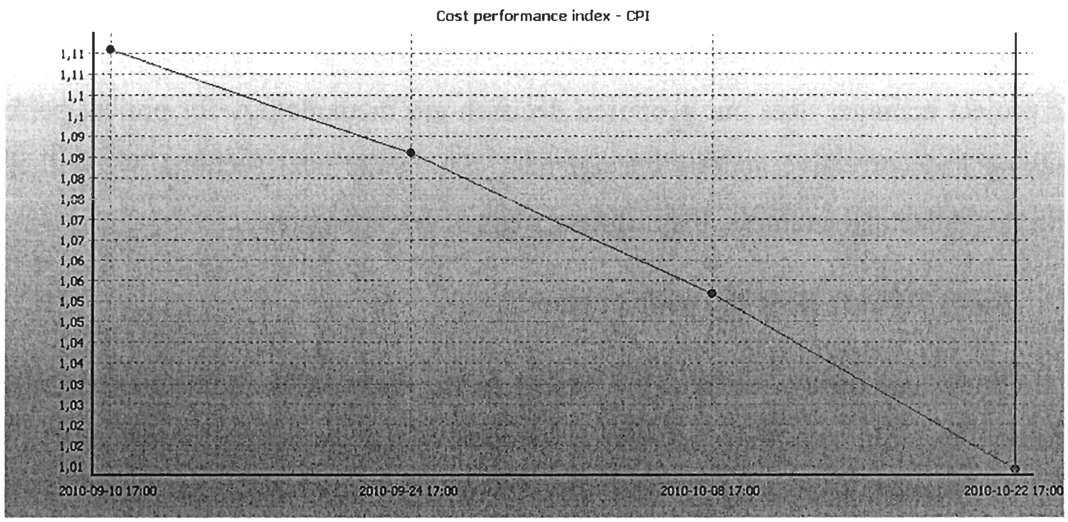


Figure 11. CPI at the different tracking periods

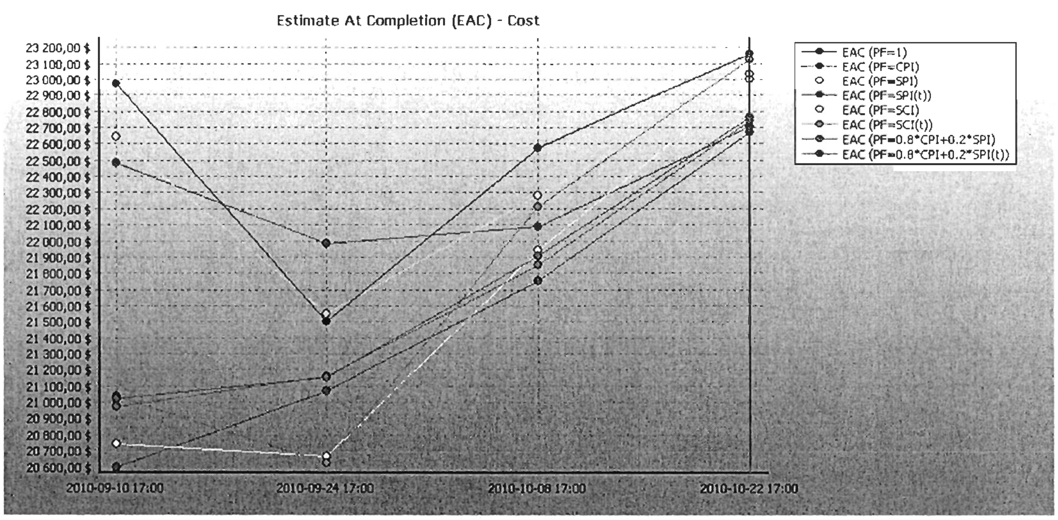


Figure 12. EAC at the different tracking periods

Nevertheless, the project is not on time (figure 13 à figure 15) and this problem doesn't seem to be resolved. In fact the delay is 4 days 3 hours on the 22-10-2010, and the

SPI dropped from 1.04 to the actual value (the 22-10-2010) .92, which is less than the Schedule Ratio fixed at .95.

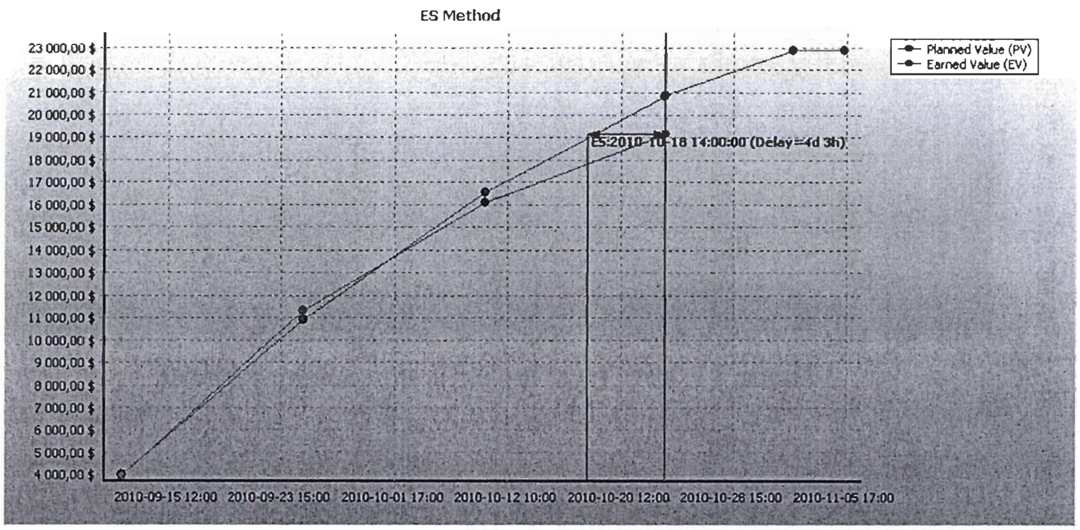


Figure 13. ES curve at 22-10-2010

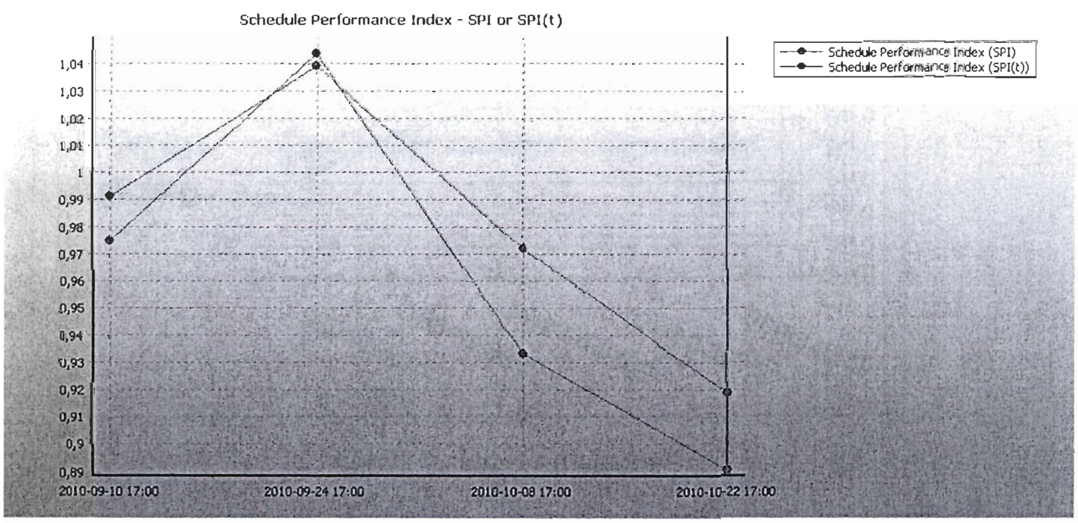


Figure 14. SPI and SPI(t) at the different tracking periods

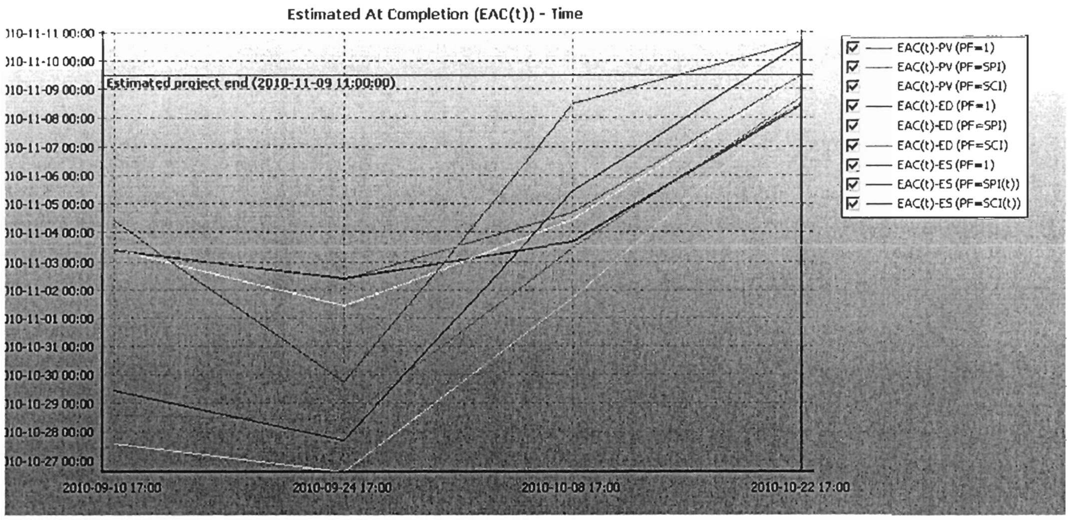


Figure 15. EAC(t) at the different tracking periods

Moreover, the QPI (quality performance index) decreases in time (figure 16) and it is less than the Quality Ratio fixed at .95.

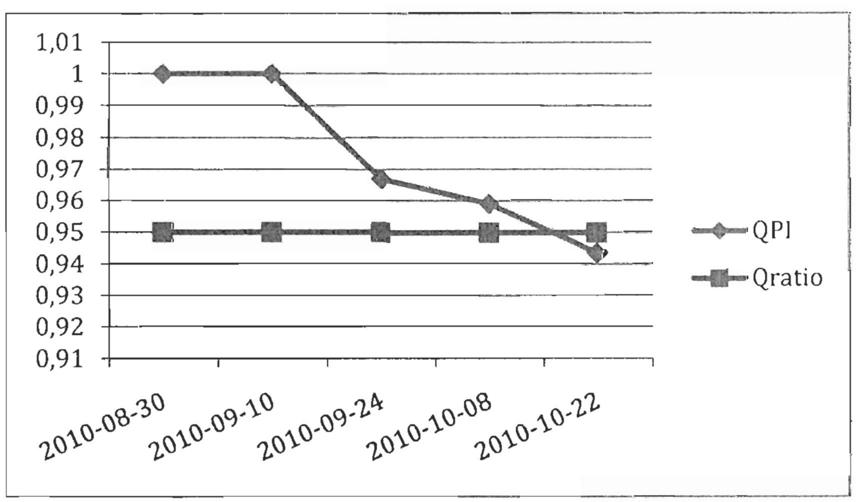


Figure 16. QPI evolution

In view of these various indicators for the project manager, like Lipke (2003b) may ask the following questions:

Do the indicators show poor project performance? The response is affirmative in our example and more precisely, there is a problem with the quality and with the schedule of the project.

Is enough data available to make a good decision? In our example, the project manager can see the necessity to implement a recovery strategy because for the quality and the schedule indicators, there is a decreasing tendancy for several weeks.

The next questions, addressed by Lipke (2003b), are the following ones:

Can a strategy be created to recover the project?

Is there enough time remaining to use the strategy?

These questions are part of our second step.

Step2. What are the possible corrective actions or recovery strategies?

In this second step, the project manager may imagine different strategies in order to recover the project. The problem he faces to is then how to evaluate these strategies and how to choose the 'best' one or, more precisely, the best compromise strategy. This last aspect will be the objective of the last step of our proposed methodology.

In our example, we suppose that the project manager can consider (table 6) the following possible strategies[21]:

[21] At this point of time, all the activities, except for the activities C6, C8 and C9, are finished so the possible strategies are different combinations of time, cost or quality values of these unfinished activities.

Table 6. The possible strategies

	Activity C6	Activity C8	Activity C9
Status quo	3h remaining	6 days remaining	5 days remaining
Overtime	3h remaining	4 days remaining	4 days remaining
Quality	11h remaining	7 days remaining	6 days remaining
Status quo& Overtime	6h remaining	5 days remaining	5 days remaining

The evaluation of these strategies can be resumed by the EVM/ES report in Table 7 and the Quality indicator of Table 8.

Table 7. EVM/ES report of the possible strategies

Recovery strategy	**Duration**	**CBTE**	**CBTP**	**CRTE**	**Cost**	**ES**
Status quo	51,25 j	19 184,00 $	20 880,00 $	19 010,00 $	22 730,00 $	285h
Overtime	48,25 j	19 184,00 $	20 880,00 $	19 010,00 $	22 970,00 $	285h
Quality	54,25 j	18 986,67 $	20 880,00 $	19 010,00 $	23 690,00 $	280h
scenarQualiOrigin	50,63 j	19 101,33 $	20 880,00 $	19 010,00 $	22 750,00 $	283h

Table 8. Quality indicator[22] of the possible strategies

Recovery strategy	**QPI**
Status quo	.9435
Overtime	.9195
Quality	.9790
scenarQualiOrigin	.9680

[22] For more details, see annex 3

Step 3. What is the ranking of the possible strategies?

In this step, the project manager (or the customer) has to choose the indicators of the project performance to be considered in the choice or ranking of the strategies. In this case, the chosen indicators are those in Table 9. Some of them contribute to the estimations of the time performance of the project, some for the quality and for the cost performances of the project.

Table 9. Performance indicators of the recovery strategies[23]

	Time indicators				Cost indicators			Quality indicator
Recovery strategy	SPIcum	TSPI_EVM	TSPI_ES	SPI(t)	CPIcum	CPIfin	TCPI	QPI
StatusQuo	0.919	1.1568	1.1331	0.91	1.009	1.010	0.986	.9435
Overtime	0.9188	0.8091	0.8846	0.97	1.009	0.990	1.123	.9195
Quality	0.909	1.6143	1.3964	0.86	0.999	0.960	1.297	.9790
StatusQuo&Quality	0.915	0.9933	1.0244	0.93	1.005	1.010	0.965	.9680

To obtain a ranking of the strategies, we choose to use the PROMETHEE[24] method (Brans & Vincke, 1985). Our other choice would have been able to focus on multi criteria methods (special method ELECTRE), but the related convivial software (DecisionLab) with an integrated sensitivity analysis is involved during the following illustrations.

Our problem consists to aid the project manager to choose the best compromise recovery action taking into account different and conflicting criteria. This problem is represented in table 9 by the evaluation matrix.

[23] For the calculations, see Annex 4

[24] For more explanation about the PROMETHEE method, see Annex 5

Table 10. Multicriteria Evaluation matrix

	SPIcum	TSPI_EVM	TSPI_ES	SPI(t)	CPIcum	CPIfin	TCPI	QPI
Min/Max	Maximize	Minimize	Minimize	Maximize	Maximize	Maximize	Minimize	Maximize
Weight	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000
Preference Functi	V-Shape	V-Shape	V-Shape	V-Shape	V-Shape	V-Shape	V-Shape	V-Shape
Indiference Thres	-	-	-	-	-	-	-	-
Preference Thres	0.0100	0.8000	0.5000	0.1100	0.0100	0.0400	0.3300	0.0600
Gaussian Thresh	-	-	-	-	-	-	-	-
Threshold Unit	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute
Unit								
status quo	0.9190	1.1568	1.1331	0.9100	1.0089	1.0100	0.9860	0.9435
Overtime	0.9188	0.8091	0.8846	0.9700	1.0090	0.9900	1.1230	0.9195
Quality	0.9090	1.6143	1.3964	0.8600	0.9990	0.9600	1.2970	0.9790
StatusQuo&Qualit	0.9150	0.9933	1.0244	0.9300	1.0050	1.0100	0.9650	0.9680

PROMETHEE requests additional information. For each criterion, a specific preference function must be defined. This function is used to compute the degree of preference associated to the best action in case of pairwise comparisons. Six possible shapes of preference functions, described in Brans et al (1986), are available in the software. In this example, the V-shape has been associated to the eight criteria and the preference thresholds have been fixed, for every criterion, to the maximum deviation between all the recovery actions.

From the PROMETHEE I partial ranking obtained (Figure 17), one can immediately see that the StatusQuo&quality recovery action dominates all the others. It looks as the best compromise, according to the basic weight distribution. On the other hand, Overtime strategy and StatusQuo strategy seem to be incomparable. The Overtime strategy is strong on the time indicators but costs more than the statusQuo strategy.

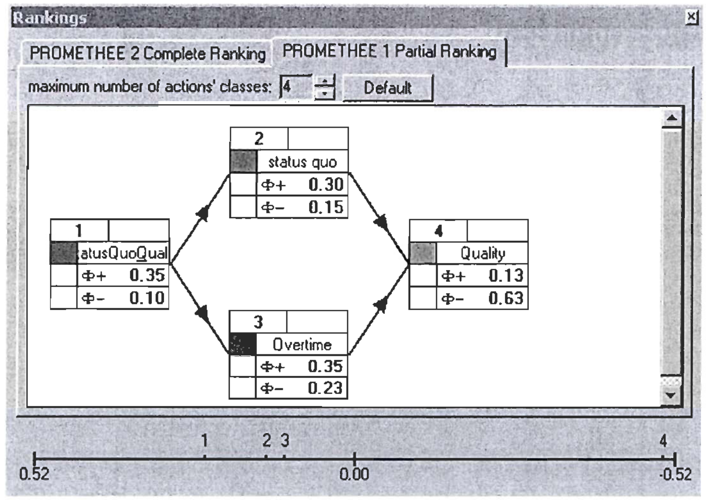


Figure 17. Partial ranking with PROMETHEE I

Nevertheless, if we have to decide, we can 'force' a total ranking with the PROMETHEE II method. One can see (figure 18) that the StatusQuo strategy is then preferred to the overtime strategy.

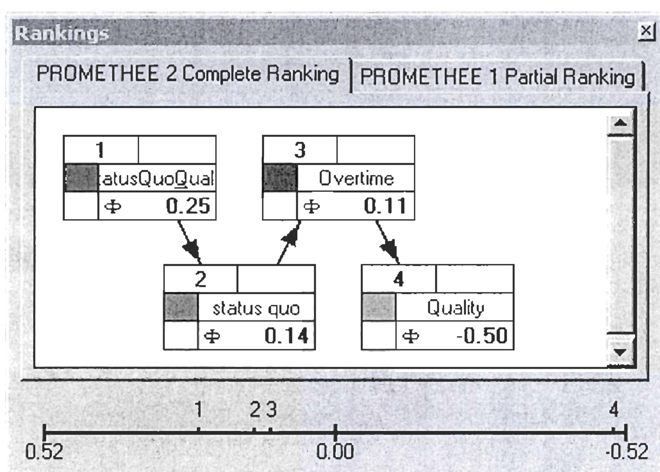


Figure 18. Complete ranking with PROMETHEE II

As the rankings are influenced by the weights allocated to the criteria, the software allows to modify the weights and to observe the resulting modifications of the ranking. This sensibility analysis can be realized with the basic indicators (figure 19) or with the aggregated indicators (figure 20).

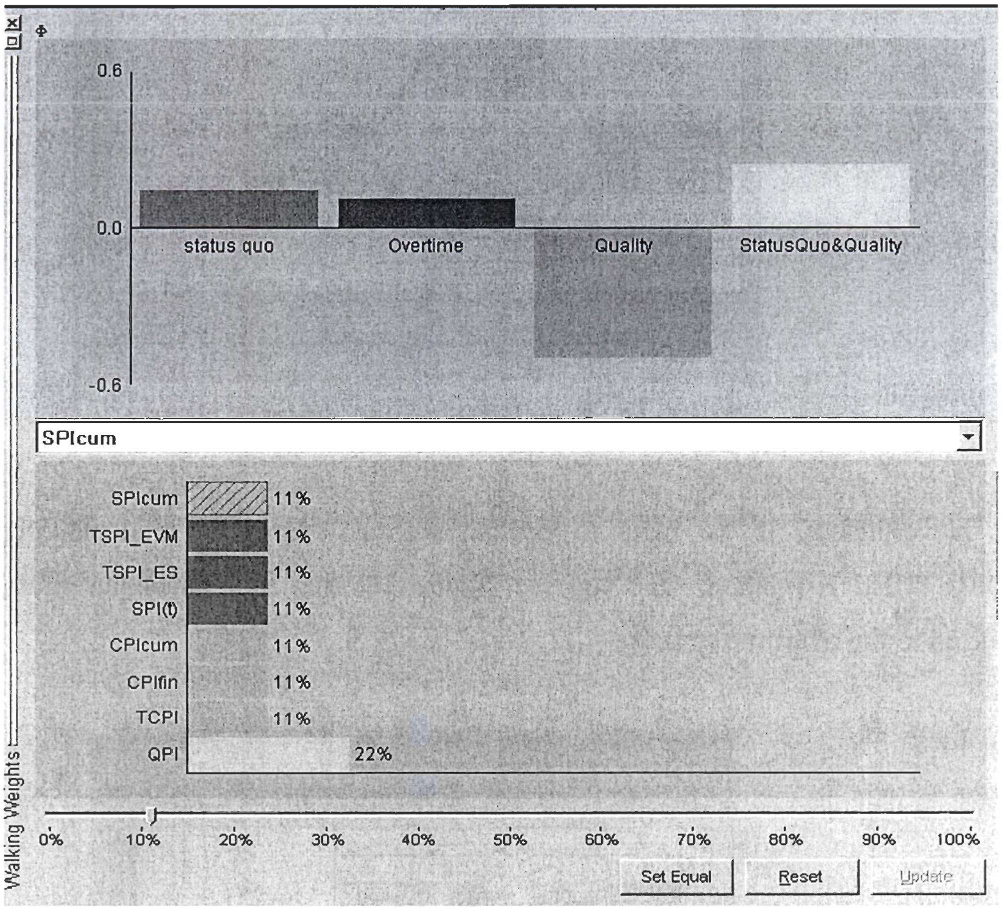


Figure 19. Walking weights for the basic indicators

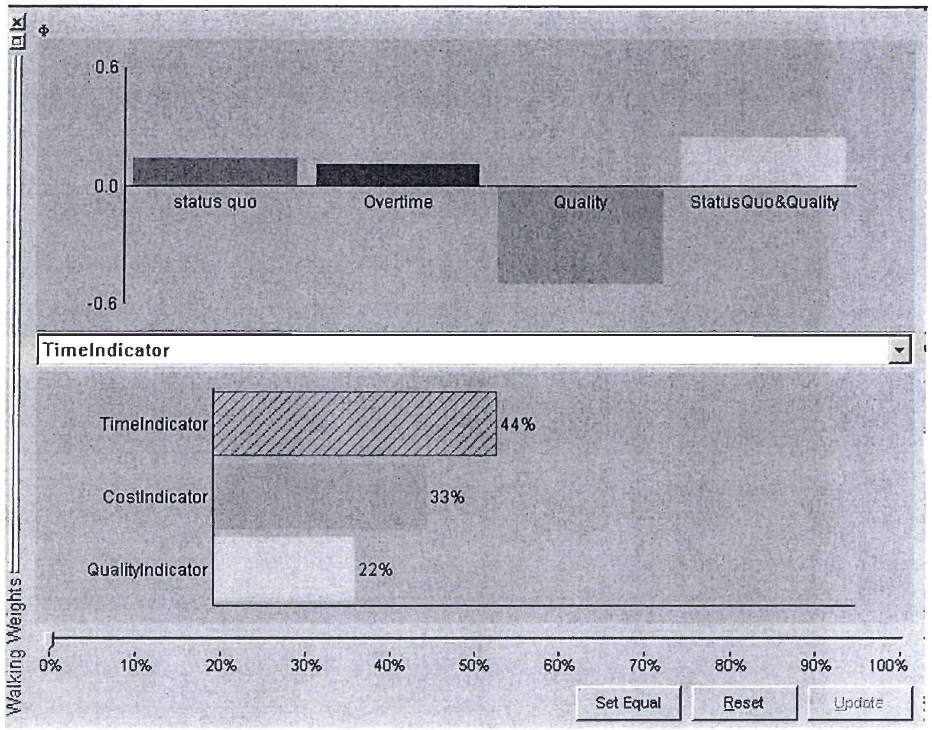


Figure 20. Walking weights for the aggregated indicators

One can see that if the project manager wants to give more importance to the time (aggregated indicator) so, the best compromise recovery action becomes the Overtime strategy (figure 21).

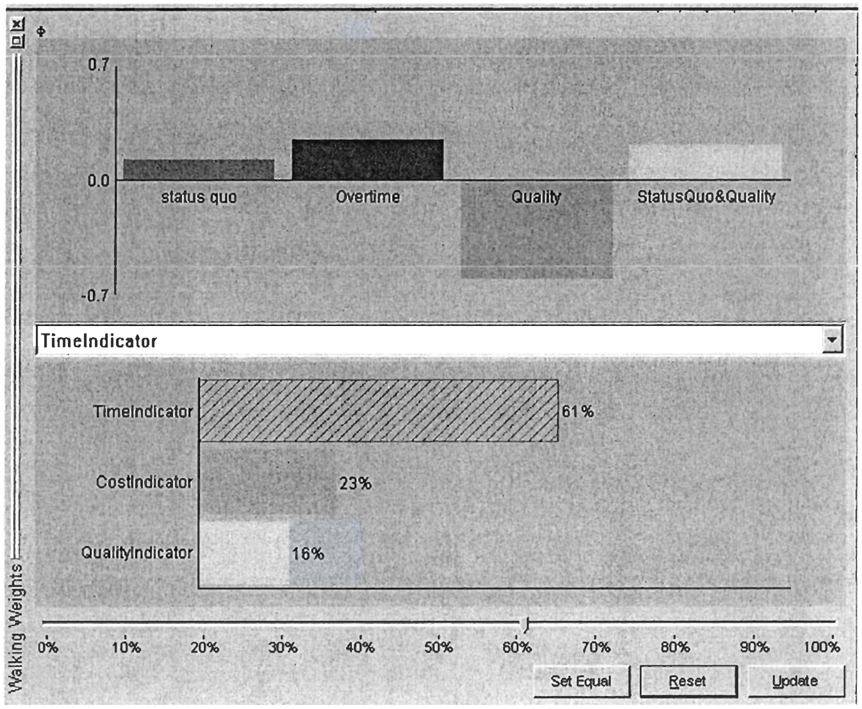


Figure 21. Sensibility to the time aggregated indicators

It's also possible to obtain the stability intervals for the aggregated indicators (Table 11) or for the performance indicators (Table 12).

Table 11. Stability intervals for the aggregated indicators

Stability Intervals

Stability Level: 4 first actions — AutoLevel

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
TimeIndicator	4.0000	0.0000	4.5604	44.44%	0.00%	47.70%
CostIndicator	3.0000	2.2854	9.0588	33.33%	27.58%	60.16%
QualityIndicator	2.0000	1.4923	6.1975	22.22%	17.57%	46.96%

To interpret these tables, we can conclude, from the table 11, that the ranking obtained in figure 18 would be the same if the weight of the aggregated time indicator has a value between 0% and 47.7%. In this case, we can also note that the ranking is not very stable because it will change for a little increase of the weight of this time indicator.

Table 12. Stability intervals for the performance indicators

Stability Intervals

Stability Level: 4 first actions ☑ AutoLevel

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
SPIcum	1.0000	0.0000	4.5604	11.11%	0.00%	47.70%
TSPI_EVM	1.0000	0.0000	1.4690	11.11%	0.00%	15.51%
TSPI_ES	1.0000	0.0000	1.4136	11.11%	0.00%	15.02%
SPI(t)	1.0000	0.0000	1.3723	11.11%	0.00%	14.64%
CPIcum	1.0000	2.2854	9.0588	11.11%	27.58%	60.16%
CPIfin	1.0000	0.5358	Infinity	11.11%	6.28%	100.00%
TCPI	1.0000	0.5108	Infinity	11.11%	6.00%	100.00%
QPI	2.0000	1.4923	6.1975	22.22%	17.57%	46.96%

Similarly, the most sensitive indicator seems to be SPI(t). In fact for a value of 16% for the SPI(t) indicator (figure 22) , the ranking (figure 23) is modified and for a value of 31%, the corrective action named Overtime (figure 24) becomes the best choice for the project manager.

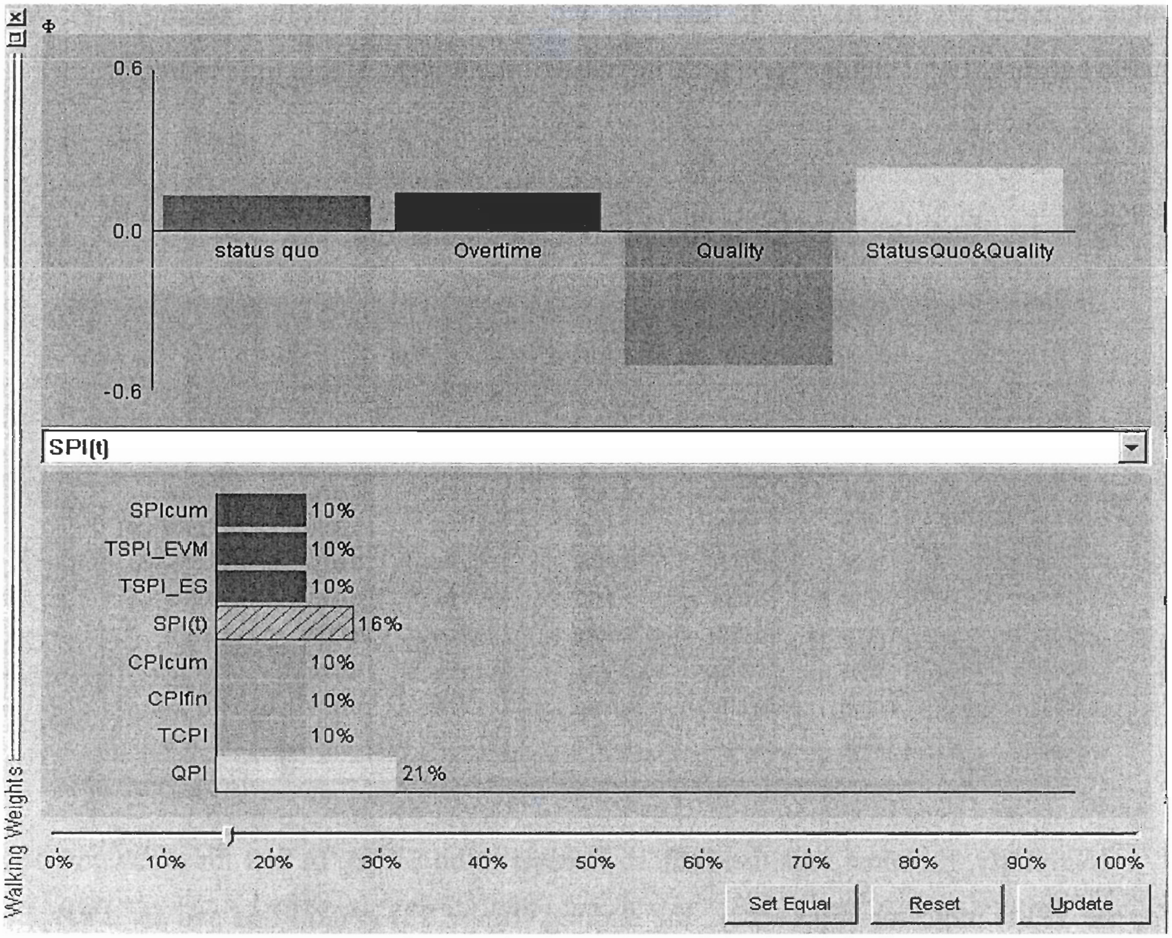


Figure 22. Change in the weight of the SPI(t) indicator

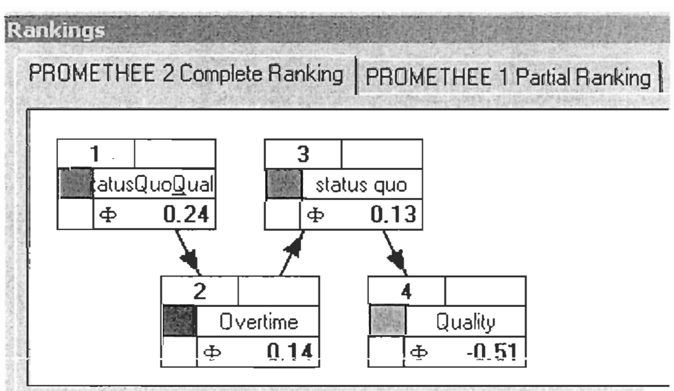


Figure 23. Ranking for weight of SPI(t) indicator = 16%

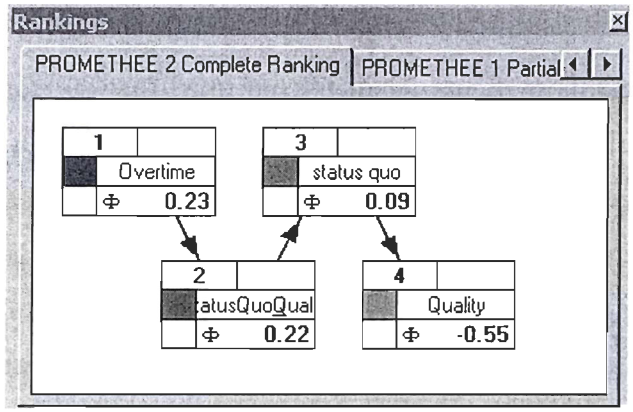


Figure 24. Ranking for weight of SPI(t) indicator = 31%

In addition to the representation of the alternatives and criteria, the projection of the weights vector in the GAIA plane corresponds to another axis Pi (the PROMETHEE decision axis in red) that shows the direction of the compromise resulting from the weights allocated to the different criteria. The project manager is thus invited to consider the corrective actions located in that direction.

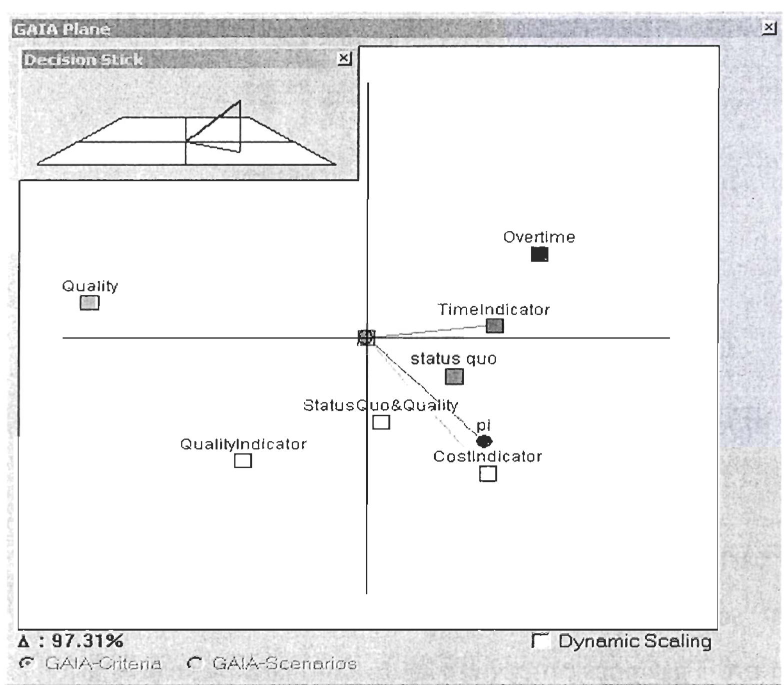


Figure 25. GAIA plane for weight of SPI(t) indicator = 16%

In the case of the weights in figure 22, it is confirmed that the corrective action 'Status Quo&Quality' is the best compromise (figure 25). When the weights are modified, the positions of the alternatives and the criteria remain the same and only the decision axis Pi is changing. The software allows using the weights vector as a *decision stick* to orientate the decision. For example, one can see that the decision axis is, in figure 26, near the corrective action 'Overtime'. It's not surprising because the weight of the dimension 'Time' is more important than before.

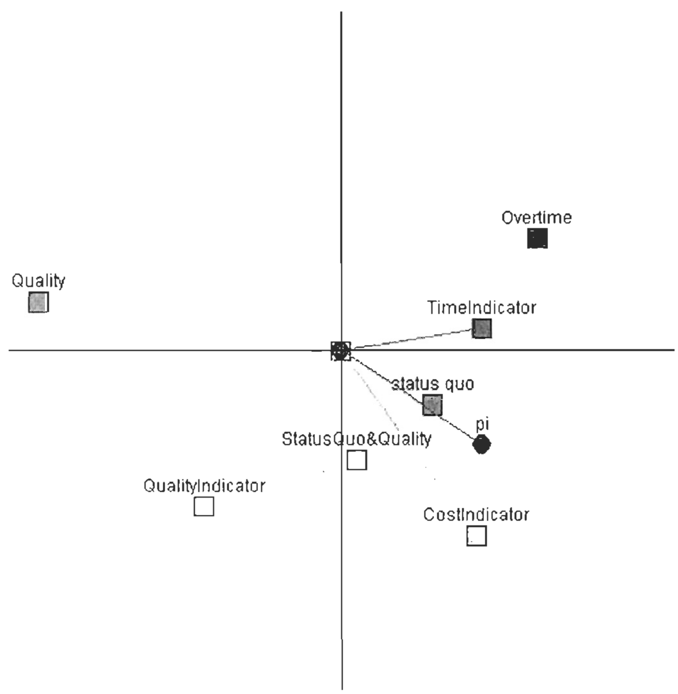


Figure 26. GAIA plane for weight of SPI(t) indicator = 31%

Decision-makers particularly appreciate this sensitivity analysis tool. Now, it's possible to generate different scenarios, each one representing a special combination of weights, thresholds and so on. That possibility permits to compare these scenarios and represents a first step through a robust analysis.

CONCLUSION

Our work takes place in the same trend, the same movement movement than the works of Binbin (2007) and Xu (2009) which consisted to develop a decision aid tool for the control and planning of project. These works focus on the integration of methods to assess project performance in planning and controlling phase or in implementing phase. However, to make a proper assessment of project performance is only the first step towards a better control of the project. The second step is to define and implement, if necessary, a set of corrective actions. Corrective action refers to an action taken to eliminate the causes of an existing nonconformity or other undesirable situation in order to re-align the project from the pre-specified direction it was intended to take. This new direction should be well-documented and should, upon execution, turn the project in a way such that it better aligns with the goals, expectations, and ultimate results laid out in the project management plan. To do that the project manager needs indicators that can specify where the project stands and where it goes if corrective actions are taken. To achieve this, a literature review on project performance indicators for the management of corrective actions has been realized in a first step. An original model that makes a link between a multidimensional analysis of project performance and type of corrective action strategy has been proposed. Finally, this model will be illustrated and discussed by a didactic example. Rather than using an approach based on a binary logic as the model proposed by Lipke (2003b), we opted for a multicriteria approach based on the PROMOTHEE method. That multicriteria approach permits to choose the 'best' corrective actions and it's, to our knowledge, the first paper in that aspect of corrective actions management. In a future research, it'll be interesting to develop a methodology to generate different corrective action so that our proposed decision aid methodology for corrective actions management.

Conclusion générale

Ce mémoire fait suite aux travaux de Binbin (2007) et de Xu (2009) visant à développer un outil convivial d'aide à la planification et au suivi de projet. Ces travaux se concentraient sur l'intégration de méthodes permettant d'évaluer la performance du projet tant dans la phase de planification que durant le suivi du projet lors de la phase d'exécution. Cependant, faire une bonne évaluation de la performance du projet n'est que la première étape vers un meilleur contrôle du projet. La seconde étape est celle visant à définir et mettre en œuvre, si nécessaire, un ensemble d'actions correctives. Cette dernière étape est énoncée dans le processus de suivi et contrôle de projet mais n'est pas supportée par une modélisation comme si cette gestion des actions correctives était trop contextuelle. Une action corrective est une action prise par le gestionnaire de projet dans le but d'éliminer les causes d'une non conformité ou d'une situation indésirable pour le projet. Une action corrective vise donc à réaligner le projet vers les objectifs qui avaient été spécifiés au début de celui-ci. Notre recherche a consisté à développer un modèle d'aide à la gestion des actions correctives. Pour y parvenir, une revue de littérature sur les indicateurs de performance des projets comme sur la gestion des actions correctives a été menée dans un premier temps. Une modélisation originale, permettant de faire un lien entre une analyse multidimensionnelle de la performance du projet comme d'autres considérations (possibilité d'avoir une stratégie de réaction, ..) et le type de stratégie d'actions correctives a alors été proposé. Plutôt que de recourir à un système d'aide à la décision reposant sur une logique binaire comme celui proposé par Lipke (2003b), nous avons choisi d'asseoir notre système d'aide à la décision sur une méthodologie multicritère du type PROMETHEE. Ce choix aurait pu être différent mais il ne remet pas en cause la méthodologie proposée. De fait, on aurait tout aussi bien pu choisir la méthode multicritère de rangement ELECTRE II, voire la méthode de choix ELECTRE I. Nous pensons que la méthodologie présentée est suffisamment compréhensible pour être adoptée par les gestionnaires de projet. La possibilité de procéder à des analyses de sensibilité nous apparait être un aspect particulièrement utile pour les gestionnaires de projet. Enfin, et cet aspect a été éludé dans cette recherche, pour choisir une action corrective, il faut disposer de plusieurs actions correctives intéressantes. Dans une recherche future, nous pensons qu'il serait intéressant, à une date de mise à jour donnée, de disposer d'une méthodologie de génération d'un ensemble d'actions correctives pertinentes. Notre outil deviendrait alors un élément indispensable à une véritable méthodologie de gestion des actions correctives.

ANNEX

Annex 1: The Principle of Earned Value

Actually, the foundational principles of earned value management borrow the statistics method and use the intermediate variable to set up a managerial model. The deduction as follow,

$F = P \times Q$,

Where F is a variable, P is a price variable, and Q is a quantity variable.

While, we have the following formulas,

$F_0 = P_0 \times Q_0$, we assume F_0 is planned value here.

$F_1 = P_1 \times Q_1$, we assume F_1 is actual cost here.

Where P_0 is a planned value of price variable, and Q_0 is a planned value of quantity variable; where P_1 an actual value of is price variable, and Q_1 is an actual value of quantity variable,

Meanwhile, we induct another intermediate variable $P_0 \times Q_1$, which is marked F_e. If we use F_e minus F_0, the difference will be $(P_0 \times Q_1) - (P_0 \times Q_0) = P_0(Q_1 - Q_0)$; if we use F_e minus F_1, the difference will be $(P_0 \times Q_1) - (P_1 \times Q_1) = Q_1(P_0 - P_1)$. Actually, the two differences represent the schedule variance and cost variance respectively.

Annex 2: The Principle of Earned Schedule

Actually, the method of calculation ES used the mathematical concept named liner interpolation between tow know points, the basic principles are shown in Figure 6,

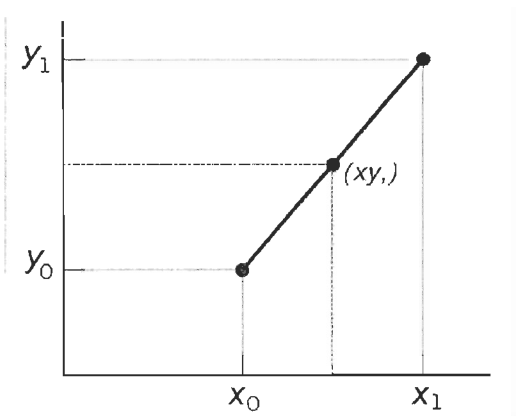


Figure 27. linear interpolation between tow know points

If the two know points are given by the coordinates (x_0, y_0) and (x_1, y_1) and the linear interpolate is straight line between these points. For a value of x in the (x_0, y_1), the value y along the straight line is given from the quotation as follow:

$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0}$, solving the equation for y, it gives y as follow:

$$y = y_0 + (x - x_0)\frac{y_1 - y_0}{x_1 - x_0}$$

Kym Henderson (2007)[25] also gave the interpretation during his presentation, which was illustrated in the Figure 7 as follow:

[25] Walt Lipke & Kym Henderson, *Earned Schedule, something new for EVM and schedule analysis,* 2007 http://www.earnedschedule.com/Presentations.shtml

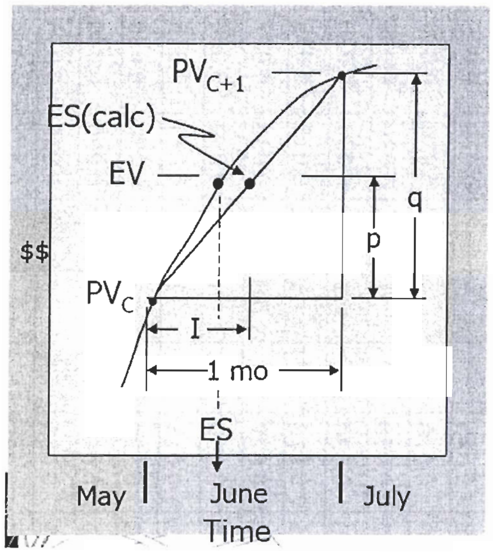


Figure 28. Interpolation Calculation

It is clearly form the Figure 7, we can get the following equations,

I/1mo=P/q

I=(p/q)*1mo

P=EV-PV_c, while q=PV_{c+1}-PV_c

So, $I = \frac{EV - PV_C}{PV_{C+1} - PV_C} \times 1mo$

In that case, $EV_{cum} = C + \frac{EV - PV_C}{PV_{C+1} - PV_C}$

Annex 3 : Quality f the possible strategies

	Status quo					Overtime					Quality						Status quo&Quality		
Phi1	Phi2	Phi3	QATR	QCTR	Phi1	Phi2	Phi3	QATR	QCTR	Phi1	Phi2	Phi3	QATR	QCTR	Phi1	Phi2	Phi3	QATR	QCTR
1			0,020	0,020	1			0,020	0,020	1			0,020	0,020	1			0,020	0,020
1			0,010	0,010	1			0,010	0,010	1			0,010	0,010	1			0,010	0,010
1			0,020	0,020	1			0,020	0,020	1			0,020	0,020	1			0,020	0,020
1			0,020	0,020	1			0,020	0,020	1			0,020	0,020	1			0,020	0,020
1			0,010	0,010	1			0,010	0,010	1			0,010	0,010	1			0,010	0,010
1			0,020	0,020	1			0,020	0,020	1			0,020	0,020	1			0,020	0,020
1			0,020	0,020	1			0,020	0,020	1			0,020	0,020	1			0,020	0,020
1			0,010	0,010	1			0,010	0,010	1			0,010	0,010	1			0,010	0,010
1			0,020	0,020	1			0,020	0,020	1			0,020	0,020	1			0,020	0,020
0,9	0,8		0,050	0,042	0,9	0,8		0,050	0,042	0,9	0,8		0,050	0,042	0,9	0,8		0,050	0,042
1	1		0,025	0,025	1	1		0,025	0,025	1	1		0,025	0,025	1	1		0,025	0,025
	1		0,030	0,030		1		0,030	0,030		1		0,030	0,030		1		0,030	0,030
	1		0,030	0,030		1		0,030	0,030		1		0,030	0,030		1		0,030	0,030
	1		0,030	0,030		1		0,030	0,030		1		0,030	0,030		1		0,030	0,030
	1		0,015	0,015		1		0,015	0,015		1		0,015	0,015		1		0,015	0,015
	0,9		0,030	0,027		0,9		0,030	0,027		0,9		0,030	0,027		0,9		0,030	0,027
	1		0,030	0,030		1		0,030	0,030		1		0,030	0,030		1		0,030	0,030
	1		0,015	0,015		1		0,015	0,015		1		0,015	0,015		1		0,015	0,015
	1		0,030	0,030		1		0,030	0,030		1		0,030	0,030		1		0,030	0,030
		0,8	0,050	0,040			0,8	0,050	0,040			0,8	0,050	0,040			0,8	0,050	0,040
1		1	0,035	0,035	1		1	0,035	0,035	1		1	0,035	0,035	1		1	0,035	0,035
		1	0,025	0,025			1	0,025	0,025			1	0,025	0,025			1	0,025	0,025
		1	0,025	0,025			1	0,025	0,025			1	0,025	0,025			1	0,025	0,025

	0,8	0,8	0,115	0,092		0,8	0,8	0,115	0,092		1	1	0,107	0,107		1	0,9	0,115	0,105
		1	0,050	0,050			1	0,050	0,050			1	0,050	0,050			1	0,050	0,050
1		1	0,110	0,110	0,9		0,8	0,110	0,089	1		1	0,000	0,000	0,9		1	0,110	0,109
	1	0,9	0,155	0,143		0,9	0,9	0,155	0,140		1	1	0,000	0,000		1	1	0,155	0,155
			1,000	0,944				1,000	0,920				0,727	0,706				1,000	0,968
			IPQ=	0,9435				IPQ=	0,9195				IPQ=	0,9711				IPQ=	0,9680

Annex 4: Performance indicators of the recovery strategies

CBTE	CBTP	CRTE	Coût	Recovery strategy	TCPI	CPIcum	SPIcum	EV%	TSPI_EVM	SPI	CPI	tcpical	ES%	Es	TSPI_ES
19 184,00	20 880,00	19 010,00	22 970,00	Overtime	0,96	1,009	0,9188	0,8385	0,8091	0,97	0,990	1,123	0,76	285	0,8846
18 986,67	20 880,00	19 010,00	23 690,00	Quality	1,01	0,999	0,909	0,8298	1,6143	0,86	0,960	1,297	0,74	280	1,3964
19 184,00	20 880,00	19 010,00	22 730,00	Status quo	0,96	1,009	0,919	0,8385	1,1568	0,91	1,010	0,986	0,76	285	1,1331
19 101,33	20 880,00	19 010,00	22 750,00	scenarQualiOrigin	0,98	1,005	0,915	0,8348	0,9933	0,93	1,010	0,965	0,75	283	1,0244

Annex 5: the PROMETHEE method

La méthode PROMETHEE de Brans et Vincke (1985) relève de la problématique de rangement P(γ). Cela consiste à poser le problème en termes de rangement des actions, c'est-à dire à orienter l'investigation vers la mise en évidence d'un classement défini sur un sous-ensemble de l'ensemble des actions (A).

Cette problématique prépare une forme de recommandation visant à indiquer un ordre partiel ou complet portant sur des classes regroupant des actions jugées équivalentes. La méthode PROMETHEE vise à construire une relation de surclassement valuée en s'appuyant sur la comparaison des actions deux à deux dans le but de ranger les actions de la meilleure à la moins bonne.

Construction de la relation de surclassement valuée

Pour chaque critère (j), on dispose d'un poids w_j proportionnel à son importance relative et on calcule pour chaque couple (a,b) d'actions de l'ensemble des actions A, le degré de surclassement de l'action a sur l'action b par :

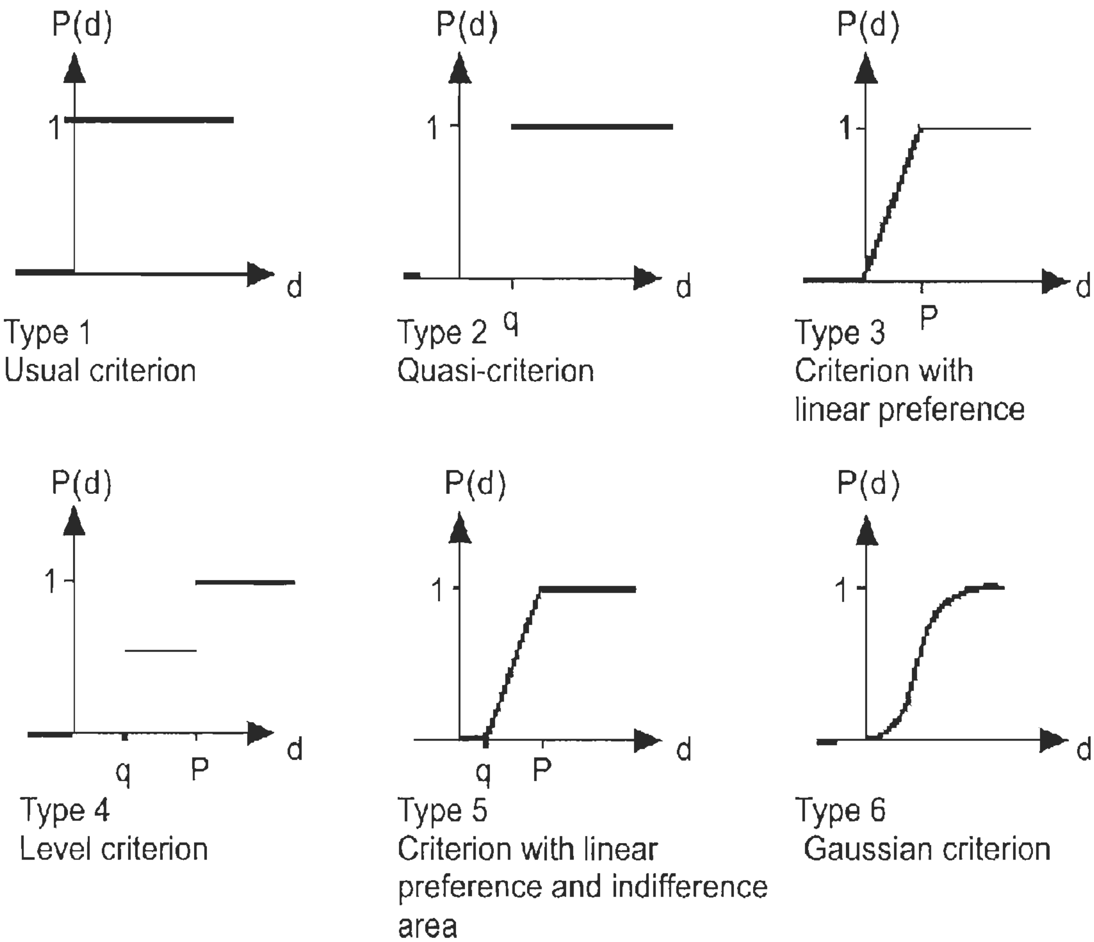
$$\pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j,$$

où $P_j(a,b)$ est un nombre compris entre 1 et 0 et qui est d'autant plus grand que $g_j(a)$-$g_j(b)$ est grand et nul si $g_j(a) \leq g_j(b)$. Concrètement, on calcule $P_j(a,b)$ de la manière suivante :

$$P_j(a,b) = F_j\left[d_j(a,b)\right] \quad \forall a,b \in A,$$

$$d_j(a,b) = g_j(a) - g_j(b)$$

Pour estimer les $P_j(a,b)$, on propose au décideur de choisir, pour chaque critère, une des six formes de courbes qui suivent. En fonction de la manière dont sa préférence croît avec l'écart $g_j(a)$- $g_j(b)$, le décideur fixe donc, pour chaque critère, la forme de P_j et le(s) paramètre(s) associé(s). Les paramètres à estimer ont une interprétation simple puisque ce sont des seuils d'indifférence et de préférence; pour la 6^{éme} forme proposée, le paramètre à estimer est l'écart-type d'une loi gaussienne.



Exploitation de la relation de surclassement valuée

Deux préordres totaux peuvent être établis à partir du calcul de la matrice représentant la relation de surclassement : l'un consiste à ranger les actions dans l'ordre décroissant des nombres $\Phi^+(a)$ tels que :

$\Phi^+(a) = \sum_{b \in A} \pi(a, b)$ (flux sortant)

Et l'autre dans l'ordre croissant des nombres $\Phi^-(a)$ tels que

$\Phi^-(a) = \sum_{b \in A} \pi(b, a)$ (flux rentrant).

PROMETHEE I établit son rangement en cherchant l'intersection de ces deux préordres totaux afin d'obtenir un préordre partiel.

Par définition, on dira que

- l'action a surclasse l'action b si :

$\Phi^+(a) > \Phi^+(b)$ et $\Phi^-(a) < \Phi^-(b)$, ou

$\Phi^+(a) > \Phi^+(b)$ et $\Phi^-(a) = \Phi^-(b)$, ou

$\Phi^+(a) = \Phi^+(b)$ et $\Phi^-(a) < \Phi^-(b)$, ou

- l'action a est indifférent à l'action b si :

$\Phi^+(a) = \Phi^+(b)$ et $\Phi^-(a) = \Phi^-(b)$

- l'action de a est incomparable à l'action b si :

$\Phi^+(a) > \Phi^+(b)$ et $\Phi^-(a) > \Phi^-(b)$, ou

$\Phi^+(a) < \Phi^+(b)$ et $\Phi^-(a) < \Phi^-(b)$, ou

Quant à la méthode PROMETHEE II, elle range les actions dans l'ordre décroissant des nombres $\Phi(a)$ tels que :

$\Phi(a) = \Phi^+(a) - \Phi^-(a)$

Et donc l'action a surclasse l'action b $\Phi^+(a) > \Phi^+(b)$ et les actions a et b sont indifférentes si $\Phi^+(a) = \Phi^+(b)$. On génère dans ce cas un rangement complet, c'est-à-dire sans incomparabilité.

Le principal mérite de cette méthode est d'intégrer de façon très simple les idées récentes de la modélisation des préférences. Néanmoins, comme pour les autres méthodes de surclassement, il lui manque la base théorique qui permettrait de mieux apprécier les hypothèses implicites sur lesquelles elle repose.

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