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A MULTI-DIMENSIONAL MODEL FOR PROJECT PERFORMANCE ANALYSIS

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ABSTRACT: *Despite significant research on both project management and project performance assessment, there is no consensus about a universal method to control project performance. We could use a different approach for each project. Most project managers exclusively focus their control efforts on the elementary component of the "Iron Triangle": Cost, Time, Quality. Furthermore, in most cases, comparing results to preliminary objectives is the only way to "evaluate" performance level. According to the standards of the International Standardisation Organisation and the Project Management Institute, we propose a Project Performance Measurement System (PPMS) to assist project managers in project performance controlling. This PPMS is based on three main dimensions of project management: uniqueness of each project, universality of project management scope and the dynamics of the project. This is represented in a performance cube. We use a tool from Business Process Management (BPM) to analyse the performance of the project process: the Performance Triptych: Effectiveness, Efficiency, Relevance. After dimensioning the cube according to project specificities and choosing and balancing the Performance Indicators, the MACBETH method is finally used to aggregate the performance expressions. A real project management case study situation is finally proposed to illustrate the purpose.*

KEYWORDS: *Project Performance, Performance Measurement System, Project Management, Multiple Criteria Analysis*

1 INTRODUCTION

Everything is project! Although excessive, this sentence could describe the passion that companies carry to project management without distinction between project management and operational management of tasks. Project management can be viewed as a guarantee of success. Consequently, as a project manager, you have to ensure the project performance. But, a project is intrinsically unique and subject to its environment (Zwikael, 2005). In this condition, to give a clear and accurate definition of the performance of your project is probably one of the most important actions you can take to ensure this success. Indeed, you have to clarify in the minds of the project team and service managers what are the essential benefits that the project will deliver. The clearer the target, the more likely you are to hit it.

But how to define this target? And how to be sure that you control the project performance according to this target?

Performance is a key part of Project Management. It makes reference to the completion of pre-established objectives (ISO, 2003) and so to the assessment of potential divergence from these objectives. To implement such a strategy, project managers need to define a system which provides relevant dashboards that help them monitoring and scoring project results. This knowledge will enable them to track trends based on Key Performance Indicators (KPIs), to make decisions in order to optimize the way they work on the one hand, and to guarantee the final result on the other hand.

For many project managers, the "Iron Triangle" - Time, Cost and Quality - defines the performance dimensions of a project. According to this idea, many project managers only use these three criteria. However, other success criteria should be considered in order to incorporate local project specificities (Atkinson, 1999). Moreover, analyzing the performance of a project in accordance with all these dimensions could become a very complex thing.

The purpose of this paper is finally to propose a project performance model suitable for design a Project Performance Measurement System (PPMS) that can consolidate all the good practices in terms of project performance.

The paper comprises four main sections: first, a bibliographical study to identify good practices in terms of performance management in a project context. Second, the problem under study is described on the basis of this literature review. Third, our model of project performance is presented and implemented in a PPMS. Fourth, a real-life case study based on the MACBETH method is developed to illustrate our proposition. Finally, some conclusions and areas for discussions are presented.

2 LITERATURE REVIEW

Performance evaluation is used either to design/modify a system, or to control an existing system. We speak of *a priori* or *a posteriori* evaluation respectively, either to help decision-making or to evaluate the quality of the most recent decisions. In this study, we focus on an *a posteriori* performance evaluation of a particular system, a project in this case.

2.1 Dimensions of Project Performance

Project is unique and limited over time. Projects have a unique content and unique scope. Each Project differs from others regarding its goals, activities (tasks), resources and deliverables. According to Yu Angus (2005), different project definitions might warrant different success criteria. In other terms, "the Iron Triangle" is not sufficient to cover all the particularities of each project. So, each project manager has to develop her/his range of KPIs. But can the relevance of these choices be certified?

According to Swink (2005), the effectiveness of a project is the degree to which the managers of the project make use of techniques which improve the efficiency of project execution. Critical success factors can be described as characteristics, conditions, or variables that can have a significant impact on the success of the project when properly sustained, maintained or managed (Milosevic and Patanakul, 2005). Dweiri and Kablan, (2005) claim that standard performance management metrics and tools impact standard performance management methodology, which in turn influence project success. Classically, the standard performance management metrics are composed of cost, time and quality performance indicators, the "Iron Triangle". However, Atkinson (1999) shows that using the "Iron Triangle" as the criterion of success is not optimal. Something is missing, the system is not as good as it could be. Many authors as Grey (1995) or Pritchard (1997) advocate using a risk assessment report to complete a Project Performance Management System. This report provides the information needed to start any actions for the correction of potential problems.

Dweiri and Kablan (2005) show that project management activities using only time, cost or quality measures may fall through the gaps. Consequently, areas covered by performance management must be as complete as possible. The PM Body Of Knowledge proposes nine essential knowledge areas and management areas to describe project management (Project Management Institute, 1996). A complete project management dimension is defined:

- Project Integration: ensure that the various elements of the project are properly coordinated;
- Project Scope: ensure that the project includes all the work required to complete the project successfully;
- Project Time: ensure timely completion of the project;
- Project Cost: ensure that the project is completed according to the approved budget;
- Project Quality: ensure that the project will satisfy;
- Project Human Resource: make the most effective use of the people involved with the project;
- Project Communications: ensure timely and appropriate generation, collection, dissemination, storage and ultimate disposition of project information;
- Project Risk: identity, analyse and response to project risk;
- Project Procurement: acquire goods and services outside the performing organization.

2.2 Aggregation and Stakeholders Needs Regarding Project Performance

Each KPI should be examined separately and then in related groups of indicators (Pritchard, 1997). Analysts such as project manager, task leader or senior manager must simultaneously consider all these factors.

2.2.1 Disparate Measurement Systems

Dweiri and Kablan (2005) note that disparate measurement systems may result in superfluous and incompatible performance measurement frameworks. There is a need for project managers to quantify performance as a whole and to be able to drill down to different measurements at different levels of detail and time. Consequently, any project performance evaluation supposes the need to analyze the measurements taken, whatever the dimensions. It is a question of considering the impact of each component of a performance. Dweiri and Kablan (2005) propose a fuzzy decision making system to quantify a global project management internal efficiency. Some authors, such as Xiaoyi Dai and Wells (2004), rather develop a consensus for determining project failure rather than considering the multiple dimensions for evaluating project performance. As the majority of existing project performance measurement tools focus on financial aspects such as the return on investment and profit per unit, they argued that financial parameters are useful, but there are inadequacies, such as lagging metrics, a lack of strategic focus, and a failure to provide data on quality, relationships, and the environment (Cheung, 2004). In addition they do not permit the production of aggregated indicators to control projects. In fact, as (Clivillé, 2004) points out, as soon as managers use more than one KPI, problems of comparison and aggregation of the performance expressions will exist. Thus, they have to ensure that:

- these expressions are interpretable in the same way by the entire control system: commensurability;
- mathematical operations carried out on these expressions are coherent: meaningfulness.

2.2.2 Different Views on Project Performance

Rosenau and Githens (2005) emphasize the trend for project managers to try to circulate a single report between many different recipients. They explain that this is a mistake as senior management will look for summary status and forecast data, whereas middle managers will look for more specific and tailored information on operational details. They stress on the necessity to have a system of KPIs which allows visibility of performance at different levels as well as ensuring coherence between these views. Milosevic and Patanakul (2005) affirm that measures of project success need to include the diversity of stakeholders' interests. This is the principal value of indicators aggregation: to provide an immediate and global overview of the project interpretable by an entity not conversant with the details of activities.

2.3 Project Performance Analysis as Business Process Analysis

The International Organization for Standardization (2003) defines a project as "a unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements." This definition assimilates projects to business process. From this standpoint, we can associate Project Management with Business Process Management (BPM). This allows standard business process Performance Measurement Systems (PMS) to be extend to project management.

A large number of these standards relates to measures needed to capture the relevant characteristics of activities that compose business processes. We can cite the Holistic Process Performance Measurement System, the Integrated Dynamic Performance Measurement System, Earned Value Added, the Fraunhofer approach, or more basically, the Activity Based Costing / Management, and the Supply Chain Operations Reference model (Bourne *et al.*, 2003). According to this idea, project tasks should be assimilated as business process activities. Each task can be described into input(s), output(s), resource(s) and control(s) as described by IDEFO.

Finally, PMS can be defined as the set of metrics, or performance measures, used to quantify both the efficiency and the effectiveness of actions (Nelly et *al.*, 1996). Performance evaluation supposes the need for tools to analyze the measurements taken according to these two dimensions of efficiency and effectiveness. It is a question of considering the impact of each component of the performance. Basically, BPM analysis adds a third component: Relevance. The performance analysis could then be made with an approach based on Relevance, Effectiveness and Efficiency (REE) dimensions (Jacot, 1990). REE compares the objectives-results-resources of a business activity (in our case, a project task), and comprises a triptych that aims to describe an activity performance (Figure 1). Effectiveness measures whether the results of the activity meet the objectives. Efficiency expresses whether the resources were well used to attain the results. Relevance measures the adequacy of the means to the objectives.

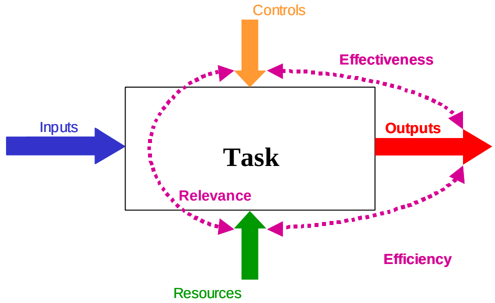


Figure 1. Performance Triptych

3 PROBLEM UNDER STUDY

In this paper, we address the problem of modelling project performance in order to be able to design a relevant Project Performance Management System (PPMS). The quantity and diversity of academic research works testify to the difficulty of building a universal model to tackle the question of project performance. Nevertheless, several good practices for the design of a PPMS can be extracted from this literature review (Figure 2):

- project performance has to take into account the *uniqueness* of each project;
- project performance must consider the *dynamic* of a project (lifecycle, risks…);
- project performance must consider some *universal* dimensions of project management, for instance measuring performance with the nine knowledge areas defined by the PMI.

Finally, this PPMS has to permit an analyze of the performance in terms of Relevance, Effectiveness and Efficiency triptych.

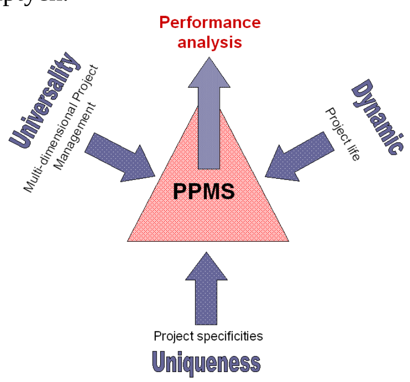


Figure 2. Good Practices to Design a PPMS

Moreover, the bibliography study has shown that project performance has to be adapted to the different project stakeholders. Consequently, PPMS must allow KPIs to be *aggregated* regardless their dimension**.**

4 MODEL PROPOSITION: PROJECT PERFORMANCE CUBE – P^CUBED

4.1 Project Performance Unicity: The Task Control

The first dimension focuses on the main phase of breaking down the project tasks. This is based on work packages defined by the Work Breakdown Structure of the project. Work packages represent the fundamental units of the project that the project manager has to manage. Rosenau and Githens (2005) stress the fact that the size of a work package depends on the control needs. So, this dimension of the analysis could be broken down into several detail levels from main activities to elementary tasks. In a very complex project, we could also imagine only analyzing tasks on the critical path (according too many measures to control).

Followed tasks are not fixed for the entire project. The project manager has to take into account the project dynamic. It will has to remove or insert tasks in order to ensure relevance of performance management.

4.2 Project Performance Dynamic: The Control Theory

Concretely, to facilitate the analysis of information associated with each category of indicators relating to a given period, we suggest, as the second dimension: the project performance dynamic. As we consider the dynamic of the project, we have to consider the performance evolution in time: the following three criteria of analysis (particular score could be specified on a continuous scale in order to qualify the value of these criteria):

- *State (S_t):* defines the position compared to a preset objective. Three particular values for the expression of the performance could be expressed as: problem, conform or good;
- *Evolution (E_t):* determines the speed of change on a scale. Three particular values for the expression of the performance could be expressed as: decline, equal or growth;
- *Trend (T_t):* characterizes the acceleration of this change. Also three particular values for the expression of the performance could be expressed as: retreat, stable or progress.

Actually, project management is a complex system which is not easy to monitor globally. So, the third dimension must be directly associated to the concept of performance management. It characterizes the activities which make it possible to control and guide the operation and the evolution of a project. This kind of management is based on three fundamental concepts: The evaluation, the control (consideration of the objectives) and the regulation (maintenance of the system within the limits of the preset framework). We propose to support these concepts by analogy, (Lauras *et al.*, 2006) as follows:

- *Evaluation:* collection of indicator's values and analyze their "position" (in comparison with reference values at a given date). This defines the state of the system, and allows to analyze, if necessary, the cause of a failure or a success.
- *Control:* analyzing the "trend" (variation of the indicator between two dates) and the "rate of evolution" (variation of the trend) of the indicators, helps understand the dynamics of the system and in particular the impact of the actions undertaken. This consists in identifying a deterioration or improvement of the global project performance.
- *Regulation:* the preceding analysis enables us to consider the control of action plans committed and to define new ones, whether there is a particular need.

Since our study considers complex projects which have a long execution time, we can make the hypothesis that the project status between two periods of time could be compared. Therefore, we must consider a second hypothesis which supposes that we can associate each elementary performance indicator with an objective (whatever the dimension of the indicator). This hypothesis can be considered valid because everything should be associated to a particular request in a project, normally writing specified (Bonnal, 2002).

4.3 Project Performance Universality: PMI Knowledge Areas and BPM Analysis Axes

4.3.1 Multi-dimensional Project Management

According to Westerveld (2003), the PMI's definition of project management is unclear and it is difficult to link areas and project situations. However, if we consider the project as a business process as defined by the ISO 10006:2003 standard, it becomes possible to break the project into activities (tasks). We could then apply the PMI's nine areas to each task. The nine areas appear as nine points of view we take of the activity being considering. In our case, we could apply this breakdown to tasks which appear in the Project Work Breakdown Structure (WBS). In other words, we can associate nine *characters* with each task. These nine points of views define a set that we call character set C.

By definition, this KPI's framework allows to reach all aspects of project management to be reached. Of course, we should underline that independence between each character is not total. However, the aim is not to produce a single reduced evaluation of the project, but to control it. If our evaluation is exclusively time and cost centred, we cannot immediately know the origin of a deviation in the performance level. Having a complete vision of all aspects of the project allows faster and better targeted corrective actions.

4.3.2 Performance Analysis

We define:

- D, the set of project review dates. There are R review dates during the project. One review date, t, belongs to D=[1; R] ($R \in \mathbb{N}^*$)
- C, the set of the characters (time, cost, etc.). We can analyze the performance of 1 to m characters. One character, I, belongs to C=[1; m] ($m \in \mathbb{N}^*$)
- T, the set of the tasks. There are n tracked tasks in the project. One task, k, belongs to T=[1; n] ($n \in \mathbb{N}^*$)

Each project task can be modeled as an activity with its inputs, outputs, resources and controls. These tasks represent the operational and support processes of a project. At a given $t \in D$, we can analyze the state of the task $k \in T$ with the character $i \in C$:

$$D \times T \times C \rightarrow KPI$$
$$\text{date (t), task(k), character(i)} \mapsto S(t,k,i) = \{E_{ft}; E_{fc}; R_{vc}\}$$

Effectiveness (E_{ft}), Efficiency (E_{fc}), Relevance (R_{vc}) are not obligatory quantitative values. They could be qualitative or even equal to an empty set. Another function E_{xt} can be defined. This allows one particular element to be extracted from the triptych:

$$KPI \times \{1,2,3\} \rightarrow E$$
$$S(t,k,i) \times p \mapsto E_{xt}(S,p) = \begin{cases} E_{ft} \text{ if } p=1 \\ E_{fc} \text{ if } p=2 \\ R_{vc} \text{ if } p=3 \end{cases}$$

The task k^i is then observed using the three views of the triptych {Relevance; Effectiveness; Efficiency}. For one j, i.e. one view ($j \in [1; 2; 3]$), the manager defines 0 to L^{kij} metrics to measure the performance. L^{kij} is a parameter previously defined for all kij. For each j, i.e.; each view, we have a vector with $L^{kij} \times 1$ dimension. This is resumed in Figure 3.

$$E \times N \rightarrow L$$
$$E_{xt}(S,p), l \mapsto E^l_{xt}(S,j)$$

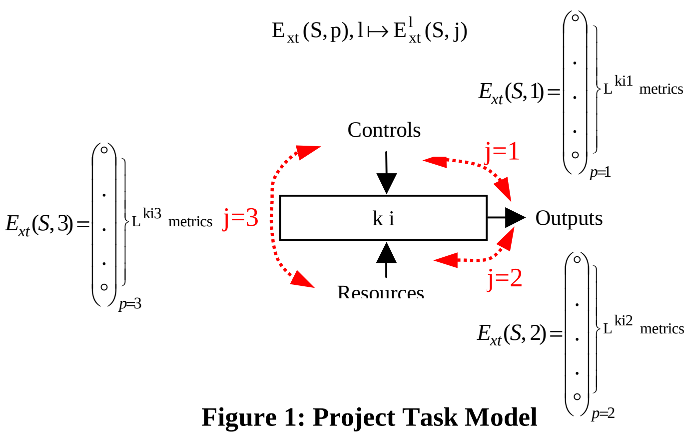


Figure 1: Project Task Model

One KPI is defined by the triptych {Relevance; Effectiveness; Efficiency}. According to the way that each view of triptych is built, one KPI will not be a 1×3 dimension matrix but a Max $L^{kij} \times 3$ dimension matrix.

4.4 The Project Performance Cube

All the performance measures of a project can be arranged into a cube defined by the three dimensions cited previously (Lauras and Gourc, 2007). A cell of this cube includes the KPIs of a given project activity (task), considering a given character (knowledge area), and having the same temporality (Figure 3). As an example, we can consider a cell that corresponds to the Task "To Design product A", considering the "Time" character and the "State" Temporality.

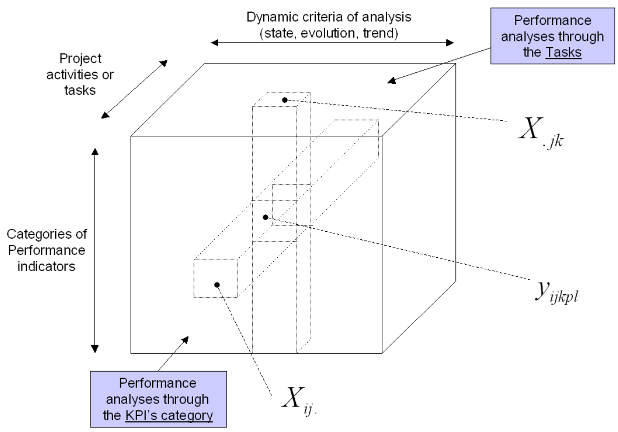


Figure 4. Principle of Construction of the Performance Cube

Let:

- i = Categories of Performance Indicators, [1 ; m]
- j = Dynamic criteria of analysis [1 ; p] (here p=3)
- k = project activities or tasks [1 ; n]
- p = number of KPI dimensions [1 ; q] (here q=3)
- l = number of the value of the elementary component of a KPI [0 ; L^{kij}] ($L^{kij} \in \mathbb{N}$)
- y_{ijkpl} = measure associated to a elementary component of a KPI
- X be a KPI on a cube's face

Implementation of the performance cube model comprises three main steps:

1. scaling the cube to the project dimension. This step defines the task dimension;
2. parameterizing the cube to reflect the performance management choice. This step adjusts the KPI categories dimension. We have to consider that the definition of the categories depends on the point of view chosen. Actually, two different ways must be considered. Either the project performance is split up in 9 characters and then 3 analysis dimensions are considered for each character or the project performance is split up in 3 analysis dimensions and 9 characters are considered for each dimension. With the previous notation, m = 9 and q = 3 in the case of characters and m = 3 and q = 9 in the triptych case;
3. using the cube from the starting date of the project. We exploit the dynamic dimension.

4.5 Project Performance Control with the cube: The Aggregation Process

As explained previously, the cube objective consists in supporting decision makers in terms of project performance control. To achieve this target, we have stressed the necessity to produce different analysis reports that include different points of view and levels of granularity. The multi-dimensional property of the model allows this.

4.5.1 Cube Aggregation Structures

KPIs can be aggregated from different angles. In fact, each project stakeholder should be able to interpret the model from her/his point of view. For example, senior management should be interested in a greater aggregation (for instance, a unique value for judging project performance) than the project manager, who will concentrate her/his analysis on task or character performance. Consequently, aggregation methodology must be adapted to the different actor's points of view. According to previous cited constraints, we have constructed three different ways of aggregating the cube values (Figure 5):

- tasks-oriented;
- characters-oriented (9 PMI's areas);
- triptych-oriented (E_{ft}, E_{fc}, R_{vc}).

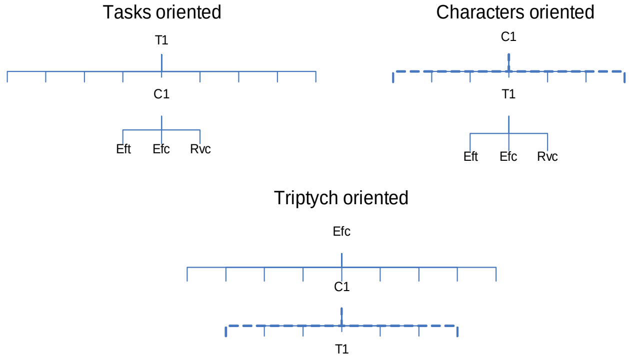


Figure 5. Cube Aggregation Tree Structures

T1,…Tn are project tasks. C1,…C9 are the nine characters. These three aggregation orientations don't have the same interest for all members of the project (Table 1).

Orientation	Intended for		
	Task Leader	Project Manager	Top Manager
Task	++	++	--
Character	+	++	+
Triptych	--	+	++

Table 1. Intended aggregation models

4.5.2 Commensurability and Meaningful

Each KPI has its own metrics and measures. But as we have discussed in Part 2.2., we have to consider the commensurability and the meaningfulness of these three dimensions. In an ideal case, performance expressions should be defined without any dimension (units) to ensure the commensurability. The calculated values are standardized to be comparable.

4.5.3 KPIs weighting

The implementation of one of these aggregation methods is subject to constraints. It should be noted that some limits appear on the aggregation criteria of the individual measures. Indeed, all project tasks and reciprocally, all categories of KPI have the same weight in the final result. It is obvious that a project manager will lend more or less importance to such a task as a function of the aims of the global project or according to her/his own personal preferences.

Consequently, we want to achieve greater relevance by weighting each element criterion. But, in a complex project (with many tasks and categories of indicators) it is quite difficult to quantify the exact weight of each performance category indicators or the exact weigh of each project task. With the orientations previously defined, we have:

- tasks-oriented: $9 \times 3 = 27$ criteria to compare;
- characters-oriented: $T \times 3$ criteria to compare, where T is the number of tasks;
- triptych-oriented: $T \times 9$ criteria to compare.

It is increasingly difficult to attribute weight to each criterion. In fact, it is proportional to the project complexity. However, it could be easier to evaluate the relative position between two of them.

Consequently, we intend using a MACBETH (Measuring Attractiveness by a Categorical Based Evaluation TecHnique) approach to weight the aggregation process. MACBETH employs a non-numerical interactive questioning procedure that compares two stimuli at the same time, requesting only a qualitative judgment about their difference of attractiveness (Bana e Costa and Chagas, 2004). As the answers are given, the consistency is verified, and a numerical scale that is representative of the decision-maker's judgments is subsequently generated and discussed. An overview and some applications of MACBETH are presented, for instance, in (Bana e Costa and Chagas 2004; Roubens *et al*, 2004) and on www.m-macbeth.com

4.6 Global Step for Implementing the cube

In summary, we suggest adopting the following five steps for using cube proposition:

1. to dimension the cube;
2. to design KPIs;
3. to balance KPIs;
4. to aggregate Project Performance;
5. to analyze performance and to make decisions.

5 CASE STUDY: A LANDING GEAR DOORS MANUFACTURING PROJECT

In this section, we propose to implement our cube proposition by controlling the performance of a product development project.

5.1 Project Overview

Let us consider a 2nd tier supplier of the aeronautics sector. This supplier produces composite equipment for aircraft manufacturers. The project examined deals with "study and industrialization" phases of new composite landing gear doors. The project is initially proportioned as follows:

- length: 146 days
- projected start day: 03/09/2007
- projected finished day: 08/04/2008
- projected budget: 100 000 €
- project Team: Project Manager, Quality Project Manager, Purchase Manager, Technical Manager, Research Department, Worker, Logistic Manager and Equipment unity.

5.2 Step 1: Scale the Cube

We use the Work Breakdown Structure (Table 2) to identify the project tasks. This allows us to deduce the useful dimensions of the cube. Here, they are numbered from 1 to 55. The numbering does not differentiate simple and recapitulative tasks. Without these summary tasks we have 45 simple tasks. Concerning the knowledge area, we have chosen to focus the project performance analysis only on the dimensions of Time, Cost, Quality and Risk. The three performance analysis axes have been retain. In addition, ten review dates are programmed, labeled D1, …, D10. We have monitored this project in its entirety. However, due to space restrictions we have only developed a performance analysis of review date D6. Using the letter notation cited above, the parameters of the cube are for this project:

- $m = 4$;
- $p = 3$;
- $n = 45$;
- $q = 3$.

5.3 Step 2: KPI Design

When the project manager establishes project dashboards, s/he has to design the project KPIs. The problem here is how to define coherent KPIs for the project. The performance analysis triptych dimensions can be used to direct this step. Because effectiveness compares results levels against objectives, then the effectiveness component of KPIs could express a notion of "achievement progress". Because efficiency expresses resources bonding to achieve the task, then the efficiency component of KPIs could be associated with the "using rate" dimensions. Finally, because relevance expresses appropriateness between targets and bound resources, the "re-estimation level" notions could constitute an appropriate dimension to define the relevance KPIs.

Composites Landing Gear development project			
2	Initialization step		
3			Project organization specification
4			Contract negociation
5			Contract signed
6	Research step		
7			Preliminary study
8			Development
9			Customer agreement
10			Plans and definition bundle reception
11	Industrialization step		
12		Moulding equipment fabrication	
13			Specifications drafting
14			Specifications validation
15			Industrialization study
16			Materials supplying
17			Equipment machining
18			Equipment fitting
19			3D control
20			Test utilization
21		Fitting equipment fabrication	
22			Specifications drafting
23			Specifications validation
24			Industrialization study
25			Materials supplying
26			Equipment machining
27			Equipment fitting
28			3D control
29			Test utilization
30		Production documents drafting	
31			Pre-impregnated material numerical cutting programming
32			Moulding Instructions sheet drafting
33			Polymerization Instruction sheet drafting
34			Fitting Instruction sheet drafting
35		First Article Inspection (Quality document) drafting	
36			Pre-impregnated material numerical cutting program controling
37			Moulding Instructions sheet controling
38			Polymerization Instruction sheet controling
39			Fitting Instruction sheet controling
40			Moulding phase controling
41			Control Instruction Sheet drafting
42			3D Control
43			FAI finalization
44			FAI send to customer
45			FAI accepted dy customer
46		First Article Production	
47			Pre-impmregnated material cutting
48			Moulding
49			Polymerization
50			Machining
51			Fitting
52			Final Controling
53			Expedition
54			Article receipt
55	First article accepted by customer		

Table 2. WBS of Landing Gear Doors Project

5.4 Step 3: KPI weighting

In line with senior management performance strategy, we have to determine the respective weight to accord each project performance criterion. According to the MACBETH methodology, we indicate existing subordinations that could or should exist between KPIs by implementing the judgment matrix. A ranking of the Categories of KPIs is then established. At this stage information is purely ordinal. The solutions are then compared pair to pair for each criterion. Two fictional alternatives are introduced into the comparison process; these provide the reference values corresponding to the two extreme degrees of performance (Lauras and Gourc, 2007). The comparison then consists in quantifying the difference of performance degree for each criterion. The resulting set of constraints defines a linear programming problem. The solution of this problem provides the cardinal scale of performance associated with a criterion. This step is repeated for each criterion. Figure 6 illustrates this process. The project manager compares all criteria pair by pair. In our example, "Delay Effectiveness" and the "Cost Effectiveness" KPIs appear as the most important criteria whereas "Quality Relevance" is the least important.

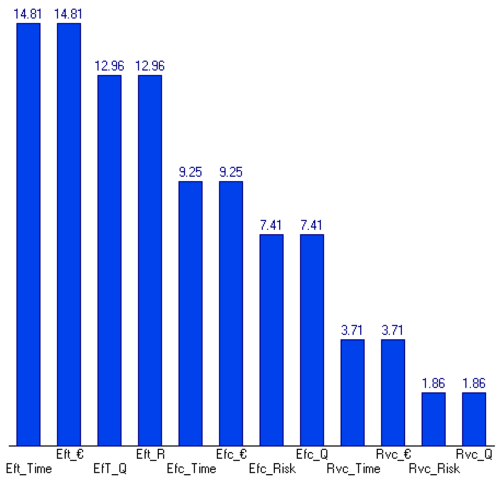


Figure 6. KPI's relative weight

5.5 Step 4: project Performance Aggregation

The Figure 7 shows the project KPIs and their values at D6. This Figure shows how difficult it is to identify clear trends and, therefore, to define improvement decisions. The most problematic tasks are quite difficult to identify.

We choose to develop here only the tasks oriented performance aggregation and only for "State" dimension (not for the "Evolution" and "Trend" Dimensions). The procedure has to be duplicated in order to obtain the complete analysis. The purpose of this section is to explain how we worked in order to properly identify Global State Performance of this example.

Ten criteria (r = 10) corresponding to 10 KPIs could be measured at D6 (Figure 7). Following our proposition, we implemented the characteristics of this project in the M-MACBETH software. The Figure 9 shows the transcription of the Value tree adapted to this particular project and its KPIs on the one hand, and the transcription of the different performance values on the other hand.

5.6 Step 5: performance Analysis

Finally, we have obtained the results presented on the Figure 8. We can clearly identify on which tasks need corrective actions. In this case, tasks 37, 41, 22, 23, 38 and 47 get the worst performance result. Conversely, the overall thermometer clearly shows that the global performance of tasks 43 and 24 is on track. When we develop the same approach with "KPI categories" as options, we can explain which project dimension was particularly deficient (Cost, Quality, Time or Risk) and consequently adapt the decision-making process. In our case, the project manager has to pay particular attention to time management. A third analysis should consist of aggregating the project performance according to the performance analysis triptych in order to give the improvements a more precise orientation. Through this last analysis, we can envisage to detect a trend on the project to define eccentric task objectives (Effectiveness) as shown in figure 8, use resources improperly (Efficiency) or to allocate insufficient or oversized means (Relevance).

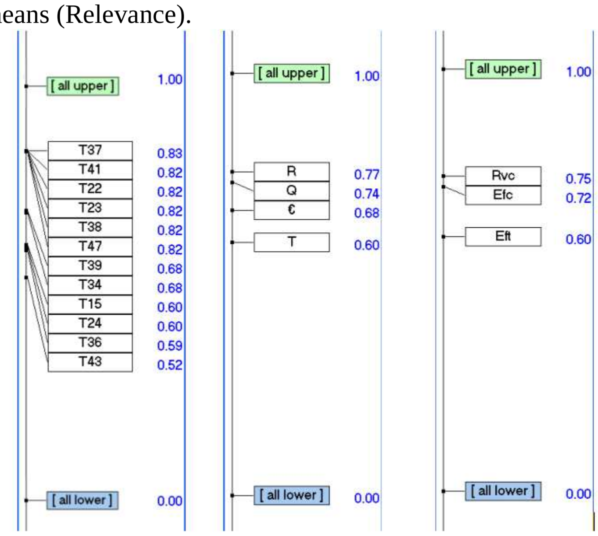
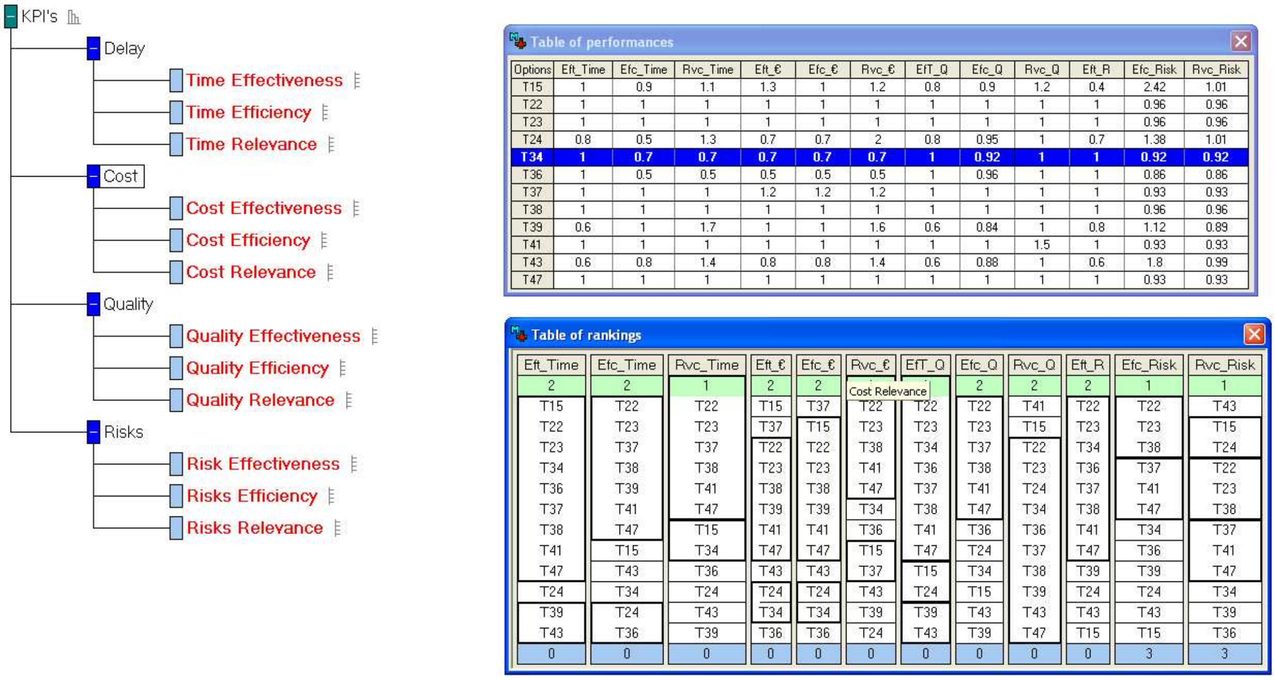


Figure 8. Tasks Oriented Performance Result

Tasks		Current Time Progress	Current duration	Re-estimated fianl duration	Current Cost	Re-estimated total cost	Current Physic Progress	Re-estimated Final physic level	Current Criticity
		6	6	6	6	6	6	6	6
Composites Landing Gear development project									
15	Industrialization study	80%	18	22	5 000 €	6 000 €	40%	1,2	0,6
22	Specifications drafting	100%	6	6	2 940 €	2 940 €	100%	1	0
23	Specifications validation	100%	3	3	1 260 €	1 260 €	100%	1	0
24	Industrialization study	50%	10	25	2 000 €	10 000 €	25%	1	0,3
34	Fitting Instruction sheet drafting	100%	4	4	1 500 €	1 500 €	100%	1	0
36	Pre-impregnated material numerical cutting program controling	100%	0,5	0,5	210 €	210 €	100%	3	0
37	Moulding Instructions sheet controling	100%	4	4	2 000 €	2 000 €	100%	1	0
38	Polymerization Instruction sheet controling	100%	1	1	420 €	420 €	100%	1	0
39	Fitting Instruction sheet controling	60%	3	5	1 260 €	2 000 €	60%	1	0,2
41	Control Instruction Sheet drafting	100%	4	4	1 680 €	1 680 €	100%	1,5	0
43	FAI finalization	57%	4	7	1 680 €	3 000 €	25%	1	0,5
47	Pre-impmregnated material cutting	100%	1	1	100 €	100 €	100%	3	0

Figure 7. Scorecard at D6

Thus, a cross comparison from these three analyses will allow relevant improvement actions to be taken. Finally, we are able to drill down measurements at different levels of detail and time on the one hand, and at different dimensions on the other hand.



Options	Eft_Time	Efc_Time	Rvc_Time	Eft_€	Efc_€	Rvc_€	EfT_Q	Efc_Q	Rvc_Q	Eft_R	Efc_Risk	Rvc_Risk
T15	1	0.9	1.1	1.3	1	1.2	0.8	0.9	1.2	0.4	2.42	1.01
T22	1	1	1	1	1	1	1	1	1	1	0.96	0.96
T23	1	1	1	1	1	1	1	1	1	1	0.96	0.96
T24	0.8	0.5	1.3	0.7	0.7	2	0.8	0.95	1	0.7	1.38	1.01
T34	1	0.7	0.7	0.7	0.7	0.7	1	0.92	1	1	0.92	0.92
T36	1	0.5	0.5	0.5	0.5	0.5	1	0.96	1	1	0.86	0.86
T37	1	1	1	1.2	1.2	1.2	1	1	1	1	0.93	0.93
T38	1	1	1	1	1	1	1	1	1	1	0.96	0.96
T39	0.6	1	1.7	1	1	1.6	0.6	0.84	1	0.8	1.12	0.89
T41	1	1	1	1	1	1	1	1	1.5	1	0.93	0.93
T43	0.6	0.8	1.4	0.8	0.8	1.4	0.6	0.88	1	0.6	1.8	0.99
T47	1	1	1	1	1	1	1	1	1	1	0.93	0.93

Eft_Time	Efc_Time	Rvc_Time	Eft_€	Efc_€	Rvc_€	EfT_Q	Efc_Q	Rvc_Q	Eft_R	Efc_Risk	Rvc_Risk
2	2	1	2	2	[illegible]	[illegible]	2	2	2	1	1
T15	T22	T22	T15	T37	T22	T22	T22	T41	T22	T22	T43
T22	T23	T23	T37	T15	T23	T23	T23	T15	T23	T23	T15
T23	T37	T37	T22	T22	T38	T34	T37	T22	T34	T38	T24
T34	T38	T38	T23	T23	T41	T36	T38	T23	T36	T37	T22
T36	T39	T41	T38	T38	T47	T37	T41	T24	T37	T41	T23
T37	T41	T47	T39	T39	T34	T38	T47	T34	T38	T47	T38
T38	T47	T15	T41	T41	T36	T41	T36	T36	T41	T34	T37
T41	T15	T34	T47	T47	T15	T47	T24	T37	T47	T36	T41
T47	T43	T36	T43	T43	T37	T15	T34	T38	T39	T39	T47
T24	T34	T24	T24	T24	T43	T24	T15	T39	T24	T24	T34
T39	T24	T43	T34	T34	T39	T39	T43	T43	T43	T43	T39
T43	T36	T39	T36	T36	T24	T43	T39	T47	T15	T15	T36
0	0	0	0	0	0	0	0	0	0	3	3

Figure 9. MACBETH Implementation of the Project

6 CONCLUSION

According to Yu *et al.* (2005), project success assessment has resulted in many publications, but it has been difficult to reach consensus. Consequently, there are many disagreements about the definition of project success. In his Project Excellence Model, Westerveld (2003) defines two components for success project: criteria, which is centred on the result of a project; and factor, which is centred on the project management. He highlights the distinction between "What is my result" and "How I complete It". We must not attempt to oppose these two aspects of the project. The final answer to preliminary expressed goals is certainly essential, but analyze the way followed and the choices made are important to be sure to reach these goals or, at least, to ge closer to them.

Consequently, we have proposed a multi-dimensional Project Performance Management System, which integrates the main good practices on the matter: project unicity, project dynamic, universal project management dimensions and aggregation needs.

Many perspectives arise directly from this work. The main studies that we could develop now refer to some main topics:

- the robustness of the MACBETH's use: especially in projects that have many tasks to manage.
- The impact on the proposition if we consider a dependency between the performance indicators.
- The link between research in project classification and balancing KPI's relative weight choice could be studied.

In addition, the literature offers several methods of forecasting final project cost, based on the actual cost performance at intermediate points in time (Hyyari, 2005). Earned Value, for example, is a quantitative approach to evaluate the true performance of a project both in terms of cost deviation and schedule deviation. Other methods allow to forecast quality or time project status (Hyyari, 2005). However, we did not find any reference that simultaneously tries to forecast project outputs for cost, time and quality. So, a perspective could be to develop a tool to forecast the global position (considering all the dimensions: at least cost, time and quality factors) of a project at the next period. This last point clearly highlights an evolution of our work toward an *a priori* performance evaluation.

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