

Multidimensional Project Management Tracking & Control – Related Measurement Issues

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Abstract

Managers involved in “tracking & control” activities in projects are most often concerned with only two dimensions, that is, time and cost to the exclusion of other dimensions, such as quality, in the broader sense, as well as risk. Unfortunately, these other dimensions are often not explicitly taken into account in terms of their relative priorities in software measurement plans. It is therefore quite challenging to implement multiperspective performance models such as Balanced Scorecards (BSC) in software organizations.

This paper presents a procedure called BMP (Balancing Multiple Perspectives), which is designed to help project managers choose a set of project indicators from several concurrent viewpoints.

1. Introduction

Nowadays there is interest in integrated software measurement [15, 20], and some controversy about it as well. Models such as the Balanced Scorecard (BSC) and other frameworks such as *EFQM (European Foundation for Quality Management)* and *MBQA (Malcolm Baldrige Quality Award)* take into account multiple dimensions for analysis purposes; however, there are still few documented industrial implementations in the software engineering domain from the Project Manager (PM) viewpoint. Measurement programs in industry often remain focused mostly on time and cost, to the exclusion of other dimensions (such as quality, in the broader sense, as well as risk), which are not explicitly taken into account in terms of their relative priorities in a measurement plan.

The motivation for this paper derives from observations and feedback received at several training sessions given to project teams over the past few years: the measurement culture is rather limited in many software engineering organizations and, where it exists, the focus is often on minimizing measurement costs, including those incurred at the project control level. In such a culture, measurement at the project level must not decrease the required business markup or the business profits for a project. In such a context, it is therefore very challenging to implement improved measurement programs while at the same time taking into account additional factors to develop multiperspective analysis.

A procedure called **BMP (Balancing Multiple Perspectives)** is presented in this paper to help project managers and team members involved in measurement activities to implement and leverage multiperspective analysis within their measurement program.

Section 2 presents the rationale for multidimensional analysis, with some examples of models recommended to the software industry, as well as the “why” and “how” of the application of multidimensional analysis in a project management context. Section 3 illustrates the four-step BMP procedure to be performed to achieve an instantiation with four basic perspectives. Section 4 presents the conclusions and suggests the next steps in BMP usage.

2. Multidimensional analysis in Project Management

2.1. Why is it needed?

One of the frequent causes of failure in project management is the loss of project control due to inadequate project tracking [9]. To prevent such failures, the content and quality of

project tracking must itself be scrutinized: for instance, is it being performed with the appropriate number of measures, and are those measures properly integrated such that the interrelationships across the various project processes can be analyzed?

The identification and selection of the required number of viewpoints for representing a project more adequately is an issue which needs to be addressed in planning a measurement program: “*Did we plan and gather data from an appropriate number of indicators?*” Buglione et al. discuss these aspects in detail in [3], and illustrate this issue using as an analogy the Egyptian painting in Figure 1. Knowing that its source was a 3D figure, even a casual observer is aware that something is missing in the painting, that is, the *depth* of the image.



Figure 1 – Egyptian painting: a 3D concept fitted into a 2D representation

Project management, whatever its application domain, should report on several perspectives, since the use of only two dimensions (usually *time* and *cost*) represents an overly simplified view of a much more complex reality. To concurrently handle multiple project dimensions (or perspectives) including, for instance, quality and risk, a multidimensional project management approach is needed.

2.2. Some examples of multidimensional models

Some integrated models applying several perspectives simultaneously are well known in other management domains (Table 1). All these models can handle more than three dimensions at the same time (or at least three, plus the financial one as a derived dimension).

The higher the number of perspectives handled, the greater the number of measures to be collected and also the wider the range of candidate causal explanations across the variables measured within the project. When properly used, the main strength of these integrated models is that they measure, analyze and manage with multiple perspectives. Of course, with a larger number of measures comes a much more complex model, which can itself become a risk with associated costs if not adequately understood and managed.

2.3. What should be measured and analyzed?

Each type of integrated model proposes its own way of measuring the performance of the system/project, and of analyzing the measurement results. An extension of the usual IPO (Input-Processing-Output) taxonomy into the **STAR** taxonomy (**S**oftware **T**AXonomy **R**evised) was proposed in [5]: it adds two upper-level entities (*Project* and *Organization*), as in Figure 2.

Table 1 – Multidimensional models for performance management

INTEGRATED MODEL TYPES	SOURCE	# DIMENSION	DIMENSIONS/VIEWPOINTS
Balanced Scorecards (BSC)			
Balanced Scorecard (BSC)	[12] [13]	4	• Financial, Customer, Process, Learning & Growth
Balanced IT Scorecard (BITS)	[8]	5	• Financial, Customer, Process, People, Infrastructure & Innovation
AIS Balanced Scorecard	[7]	5	• Financial, Customer, Internal Business Process, Employee, Learning & Growth
JUSE Deming Prize	[10]	7	• Systematic Activities, carried out by the entire organization, to effectively and efficiently achieve Company Objectives, Provision of Products and Services, Quality, Customer
Malcolm Baldrige - MBQA			
Malcolm Baldrige (MBQA) – Business	[16]	7	• Customer, Product-Service, Financial-Market, Human Resources, Organizational Effectiveness, Governance and Social Responsibility
Malcolm Baldrige (MBQA) – Health Care	[17]	6	• Health Care, Patient-Customer, Financial-Market, Staff-Work System, Organizational Effectiveness, Governance and Social Responsibility
Malcolm Baldrige (MBQA) – Education	[18]	6	• Student Learning, Student-Stakeholder, Financial-Market, Faculty-Staff, Organizational Effectiveness, Governance and Social Responsibility
European Foundation for Quality Management (EFQM)	[6]	4	• People, Customer, Society, Financial
QEST/LIME			
QEST 3D	[3]	3	• Economic, Social, Technical
QEST nD	[4]	N	• <i>Not predefined</i>

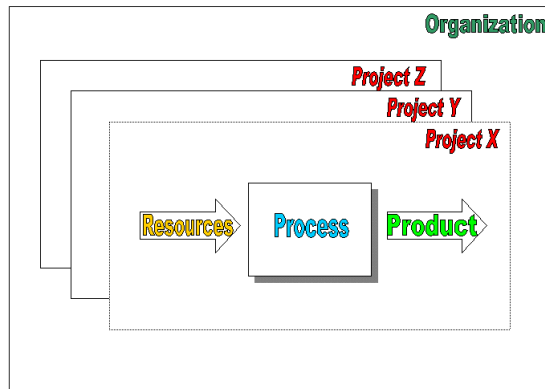


Figure 2 – The STAR Taxonomy

Some solutions have been proposed to handle measures and indicators from several perspectives simultaneously:

- Performance management models such as Baldrige, EFQM and Deming, assess specific aspects in the model directly, assigning points within a predefined range; the final result is expressed, therefore, in absolute and percentage values (e.g. EFQM has a maximum of 1000 points achievable for the 9 criteria proposed).
- A Scorecard approach [13] suggests the use of the relationships among values from indicators for the different perspectives in a causal way, but does not provide a consolidated value. BSC recommends analyzing the impact chain for improving the final

perspective (usually the financial one) designed in the Strategic Map, but does not spell out how this can be done.

- The QUEST model [3] [4] presents a technique for consolidating values from several indicators within each of the selected perspectives, summarizing the final value on a ratio scale. Its usage within the BSC has been presented in [1].

2.4. Which set of indicators to select?

A manager's typical question is: What is the right number of indicators to use? In some Software Engineering sub-domains, a rule of thumb is used at times: e.g. 7 ± 2 [14] for the right number of fields in RDBMS tables or the number of items in a navigation menu on a Web page.

Wiegiers [22], referring to the well-known analysis by Rubin [21], also reports that one of the most common pitfalls to avoid in measurement is the "misbalance" in selecting the measures critical to success. Wiegiers' recommendation is "*to select a small suite of key measures that will help you to understand your group's work better, and begin collecting them right away*", but this must be a balanced set "*measuring several complementary aspects of your work, such as quality, complexity, and schedule.*"

3. BMP: Balancing Multiple Perspectives

In practice, how can a proper balance of perspectives and indicators be selected when managing a portfolio of projects? In this section, we propose a procedure, referred to as Balancing Multiple Perspectives (**BMP**), to help project managers manage with multiple concurrent dimensions (for instance: time, cost, quality and risk).



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Figure 3 – Linus' famous blanket

Controlling one project variable might degrade another project variable: as we illustrate using a metaphor, it is possible to associate simultaneous project controls to the blanket that belongs to Linus, one of the Peanuts' characters – Figure 3): when the child grows up, his blanket will retain the same dimensions, but might then cover his head and leave his feet uncovered. Similarly, if someone takes more than his share of the blanket, then his partner might not be completely covered.

In project management, it might be easy to control and optimize one, two or three dimensions simultaneously, but it is always much more challenging to do so without negatively impacting other dimensions. How can this be done?

3.1. Proposed measurement procedure

This section proposes a measurement procedure for controlling multiple concurrent dimensions. It consists of four steps, which could be performed jointly by a project manager and his quality assurance assistant:

- 1) Determine the dimensions of interest in the project: at least three dimensions – four or five – would be a good idea, such as in EFQM, Baldrige, BSC;
- 2) Determine the list of the most representative measures associated with each dimension;
- 3) For each of the measures selected, identify which other control variables might be impacted negatively (e.g. counter-productive impacts: for instance, higher quality will often mean a greater initial cost or longer project duration; the same applies to cost and risk;
- 4) Figure out the best combination of indicators and the causal relations between them in order to build a measurement plan for the project.

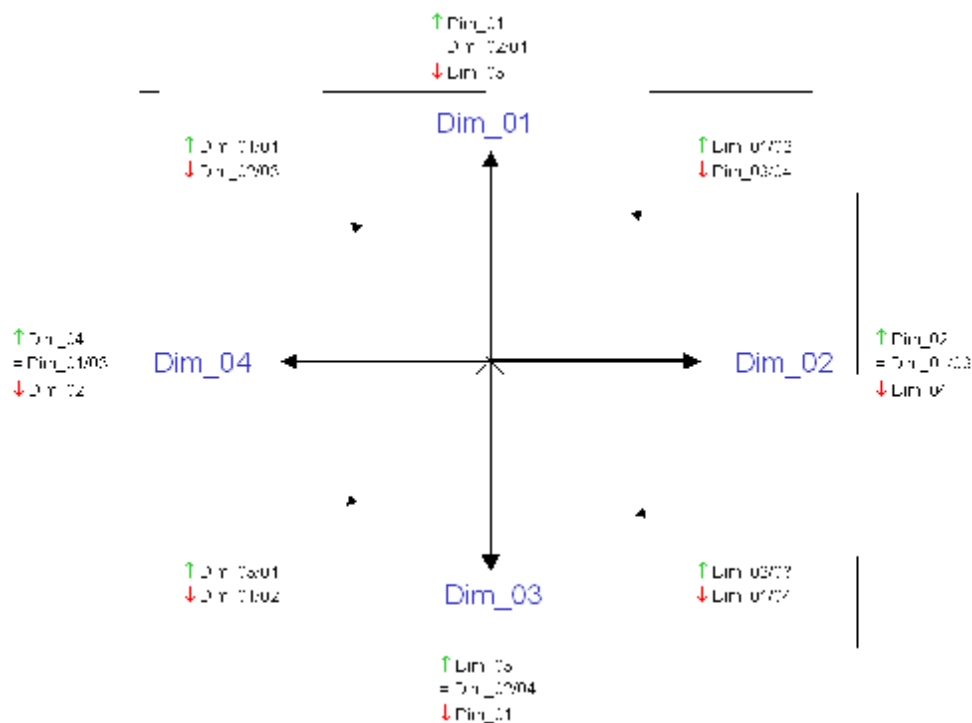


Figure 4 – A generic four-dimensional BMP

Figure 4 presents an example using four generic dimensions, where the main impacts are summarized with green (↗) and red (↖) arrows, explaining which dimension (“Dim_XX”) will be verified and tracked. For instance, if we move the “blanket” towards “Dim_03”, the impacts will be:

- Increased attention¹ to the “Dim_03” dimension
- No particular impact for the “Dim_02” and “Dim_04” dimensions
- Decreased attention to the “Dim_01” dimension

If, by contrast, we move the blanket in a south-westerly direction, mid-way between the “Dim_02” and “Dim_03” dimensions, the impact will be:

- Increased attention to the “Dim_02” and “Dim_03” dimensions
- Decreased attention to the “Dim_01” and “Dim_04” dimensions

3.2. A four-dimensional instantiation

¹ Interpret the word “attention”, and also budget, resources, etc.

This section presents an example of our proposal, using the four steps previously listed.

1) **Determine the dimensions of interest in the project:** in this example, four dimensions have been chosen: Time, Cost, Quality & Risk.

2) **Determine the indicators associated with each dimension:** an initial list of indicators² per perspective chosen is proposed in Table 2:

Table 2 – Initial list of measures for building indicators with related causal effects

Perspective/ Dimension	Indicators	Questions	Measures used to build related indicators
Time (T)	GT ₁ – Milestone Performance	<ul style="list-style-type: none"> • QT₁₁ – <i>Is the project meeting scheduled milestones?</i> • QT₁₂ – <i>Are critical tasks or delivery dates slipping?</i> 	<ul style="list-style-type: none"> • MT₁₁ – Milestone Dates • MT₁₂ – Critical Path Performance
	GT ₂ – Work Unit Progress	<ul style="list-style-type: none"> • QT₂₁ – <i>How are specific activities and products progressing?</i> 	<ul style="list-style-type: none"> • MT₂₁ – Requirement Status • MT₂₂ – Problem Report Status • MT₂₃ – Review Status • MT₂₄ – Change Request Status • MT₂₅ – Component Status • MT₂₆ – Test Status • MT₂₇ – Action Item Status
	GT ₃ – Incremental Capability	<ul style="list-style-type: none"> • QT₃₁ – <i>Is capability being delivered as scheduled in incremental builds and releases?</i> 	<ul style="list-style-type: none"> • MT₃₁ – Increment Content – Components • MT₃₂ – Increment Content – Functions
	GT ₄ – Personnel	<ul style="list-style-type: none"> • QT₄₁ – <i>Is effort being expended according to plan?</i> 	<ul style="list-style-type: none"> • MT₄₁ – Effort
Cost (C)	GC ₁ – Financial Performance	<ul style="list-style-type: none"> • QC₁₁ – <i>Is project spending meeting budget and schedule objectives?</i> 	<ul style="list-style-type: none"> • MC₁₁ – Earned Value • MC₁₂ – Cost
Quality (Q)	GQ ₁ – Functional Correctness	<ul style="list-style-type: none"> • QQ₁₁ – <i>Is the product good enough for delivery to the User?</i> • QQ₁₂ – <i>Are identified problems being resolved?</i> 	<ul style="list-style-type: none"> • MQ₁₁ – Defects • MQ₁₂ – Technical Performance
	GQ ₂ – Process Effectiveness	<ul style="list-style-type: none"> • QQ₂₁ – <i>How much additional effort is being expended due to rework?</i> 	<ul style="list-style-type: none"> • MQ₂₁ – Defect Containment • MQ₂₂ – Rework
Risk (R)	GR ₁ – Personnel	<ul style="list-style-type: none"> • QR₁₁ – <i>Is there enough staff with required skills?</i> 	<ul style="list-style-type: none"> • MR₁₁ – Staff Experience • MR₁₂ – Staff Turnover
	GR ₂ – Functional Size and Stability	<ul style="list-style-type: none"> • QR₂₁ – <i>How much are the requirements and associated functionalities changing?</i> 	<ul style="list-style-type: none"> • MR₂₁ – Requirements • MR₂₂ – Functional Change Workload • MR₂₃ – Function Points
	GR ₃ – Environment & Support Resources	<ul style="list-style-type: none"> • QR₃₁ – <i>Are needed facilities, equipment and materials available?</i> 	<ul style="list-style-type: none"> • MR₃₁ – Resource Availability • MR₃₂ – Resource Utilization

3) **Note down the counter-productive impacts:** Figure 5 shows the effects in balancing these four perspectives.

² For the sake of standardization, an excerpt from the PSM Guide [19] has been considered, applying the Goal-Question-Metric (GQM) technique [2]. The *Questions* are those proposed in Part 2, while the definitions of those *Measures* are proposed in Part 3.

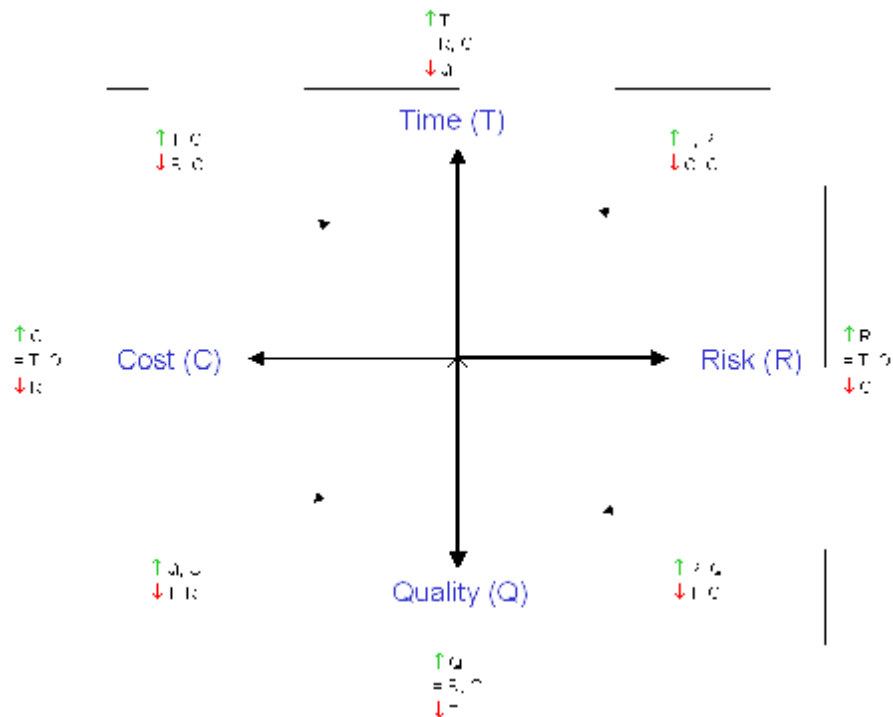


Figure 5 – BMP: an example with four dimensions

4) **Figure out the best combination of indicators and the causal relations connected with them:** starting with the initial list of indicators taken into account by dimension, we have to filter them and select only those critical to our project. The final list, based on the notes documented in Table 2, is presented in Table 3.

Table 3 – Final list of indicators with related causal impact

Perspective /Dimension	Measures	Indicators and related impact
Time	<ul style="list-style-type: none"> • MT₁₁ – Milestone Dates • MT₂₂ – Problem Report Status • MT₂₄ – Change Request Status • MT₂₆ – Test Status 	Referring to GT ₁ , the most important thing to track is respect for scheduled dates for the project, with an impact on Costs (C). The other three indicators selected are the main ones for determining the eventual amount of rework or additional work to perform, with an impact on scheduled dates and therefore also on the EV.
Cost	<ul style="list-style-type: none"> • MC₁₁ – Earned Value • MC₁₂ – Cost 	The Cost perspective, as in most BSCs, is the final dimension, where all the others converge.
Quality	<ul style="list-style-type: none"> • MQ₁₁ – Defects • MQ₂₁ – Defect Containment • MQ₂₂ – Rework 	The Quality perspective is usually associated with defectiveness and the capability of removing defects. Indicators on rework and reuse are therefore an input for planning (T) and for budgeting the effort (C) for the project.
Risk	<ul style="list-style-type: none"> • MR₁₁ – Staff Experience • MR₁₂ – Staff Turnover • MR₂₂ – Functional Change Workload • MR₃₂ – Resource Utilization 	The Risk perspective is a cross-influence perspective, since it provides input information on the probability of occurrence of several factors. The first two indicators relevant to us in this exercise concern the probability of staffing with the right people in terms of experience and with a proper turnover ratio. Looking at people issues, the % of resource utilization is also useful to the PM for allocating the proper amount of physical resources to the project for the Cost (C) dimension.

To take into account the multiple perspectives, a *strategic map* must be built, for instance using the Balanced Scorecard technique [11, 12, 13], and include the chosen perspectives – see Figure 6.

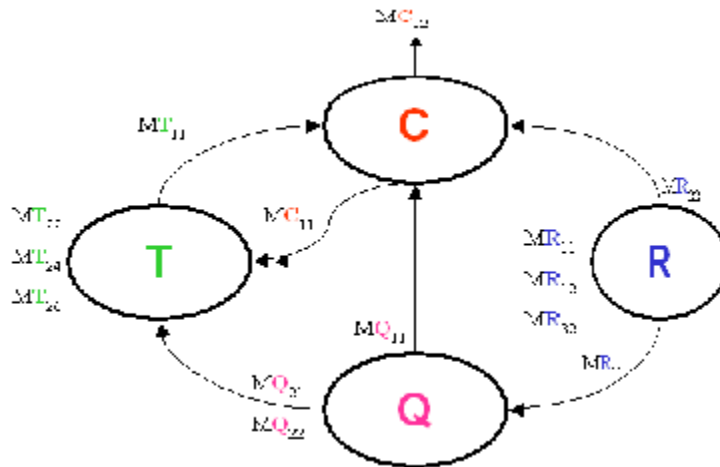


Figure 6 – Indicators by perspective and causal impacts

After gathering data from the indicators defined in the previous steps, project managers can use the BMP procedure to identify and balance the corrective/improvement actions selected from among the several perspectives that need to be addressed in any single project. Of particular importance is to manage the counter-productive impacts of each possible action to be undertaken.

3.3. Measuring project performances from multiple viewpoints

Those familiar with scorecards will readily understand the use of BMP as a tool for considering the counter-productive impacts of a possible control action in a project. But what about the measurement of the overall project value? A BSC can help in managing multiple perspectives independently, but does not provide the integrated measurement results.

This is why a family of models called QEST/LIME is introduced in Table 1 to measure the project's performance from multiple viewpoints. Initially created for concurrently managing three dimensions [3], it has been extended to n possible dimensions [4] and illustrated for its use within a BSC framework: it allows the extraction and calculation of the project performance level against expected thresholds as a dashboard to be continuously monitored during the project's lifetime [1].

4. Summary

Managers involved in "tracking & control" activities in projects are most often concerned with only two dimensions, that is, time and cost to the exclusion of other dimensions, such as quality, in the broader sense, as well as risk. Unfortunately, these other dimensions are often not explicitly taken into account in terms of their relative priority in software measurement plans. It is therefore quite challenging to implement multiperspective performance models such as Balanced Scorecards (BSC) in software organizations.

As reported in several studies, there is no magic number of indicators which will ensure that software project control will be successful: this number depends on the characteristics and nature of the individual project. This paper has presented a procedure, called BMP (Balancing Multiple Perspectives), to select an appropriate balance of indicators from the various perspectives taken into account (e.g. time, cost, risk and quality) and focus on the core indicators from each of them, thereby helping the project manager in tracking and control activities.

Due to its multidimensional nature, a future joint usage, with methodologies, tools and frameworks taking into account concurrent dimensions such as the ones listed as well as QEST/LIME, must still be investigated.

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