

The unintended consequences of metrics in technology evaluation[☆]

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Abstract

This paper describes science and technology (S&T) metrics, especially impact of metrics on strategic management. The main messages to be conveyed from this paper are: (1) metrics play many roles in supporting management of the S&T enterprise; (2) metrics can influence S&T development incentives; (3) incorrect selection and implementation of metrics can have negative unintended consequences on the research and research documentation generated and (4) before implementing metrics, an organization should identify and evaluate the intended and unintended consequences of the specific metrics' implementation, and identify the impact of these consequences on the organization's core mission.

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1. Introduction

The outcomes from science and technology (S&T) underpin modern economies and defense capabilities. Government and industry provide the bulk of resources for S&T development, with government supplying the majority of basic science resources and industry contributing substantial resources to more advanced technology development. In both sectors, S&T accountability procedures have become more requested, more visible, more frequent, and more formal. Questions persist about the most credible methods for insuring accountability to satisfy a variety of stakeholders.

Peer review, the expert judgment by specialists within a given discipline, has been the traditional method used for S&T accountability. Performance metrics (the counting of research activity, outputs, impacts, and quantification of outcomes) tend to be advocated by S&T decision makers who may not be technical specialists, but want independent credible measures of S&T quality and progress that could support resource allocation decisions. The consensus of most of the S&T community is that peer review is the preferred approach to be used for S&T accountability

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(evaluation/assessment), strongly supported by the use of appropriate metrics. However, the selection of appropriate metrics remains an outstanding issue. This paper aims to provide some insight to the role of metrics in the S&T accountability process, and the criteria for selection of metrics most appropriate to the problems being addressed. In particular, because S&T metrics can serve as S&T development incentives, this paper highlights the positive and negative intended and unintended consequences for S&T that could result from incorrect selection of S&T metrics.

The remainder of the paper describes:

- S&T accountability.
- Effects of S&T expenditures:
 - structure,
 - flow.
- Attributes of S&T metrics:
 - qualitative/quantitative metrics,
 - prospective/retrospective metrics.
- Impact of metrics selection on strategic management.
- Unintended consequences from metrics selection.
- Re-balancing quantitative and qualitative metrics.

2. S&T accountability

What is S&T accountability, how is it performed, and how does it relate to metrics?

The S&T organization can be viewed from a decision-consequences perspective as having two major components: (1) expenditures of S&T funds and (2) the S&T-related effects resulting from those expenditures. S&T accountability is the identification and assessment/evaluation of the S&T-related effects resulting from the S&T expenditures. S&T accountability is performed through evaluations/assessments of the expenditures and resulting effects by a combination of (1) experts in the relevant S&T disciplines and (2) experts in technical strategic objectives and mission areas impacted by the S&T under evaluation. Metrics are the instruments that enable the identification and assessment/evaluation of the S&T-related effects. The challenge is to identify the suite of metrics instruments that will enable credible accountability without being overly burdensome, unwieldy, or expensive.

Accountability is achieved through the demands of legal requirements and organizational or managerial needs. Much of what is reported in the effort to assess and evaluate S&T is open to some degree of interpretation as to the nature and content of the evaluation, and the degree to which such content has fulfilled the demands for accountability.

Metrics of S&T and its outcomes play a very significant role in contributing to the perception by stakeholders of the S&T organizations that their reporting indeed results in accountability. Different constituencies and stakeholders have differing standards and benchmarks of what constitutes acceptable assessment and what can be described as acceptable accountability. Thus, S&T metrics would have to effectively measure the S&T expenditures and its outcomes in such a manner that the differing perceptions would be satisfied (Rubenstein & Geisler, 1988).

Similarly, the various stakeholders of the S&T organization utilize the S&T evaluation results in different ways and for different reasons and objectives. This means that these stakeholders may wish to incorporate the metrics of the assessment/evaluation into their own systems of reporting and managerial control (Loch & Staffan-Tapper, 2002). This action by the stakeholders places additional burden on the S&T organization when it strives to achieve accountability, particularly in the selection of metrics for the assessment of S&T.

Evaluation for the purpose of accountability addresses both the expenditures for S&T and the S&T effects. The expenditures are evaluated primarily by the use of accounting methods, and are subject to a plethora of rules and regulations imposed by various government bodies for fiscal and monetary objectives of transparency and honesty. Organizational managers are also interested in the accurate and comprehensive accounting of S&T expenditures.

But, it is in the category of S&T effects from such expenditures that the main difficulties arise in establishing adequate evaluation with metrics that will satisfy the various constituencies.

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