Restructuring Taiwan's S&T Program Performance Indicator System: the Perspectives from Innovation Model, Evaluation Rationales and Policy Context

Abstract

The existing indicators system for the state-funded S&T programs implemented by ministries and agencies in Taiwan is composed of five dimensions including academic benefits, technological benefits, economic benefits , social benefits, and administrative benefits of a total of 30 indicators. The S&T programs are divided into nine categories in which these 30 indicators are available for the non-binding recommended indicator selection by the program managers. .

With the transition of science policy paradigm whose focus on technology shifted to the societal needs , the hands-on implementation experiences of Taiwan's current S&T indicator system lauched in 2001 has proved inadequate to orient and guide the planning, implementation, and evaluation process of S&T programs of multiple ministries and agencies. The problems illustrated in our research include overemphasis on output indicators reported by the multiple S&T programs , failure to target the multiple clients and co-delivery partners, dislocation with the agency's missions, and lack of clear timeframe of phased benefits realization.

Comparing and utilizing the evaluation framework for S&T program performance indicators employed by the United States, Canada, South Korea, etc., we tried to restructure Taiwan's current indicator system based on the clear logic model to reflect the science production system structure and agency's mission, respond to societal needs by targeting the clients and the outcome for the targeted clients, capture the delivery network and the intangible Triple-Helix interactive benefits, assure the correspondence of monitoring indicators to the scheduled evaluation methods, and thereby determine what to measure, when to measure, and how to interpret the measurement outcome.

Besides, we will divide the categories of programs into two dimensions with the matrix to separate the government's different intervention roles of science production and science consumption implied in the S&T programs. Through the well-specified indicators system, we will widen the horizon of S&T program evaluation to avoid underestimating the long-term, intangible, social benefits, thereby optimize the allocation of scarce resources to enhance the contribution of S&T programs to the interaction-oriented innovation and sustainability simultaneously.

I. Introduction

The rise of the NPM (New Public Management)-oriented performance evaluation contribute to the substantial increase of monitoring indicator employed in the evaluation of science programs (Georghiou & Roessner, 2000).

It is argued that indicators are proper instrument of science program evaluation on the condition of narrow scope. Once on the condition of wider scope, involving a variety of disciplines, nations, and time horizon, the rule might not apply. The challenge of indicator measure validity has something to do with the non-monogenous composition of science community, and knowledge production system which make the absolute quantification not feasible (Martin & Irvine, 1983).

As indicated by Barre'(2007), the implementation of S&T indicators should simultaneously capture the methodologies and research system structure. Feller et al. (2003) also indicated the performance indicators of state-funded S&T programs should be based on three underpinnings including science indicators, performance measurement and science research systems. The indicators employed in the assessment of S&T programs ought to take into account of science policy context in which the S&T programs reside.

Therefore, this research analyzed the science context of science evaluation while reviewing and comparing the evaluation and program classification framework of US (Feller et al., 2003), Canada (Teather & Montague, 1997; Montague &Teather , 2007)), South Korea (KISTEP, 2005), etc.

The restructuring of Taiwan's indicators system requires in-depth analyses against the innovation system theories, well-defined timeframe, knowledge production structures without solely emphasizing the indicators composition and designs. Compared with the output indicators, the reporting of outcome and impact indicators for S&T programs is relatively difficult. Therefore, the restructuring of Taiwan's current S&T indicator system in alignment with logic framework based on well-specified timeframe and targeted clients will provide inspirations for the evaluation community of S&T programs.

As researchers involved in the S&T program performance reporting and evaluation practices of STPI, a quasi-government corporation under the auspices of MOST in Taiwan, we hope this research can serve as a catalyst for the enhancement of the formative evaluation processes of S&T programs in Taiwan and interchange of ideas among those dedicated to state-funded program indicators monitoring and evaluation practices worldwide.

II. Policy Context and Its Contribution to the Problems of Current Indicator System in Taiwan

A. Policy context of science programs

As an emerging democracy in Asia, just like most of the other democratic regimes in Asia, the administration’s political clout overwhelmingly outweigh that of the parliament in Taiwan. Through the rigid party discipline wielded by the President as the leader of the majority party and the centralized legislative processes, the administration predominantly monopolize the budgeting processes. It is demonstrated in the budgeting processes in which the budget request by the administration is slightly cut down by the parliament. The constitutional reality signifies less accountability pressure for the administration to develop the sophisticated program evaluation methodologies to justify programs spending. Besides, the science program budget especially faced less accountability pressure since the administration’s science policy once played a vital role in catalyzing the rise of Taiwan’s ICT industries.

However, with the worsening fiscal deficit, lethargic economy and the bottleneck of industry restructuring in Taiwan, the evaluation policy context began to change. The public, the press, auditing office, and the parliament are becoming more concerned about the benefits and impact, especially the tangible economic impact, of the science programs on the society.

Actually, the overwhelming power of the administration takes toll on the current operation of the evaluation of science programs, contributing some of the problems facing the current evaluation and monitoring system.

B. The current Indicator system initiated by MOST

In addition to the government-wide program performance planning system launched by the central evaluation agency, National Development Commision modeled against the GPRA of the United States, the Ministry of Science and Technology (MOST) of Taiwan is in charge of the evaluation system for the science programs encompassing the major mission departments. To conduct the monitoring and evaluation of the science programs, the MOST initiated a annual performance reporting system requiring all departments carrying out the science programs to report the results and benefits of all the science programs. The required annual paper report comprise the qualitative result statement and the quantitative output/outcome/impact indicators which was guided by the indicator reference system consisting of 30 kinds of quantitative indicators divided into five dimension.

C. Problems of current evaluation system to be addressed

- Summative evaluation outweigh formative evaluation-evaluation as unilateral judgement instead of as a medium for iterative communication:
- Authorative and oversimplified indicators selection:

The current quantitative indicator system divides the science programs into nine categories corresponding to specific indicators. For example, the basic research program should choose the paper counts and paper citation as its required quantitative indicators. By the same token, the commercialization programs are required to select the industry-related impact indicators such as patents counts, and technology transfer counts and income to account for the commercialization benefits of science programs. However, the paper indicator such as co-authorship can be utilized to measure the university-industry collaborations as well (Tijssen, 2012). Likewise, the "patent citation to paper" indicators can also be employed to substantiate the benefits of basic researches on the economy and society (Grupp & Mogee, 2004). The over-simplified indicator selection criteria reflect the unilateral and summative evaluation regime which might be detrimental to the interaction-based innovation in Taiwan.

- Overemphasis on science-based linear model:
  The current indicators system emphasizes the technology creation instead of the interdisciplinary, triple-helix indicators. Actually, the technology creations do not necessarily translation into application and benefits to the stakeholders. Therefore, the linkages and interaction among the diversified stakeholders and actors need to be deliberatively captured by the quanatitative indicators.
- Measurement is disentangled with evaluation-indicators and not aligned with evaluation methods:
  The indicators selection should be based on the employment of the long-term impact evaluation methodology. For example, the employment of paper co-authorship data in the network analysis of programs' impact entails the data collection of paper data. By the same token, the paper data can be utilized in addition to the patent citation data to demonstrate the economic impact of the basic research programs on the society. In a nutshell, the indicators selections should not be based on the over-simplified alignment of program categories with specific indicators but rather on the data tracking strategy implied in the impact evaluation methods selected.
- Confusing target clients and time-frame in annual reporting:
  The current indicator system combined the annual output, short-termed outcome, and long-termed impact indicators in the annual performance report. It will result in the miscalculation of improper attribution of the annual performance. Besides, only through the specified multiple target clients, can the indicators be accurately divided into output/outcome/impact indicators and

thereby be measured at different timeframe instead of one-size-fits-all annual reporting. We should try to clarify the timeframe and transfer the focus of measurement from the researchers/program/short-term outcome to the research organization/program portfolio/long-term impact (Guy, Ken, 2003).

- Lack of well-defined indicator guide and performance plan in programs proposal formulation:

  Despite the indicator selection chart for each category of specific science program, the current indicator system do not provide the program managers with the specifications and operational definition of each ouput/outcome/impact indicator. Therefore, some of the less concrete outcome and impact indicators such as carbon reduction quantity, personnel training, job creation, and induced firms investment are not characterized in the guidance manual; consequently, the indicators data reported in the annual performance report appear to be unreliable.

D. Science policy paradigm transition and its implications for indicator system

With the transition of science policy paradigm from the traditional science policy (traditional one) to the innovation-system policy (emerging one), the focus of performance measurement and evaluation underwent substantial change as well. The traditional and innovation system policy paradigm reflect different underlying economic theory, rationale of government intervention, innovation model, actor, data source, target of measurement, and evaluator. In terms of underlying economic rationale, the traditional one is based on the neo-classical theory in which the exogenous production element assure the economic output; By contrary, the emerging one is based on the new growth theory in which the endogenous factors such as interactions and linkages significantly figure in the economic growth. In terms of rationale of government intervention, the traditional one justify the government intervention by means of the failure-of-market rationale exemplified by the underinvestment of R&D; By contrary, the emerging one justify the government intervention by means of the failure-of-system rationale exemplified by the system rigidity or insufficient linkages among sectors or disciplines. In terms of innovation model, the traditional one is based on the linear innovation model which concentrate on the commercialization of technology; By contrary, the emerging one is based on the non-linear innovation model which concentrate on the iterative interactions among researcher, entrepreneurs, consumers and policy makers. In terms of actor, the traditional one engages the researchers in industries and academia; By contrary, the emerging one involves the co-delivery partner and the stakeholders as well.

In terms of indicator data source, the traditional one typically rely on the national statistical office; by contrary, the emerging one rely on diversified data source ranging from private sector, NGO, academia, and public agencies.

In terms of target of measurement, the traditional one focuses on the input/output of researches; By contrary, the emerging one focuses on the linkage, interactions,

Table 1 Comparison of Measurement focus of Science Indicators of traditional and Innovation-system Policy Paradigm

Policy Paradigm	Traditional Science Policy	Innovation-system Policy
Underlying Economic Theory	Neo-classical Theory (Exogenous Variable)	New Growth Theory (Endogenous Variable)
Underlying Rationales of Government Intervention	Market Failure	System Failure
Innovation Model	Linear Innovation (Commercialization of research output)	Non-linear Innovation (Iterative interactions among researchers, entrepreneurs, consumers, and policy makers)
Actor	Researchers in industries and academia	Multiple co-delivery partner and stakeholders
Indicator Data Source	National statistical office	Diversified data source
Target of Measurement	Input/Output	Linkage/Outcome/Impact
Evaluator	Experts of each discipline	Inter-disciplinary experts

Source: Chang (2014)

and impact of researches. In terms of evaluator, the traditional one are typically conducted by the experts of each discipline, tending to reflect the academic hierarchy; By contrary, the emerging one are typically conducted by inter-disciplinary experts informed by the quantitative indicators to counterbalance the negative impact of disciplinary academic hierarchy on the interactions among disciplines.

E. Transition and alignment of indicators with evaluation methods selection

In earlier stage, the traditional indicators were formulated in the Frascati Manual by

OECD (OECD, 2005) whose focus was on input/output indicator in alignment with the employed econometrics evaluation method to analyze the correlation between research input and productivity, GDP, etc. The indicators constructed in this approach are insufficient to demonstrate the direct, causal relations between the input and output (Godin & Doré, n.d.). Later on, the positioning indicators began to rise to measure the interactions, linkages, mobility, and benefits flow among multiple actors of innovation.

By the same token, the emerging indicators were also formulated in the Oslo Manual by OECD whose focus was on broadly defined innovation, including process innovation indicators, product innovation indicators, organization innovation indicators, and marketing innovation indicators.

Likewise, acknowledging that the interactions with consumer, design, purchasing technology can create benefits as well, the Community Innovation Survey (CIS) by the EU focus on the non-R&D innovation activities by industries. Furthermore, the UK Innovation Survey (UKIS) separate independent R&D from purchasing technology and conducted survey of expenditure on design to address the deficiency of Oslo Manual.

It is argued that monitoring indicators should be aligned with the evaluation method selected in addition to monitoring indicators inform the program managers in the mid-term decision-makings.

III. Re-orientation of Indicators construction in alignment with Performance Framework, Program Typology, and Program Proposal Formulation

A. Connecting indicators monitoring with evaluation by performance framework in the program proposal

Reviewing the program typologies of science agencies of U.S. ,Canada, South Korea, I found the Canadian one is most inspiring under Taiwan’s current situation of indicator system. To address the problems elaborated above, we proposed a performance framework approach based on Resource-Reach-Results performance framework once employed in the science program evaluation in Canada and the U.S., trying to enable the program managers to utilize in the proposal formulation to logically articulate the planning-implementation-evaluation policy cycle.

The Resource-Reach-Results framework is regarded as an scoreboard approach in which the Reach dimension enable us to identify the target clients, co-delivery partners, potential beneficiary, and stakeholders (Teather & Montague, 1997). It was regarded as more balanced among the evaluation of efficiency (Output), Process (Reach) and effectiveness (Outcome/Impact), and more closely linked with innovation theories (McDonald & Teather , 2000)..

This framework does not exclusively concentrate on the Input, output, and results but rather involves the implementation processes and benefits diffusion processes as well. Resources (human resource and budget) representing the “How” dimension are utilized to produce “activities” and “Output”, then “Reaching” the stakeholders and partners to produce “Results”. Its advantages are as follows:

- By defining the multiple clients of each program in their proposal, it enable the science agency to clarify the target clients and timeframe for monitoring and evaluation:

  In contrast to oversimplified and authoritative indicator selection criteria of the current indicator system, my proposed performance framework allow the program managers to identify the multiple target clients and multiple results. For example, the basic research can produce the paper counts as its annual output, then after a short term producing the outcome for its target client (academic community) measured through the paper citations indicator, and then after a long term producing the impact on its other target clients (the industry or economy) measured through the paper citation to patent or new product sales yielded by the research.
- By defining the co-delivery partner, stakeholders, it enable the science agency to measure the benefits diffusion processes and innovation system interactions:

  Since the “Reach” dimension of the performance framework requires the program managers to identify the target clients, it enables the program managers to measure and maximize the benefits through collaboration and interaction, developing the positioning and Triple-Helix indicators, and targeting the source of spillover benefits required by long-term impact evaluation.
- Separate the annual output reporting from the outcome and impact reporting instead of reporting the unreliable impact information in the annual report without well-defined timeframe:

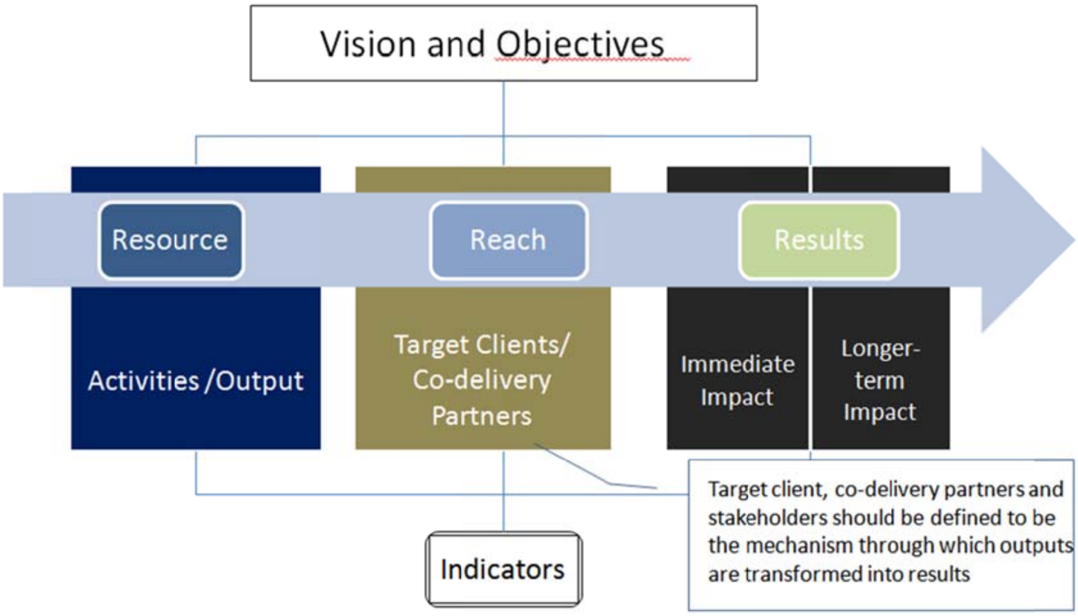

Figure1 Performance Framework and Measurement

By doing so, the indicators can be distinguished between output/outcome and logically aligned with the target clients and the proper time to be measured instead of descriptively grouped in the annual report.

B. Combining performance framework with program typology for indicator selection

Without separating the mission-oriented science programs from the others, the current indicator system cannot distinguish the government intervention as R&D provider from that as R&D consumer in which mission agency implement the science program to attain its policy goals. With reference to the Table 2, concerning the R&D purpose, the policy attainment and industrial development are inspiring and should be taken into our proposed program typology. Besides, with reference to the Table 2, it is supposed that the basic research should rely on the modified peer review, and the applied, and development programs should rely on user survey and case study to demonstrate their benefits diffusion and impact on the stakeholders.

Modifying the typology framework in Table2, I propose a program typology in which, in terms of R&D type, can be divided into Basic research, Applied research, and Commercialization Research; in terms of R&D purpose, it can be divided into “Knowledge Creation”, “Infrastructure”,” Policy Attainment”, and “Industrial Development”.

Combining Performance Framework with Program Typology, the Table 3 below are

Table 2 Program Typology and Monitoring/Evaluation Methods

R&D Type	R&D Purpose: Category 1 R&D Infrastructure	Category 2 Policy Development	Category 3 Policy Attainment	Category 4 Industrial Development
Basic/Strategic	(Modified Peer) (Partial Indicators)	Modified Peer (Partial Indicators)	Modified Peer (Partial Indicators)	Modified Peer (Partial Indicators)
Applied	(Modified Peer) (Case Studies) (Partial Indicators)	Modified Peer User Surveys Case Studies (Benefit-Cost) (Partial Indicators)	Modified Peer User Surveys Case Studies (Benefit-Cost) (Partial Indicators)	Modified Peer User Surveys Benefit-Cost Case Studies (Partial Indicators)
Development	(Modified Peer) (Case Studies) (Partial Indicators)	Modified Peer User Surveys Case Studies (Benefit-Cost) (Partial Indicators)	Modified Peer User Surveys Case Studies (Benefit-Cost) (Partial Indicators)	Modified Peer User Surveys Benefit-Cost Case Studies (Partial Indicators)

Source: McDonald & Teather (2000)

used an example to illustrate the alignment of program typology and performance framework specifications. Based on the program typology below, we will listed the

Table 3 Illustration of Aligning Program Typology with Performance Framework

	Resource		Reach			Results	
	Activities	Output	Direct client	Indirect client	Partner	Short-term (Outcome)	Long-term (Impact)
Knowledge Creation				Academia		V	v
Infrastructure							
Policy Attainment				Society			V
Industrial Development		V	Industry			V	V

intended policy goals under each of the Resource/Reach/Results columns in the manual for program proposal.The illustration can serve as conceptual guide for the agency to construct the equivalent indicators corresponding to the elements of performance framework

C. Iterative processes of constructing indicators

There should be a iterative, long-time process of methodological dialogue among MOST, science agency, stakeholders, through which the agencies can build up their evaluation capacity. The indicators construction and selection should take into account the evaluation capacity each evaluation method requires and the data availability.

Only through iterative process of methodological dialogue, can the science iindicators design correspond to agencies' data needs of evaluation, and thereby contribute to the feedback of evaluation results into the decision-making processes.

Furthermore, concerning the data source of the constructed indicators, each agency or program manager should try to engage the potential producers of indicators and data source from private companies, academia, and public sector through constant methodological dialogue. For example, bridging the gap between the national commissioned research results management platform, GRB and performance data reported by S&T agencies such as patent data to support the hotspot patent analysis of S&T programs. By doing so, it can improve and integrate the monitoring and evaluation capacity of government agencies , research institutes, and the MOST.

IV. Conclusion:

The construction of indicators for science programs should be logically aligned with the science policy context. This article try to explore the inextricable links between science indicators and policy paradigm transition demonstrated in the common ground of the advanced global science evaluation community. Besides, I elaborated the problems arising from the unique policy context of the science programs evaluation shaped by the constitutional structure from the perspectives of policy paradigm transition from failure-of-market rationales to failure-of-system rationales.

Employing the Resource-Reach-Results performance framework modeled and modified against the performance framework proposed by Teather & Montague (1997), I intend to facilitate the re-orientation of indicators for science programs by the programs manager of each ministry. In addition, the guiding manual are utilized to illustrate the articulation of Resource-Reach-Results performance framework in the program proposals, and to illustrate the alignment of indicators to the specific contents of measurement in the three dimension of indicators..

Furthermore, after reviewing the program typology employed by science agency in the U.S., Canada, and South Korea, I construct a program typology modified from that of Canada to be combined with the Resource-Reach-Results performance framework to facilitate the construction of indicators of each category of programs by the program managers. The proposed program typology distinguish between the type of R&D, and the purposes of R&D, in which the governmental roles of science policy provider and consumer are implied.

It is argued that monitoring should be aligned with evaluation. The program managers are supposed to tailor their own performance plan in which the evaluation methods to be employed and the corresponding monitoring indicators data required in the program proposal. Only through it, can the program managers identify what data are required by the program evaluation, and thereby clearly formulate the timeframe for monitoring and evaluation and the data collection strategy.

The technological outputs of science programs do not necessarily translate into benefits for the society. Therefore, the evaluation of science programs in Taiwan should serve as an medium in which the program planning, implementation and evaluation are supposed to be more closely related to the real and potential target clents. Through these interactive processes, the program managers and mission departments can keep the goals and indicators aligned with the needs of target clients , and be tailored to measure the “Reach” dimension such as linkage, Triple-Helix interactions to address the problems of failure-of-system

The contruction of specific indicators entails the iterative interactions and coordinations among program managers, mission department, MOST, and private stakeholders. Therefore, I think the MOST and relevant ministries should devote substantial budget resources and personnels to enable the development of the evaluation capacity to afford the iterative implementation processes. Actually, the implementation of program monitoring indicators construction of GPRA in the U.S. took seven years for the federal agencies to prepare for it. In the same token, the construction of indicators should be based on the consultation with stakeholders and diversified indicator sources.

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