The Canada Foundation for Innovation's outcome measurement study: a pioneering approach to research evaluation

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In Canada and internationally, there is increasing interest in the accurate and meaningful measurement of the impacts of public R&D expenditures. The Canada Foundation for Innovation (CFI), a not-for-profit foundation that funds research infrastructure, has developed an innovative method for evaluating research outcomes and impacts — the outcome measurement study (OMS). The OMS combines quantitative and qualitative evaluation approaches to assess outcomes of multidisciplinary research themes at individual institutions. This article describes the methodology, and highlights the key attributes and findings of employing the OMS approach. This methodology has proven to be effective as an evaluation and accountability tool, and as a learning experience for the CFI and participating institutions.

D URING THE PAST two decades, governments around the world have significantly increased their expenditures on research and development, most notably in university-based research. They have done so for a variety of reasons, but particularly to stimulate innovation, enhance productivity and competitiveness, improve health, the environment and quality of life, and provide a knowledge base for the development of effective public policy. In many instances, these expenditures of public funds have been accompanied by a growing insistence on greater accountability and more accurate and meaningful measurement of results. The need for public accountability is echoed by the OECD's (2008: 189) statement that:

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understanding and measuring the impacts of public R&D have become a central concern of policy makers who need to evaluate the efficiency of public spending, assess its contribution to achieving social and economic objectives and legitimize public intervention by enhancing public accountability.

The Canada Foundation for Innovation (CFI), created in 1997 by the Government of Canada to fund research infrastructure in universities, research hospitals, colleges and non-profit research institutions, has attempted to meet these demands by developing an innovative way of evaluating results. As an independent, non-profit corporation, the CFI has the latitude to take new directions in evaluation. This article reports on, and discusses the methodology behind, one of these new directions: the outcome measurement study (OMS).

Historically, in Canada as elsewhere, evaluation of the results of public R&D expenditures has tended to focus on the quantity and quality of short-term research outputs, using indicators such as the number of publications, and certain quantifiable development and commercialization outputs, including licensing contracts and patents. These measures

remain important to our understanding of research outputs and outcomes, but are insufficient to capture the full range of impacts resulting from public R&D expenditures. The shortcomings of existing indicators are often discussed in the R&D evaluation literature (e.g. Michelson, 2006) and at various international policy workshops, such as Statistics Canada's 2006 Blue Sky II conference (OECD, 2007), although some recent efforts endeavour to address the issue (e.g. CAHS, 2009).

During the Blue Sky II conference, participants discussed and debated some of the less traditional science, technology and innovation (STI) indicators and the often intangible outcomes that they are intended to measure (McDaniel, 2006). Examples of these indicators include the degree to which networking is structurally facilitated, the positive synergies of strategically developed laboratories and facilities, and the myriad connections that university researchers build with private sector firms, civil society organizations and government bodies. As the Blue Sky II conference participants emphasized, the challenge is to devise better means to evaluate medium- and long-term socio-economic impacts, not just research outputs and short-term outcomes.

These challenges were echoed in a recent advisory committee report to the US National Science Foundation (NSF) that urged the NSF to develop:

> a more holistic performance assessment program that will not only better demonstrate the value of NSF investments, but return learning dividends to NSF itself. (NSF, 2009: 9)

Specifically, the advisory committee recommended that the NSF adopt a more methodologically diverse assessment framework, which would attribute greater significance to the relationships between strategic goals and outcomes, and involve the scientific community as a partner in the process of assessment. The committee suggested that this approach should be integrated into the programmatic infrastructure of the NSF, where it would provide a means of documenting the impact of the NSF's investments in science.

Over the past four years, the CFI has also aimed to respond to these challenges by developing and applying the OMS. This is a pioneering tool in the Canadian R&D context as it integrates the principles espoused by the OECD, NSF and other organizations for more holistic evaluations with a focus on medium- and long-term impacts, developed in partnership with the scientific community and serving as a learning exercise for both the funders and the institution. Using both quantitative and qualitative approaches, the OMS evaluation tool employs five categories of outcomes to assess multidisciplinary research themes within individual institutions. The tool provides the CFI and the institutions it funds with important insights regarding intangible outcomes and impacts as well as a means to learn how better to capture research impacts.

This article describes the development and application of the OMS methodology. It highlights the key attributes of the approach, and reviews some of the relevant findings of the OMS to date. Finally, the article offers some conclusions about the value of the OMS to both funding agencies and the scientific community.

The Canada Foundation for Innovation

A unique public policy instrument, the CFI was designed to support Canada's research capacity by funding research infrastructure. The CFI normally funds up to 40% of the costs of any given infrastructure project. Provincial governments, private sector partners and research institutions themselves cover the remaining 60%. As of April 2010, the CFI has committed C$5.3 billion supporting more than 6,800 projects at 130 research institutions. This has resulted in a C$13.2 billion expenditure on research infrastructure in Canada.

From its earliest days, the CFI Board of Directors and its senior management team placed great importance on evaluation and public reporting, not only for accountability purposes but also to generate in-depth insights into the social and economic impacts of publicly funded research. They also decided that the organization would seek to develop its own evaluation processes and, where possible, make positive contributions to the expanding analytical frontier in public sector R&D evaluation.

The development and application of the OMS methodology

In developing the OMS methodology, the CFI was guided by several considerations. Due to limited resources and the absence of readily identifiable control groups, rigorous experimental approaches involving randomized selection of participating sites were not an option. Foremost, the exercise had to be feasible in terms of internal capacity and efficiency, and place only limited workload demands on funded institutions. Although many more measures could have been adopted to provide additional information, the CFI evaluation team decided to include only the most critical measures in order to lessen the burden on institutions of collecting and presenting the data. Given these considerations, the methodology was designed to address the following elements:

First, the CFI sought a methodology that would:

- serve as a learning tool for both the institutions and the CFI itself. For the institutions, participation in the OMS would ideally provide insights on how to improve their own strategic research planning, research coordination, internal assessments of scientific and socio-economic returns from their research activities, and communication of

research outcomes. It would also increase understanding of the conditions under which the outcomes are optimized.

- add to the CFI's ability to report to its own board of directors, the Government of Canada, other key stakeholders and the general public on the extent to which the CFI's investments in research infrastructure are a critical contributing factor in achieving a number of desired outcomes for Canada.

Second, the CFI was conscious of the continuing debate in the evaluation community regarding the relative merits of quantitative and qualitative approaches. Michelson (2006: 546) notes the 'widespread push for the undertaking of quantitatively based program evaluations' in the USA. There have been similar pressures in Canada. Nevertheless, as Butler (2007: 572–573) suggests, just as there are potential problems in depending solely on qualitative assessments by peers, there are real concerns about over-reliance on quantitative indicators in the absence of expert qualitative assessments. These concerns include the difficulty of capturing multidimensional and complex research outcomes and impacts with simple metrics and the sometimes perverse behavioural effects of those indicators. In addition, certain experts in the field consider that qualitative expert assessments are the most appropriate approach where the goal of the evaluation process is quality improvement and remediation — that is, a learning process (see e.g. Rons *et al*, 2008: 46). Given that the OMS is intended to serve both accountability *and* learning purposes, the CFI chose to integrate quantitative measures with expert qualitative assessments in a balanced approach as proposed by, for example, Butler (2007: 572–573), Donovan (2007: 594–595), Grant *et al* (2009: 59) and NSF (2009: 10).

Third, the evaluation of the impacts of infrastructure investments requires an approach that encompasses a variety of factors and recognizes the difficulties of demonstrating causal links. In developing the OMS, the CFI decided to move beyond the use of the traditional 'linear model of innovation' that postulates that innovation starts with basic research and follows in a continuous and direct line

through applied research and development to the production and diffusion of innovative goods and services (see e.g. Godin, 2005: 33–35, and Martin and Tang, 2007: 2–5).

The context in which the CFI operates is much more complex than a linear model would suggest. Innovations flow back and forth across the permeable barriers of institutions, firms and government bodies, generating outcomes or spurring more research through a variety of mechanisms. At the level of firms, Georghiou (2007: 743–744) suggests that it is important to take into account indirect effects and changes in organizational behaviours, for example, changing research collaboration arising from public funding or other government interventions. Georghiou demonstrates that a case study approach is an appropriate way to capture these effects.

Similarly, because of the broad scope of the elements and environmental circumstances that had to be considered in assessing the impacts of CFI-funded projects and because the CFI wanted to understand not only direct impacts but also the indirect and behavioural impacts over time, a modified case study approach appeared to be the best fit in shaping the OMS.

Fourth, in designing the OMS, the CFI was sensitive to the complexities of attributing impacts to itself, given the multiple funding partners involved in supporting the Canadian research enterprise. As a best practice, other funding partners are regularly invited to participate in the OMS review process. Although the process seeks to identify the extent to which CFI funding is a critical contributing factor in the observed outcomes and impacts, the CFI is one of a number of federal and provincial research funding agencies in Canada. Therefore, determining a causal relationship between a given CFI program or award and a particular outcome and impact is often very difficult. The CFI recognizes that its funds are only part of the support of a given research enterprise and that the OMS findings reflect the impacts of multiple funding sources, including but not limited to the CFI.

In developing the methodology, the CFI involved both international evaluation experts and key stakeholders in Canada. The CFI worked with two expert consulting firms and an organized stakeholder advisory network, including institutional research administrators, Canadian and international research evaluation experts, and federal and provincial government officials. This network was actively consulted as the methodology was developed, as were three research institutions who agreed to serve as pilots for the first three outcome measurement studies. A 2009 report prepared by RAND Europe for the Higher Education Funding Council for England (HEFCE; Grant *et al*, 2009: 58) similarly recommends that researchers, higher education institutions and research funders be widely consulted in defining impacts to be measured. At the end of the consultative process, the international stakeholder advisory

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network strongly endorsed the OMS approach and noted that it was, in many respects, at the forefront of impact assessment methodologies.

Elements and characteristics of the OMS methodology

Research theme as the level of analysis

The majority of research evaluations investigating the impacts of research grants define their level of analysis at one or another end of a spectrum: at the 'micro' or the 'macro' level. At the micro level of analysis, the focus is on individual research projects, while the macro level entails the measurement of the full range of research funded by a given program or conducted at the institutional or national level (see Michelson, 2006; Wixted and Holbrook, 2008). Between the micro and the macro levels, lies the meso — a level of aggregation that enables a better understanding of the systemic and relationship-based synergies that strategically planned investments can generate. The level of analysis in each OMS was meant to explore this neglected meso level by focussing on a particular research theme within a given institution.

The 2009 RAND Europe report to the HEFCE (Grant *et al*, 2009: 60) further substantiated this meso-level thematic approach. Referring to one aspect of the proposed research quality and accessibility framework (RQF) in Australia, the RAND report stated:

> that it would allow researchers and institutions discretion in how they organise into (impact) groupings — while still requiring groups to have some minimum size.

The OMS assessment is conducted at the meso level, employing a theme as its unit of analysis. A theme is defined as a grouping of CFI-funded research projects at an institution with an intellectual coherence either through the field of study (e.g. genetics and genomics) or a joint scientific underpinning of diverse fields (e.g. nanotechnology). The advantage of this level of analysis is the ability to assess the impacts of, and interaction between, related infrastructure projects and investments over time while avoiding the complexity, burden and cost of assessing the entire CFI investment at an institution which may include hundreds of projects.

Selection of OMS theme

Institutions applying for CFI funding must have an institutional strategic research plan in place. This is a central eligibility requirement for seeking CFI funding. The selection of an OMS theme is done in concert with a CFI-funded institution in an area of research where there has been significant CFI

support that is linked to the institution's strategic research plan. The theme definition must be made specific enough to cover an appropriate number of CFI projects, usually between 10 to 20 projects. The projects differ in their stages of maturity, with several being well-established ones (eight to10 years) and others being more recent investments. Together, the projects represent a decade's worth of research outputs and outcomes.

In general, the theme may include CFI expenditures in a range of research infrastructure, laboratories and other facilities and data and computing platforms at the institution (and could conceivably be across multiple institutions). The theme often involves a number of disciplines, departments and faculties and is comprised of projects funded under different CFI programs. To date, the CFI has applied the OMS to themes such as human genetics and genomics, advanced materials, cognition and brain-imaging, the environment and oceans, food science, and information and communications technologies.[1]

Outcome categories and indicators

While many evaluation studies of academic research concentrate primarily on research quality rather than on the impact of the research, the OMS methodology is considerably more ambitious. It is designed to evaluate the contributions of CFI expenditures to improving outcomes in five categories: strategic research planning; research capacity (physical and human); the training of highly qualified personnel (HQP); research productivity; and innovation and extrinsic benefits. More than 20 indicators are employed to evaluate outcomes in these five categories (Table 1).

The OMS indicators include both institutional research outputs (e.g. recruitment and retention of researchers, number of research trainees) and outcomes (e.g. economic or social innovations, evolving industrial clusters). Although some of the indicators would be designated as research outputs rather than outcomes in certain logic models, in the CFI logic model (Figure 1) all OMS indicators are considered CFI's outcomes. The CFI logic model links the program's activities to the expected outputs of the CFI and to the outcomes of the investment at institutions. The ultimate impacts are those at the level of national objectives. Primary beneficiaries — universities, their researchers and their HQP — are identified in the context of expected outcomes. The secondary beneficiaries — industry, the Canadian Government and the public — are associated with long-term outcomes and ultimate impacts.

The outcomes of the CFI investment are defined according to the timeframe in which they are expected to occur. Immediate outcomes principally involve changes in the infrastructure research environment. Intermediate outcomes relate to the use of the infrastructure and its effects on researchers and collaboration and productive networks. Long-term

Table 1. OMS outcome categories and overarching indicators for theme-level analysis at a research institution

Categories of outcomes	Indicators
Strategic research planning (SRP)	SRP process
	External influences on SRP
	External effects of SRP
	Complementary investments by institution (human and financial)
Research capacity	Investment value of infrastructure
	Capabilities (technical and operational)
	Sponsored research funding
	Critical mass
	Recruitment and retention of researchers
	Linkages/visiting researchers
	Multidisciplinarity
Highly qualified personnel (HQP)	Number of research trainees
	Nature of training – quality and relevance
	Knowledge transfer through HQP (e.g. number of graduates pursuing careers in private industry and in the public sector)
Research productivity	Competitiveness
	Research productivity (dissemination/awards)
	External research linkages
	Sharing of infrastructure
Innovation/ extrinsic benefits	Leverage of CFI expenditures
	Type and amount of knowledge and technology exchange
	Key innovations (economic, social, organizational) – number and importance
	Evolving industrial clusters

Note: For a complete list of OMS indicators, sub-indicators and definitions see <http://www.innovation.ca/docs/accountability/OMS/2010/OMS_instructions_institution_2010.pdf>

outcomes and ultimate impacts reflect broad R&D and societal impacts of the CFI investment.

To assess the impacts of the CFI expenditures, the current status of each outcome category (i.e. in the most recent year for which data are available) is compared to the pre-CFI period, specifically, the year prior to the first CFI award in the theme.

The outcome categories are broad and the indicators address a range of what are traditionally described as outputs, outcomes and impacts (see e.g. the discussion in AUCC, 2006: 2–5). These include:

- the direct outputs of research and knowledge transfer (e.g. research publications and citations, patents and licences, and research-trained graduates);
- the more or less direct outcomes of research (e.g. changes in government programs or public services, new products, services, and production and delivery processes);
- the indirect outcomes (e.g. strategic thinking and action on the part of the institution, the creation of new networks and linkages, especially international and more effective research environments for research training);
- the socio-economic impacts of research on health, the economy, society and the environment.

The CFI deliberately designed the process to capture the impacts of CFI expenditures on behaviour and interactions within the research institutions and between the institutions and the wider society, including the 'end-users' of research findings in the private and public sectors. Social innovations and benefits are given equal place with economic and commercial impacts (see e.g. AUCC, 2008: 66–67). A further strength of the methodology is that despite the diversity of themes, the indicators are common to all themes and, therefore, the results can be combined to produce a picture of the trends in outcomes across Canada.

Institutional self-study

Once a specific theme for the OMS has been selected, the research institution completes an in-depth questionnaire, called an institutional data document (IDD), that covers each indicator with one or more questions. Some of the 50-plus questions ask for quantitative data (e.g. the number of faculty members recruited), while many require qualitative judgements by the institution (e.g. assessments of the most important socio-economic benefits of research in the theme). The OMS instructions for the institution, including guidelines and the template for the IDD, can be found at this link: <http://www.innovation.ca/docs/accountability/OMS/2010/OMS_instructions_institution_2010.pdf>.

Review and validation by expert panel

For each OMS, the CFI assembles an expert panel that visits the institution, and meets with the researcher group and senior university administrators (e.g. vice president-research, faculty deans or department heads) who provide their own assessment of the outcomes. The expert panel consists of a chair and four members, including senior Canadian and international experts from the academic, public and private sectors. Selected experts are screened for conflict of interest, sign a CFI ethics and confidentiality form, and are requested to maintain the confidentiality of the review process and OMS documents. The CFI makes a conscious effort to include at least one member who has experience with knowledge translation in the theme area, ideally from an end-user perspective (see Grant *et al*, 2009: 63, regarding end-user participation in assessment panels). While the CFI covers all travel expenses,
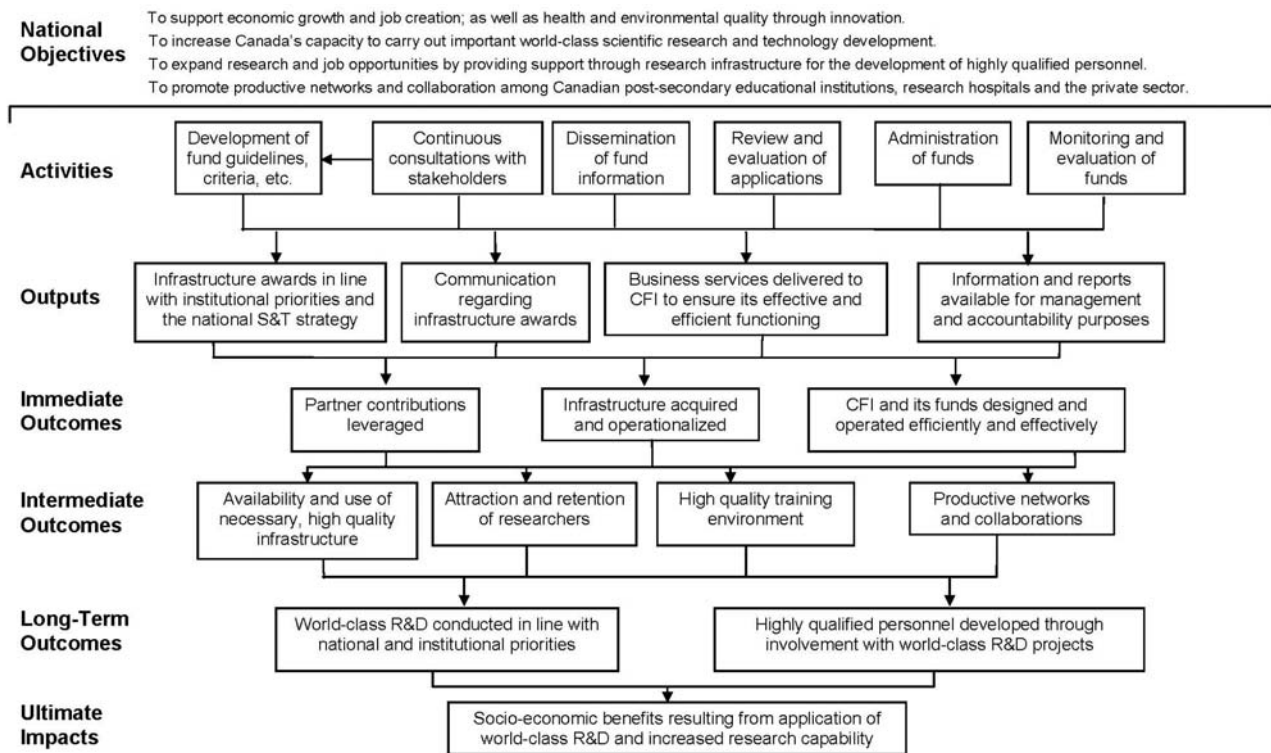
Figure 1. Logic model 2008

the panelists are not remunerated for their service. The OMS visits are chaired by a senior Canadian advisor, normally a retired public servant or academic, who has in-depth knowledge of the academic research landscape. This role is restricted to a small number of advisors, each of whom chairs multiple expert panels, thereby providing a valuable element of consistency across the studies.

The expert panels conduct a thorough review of the IDD, provided in advance of the visit, along with background documents such as the project leaders' CVs, institutional strategic research plans, the most recent project progress report,[2] and the most recent annual institutional report on the overall accomplishments and challenges at the institution, all of which are made available to the expert panel members prior to the site visit. The expert panels then visit the institution for a day and a half of meetings. These meetings are structured around presentations by institutional representatives, with each presentation addressing one of the outcome categories (outlined in Table 1). These presentations are followed by question-and-answer sessions during which the expert panel seeks a better understanding of the evolution of the theme activity and its impacts, along with further evidence regarding assertions of quality and impact.

Reporting

The expert panels are provided with a template of the OMS indicators with which they rate the current state of the indicator under consideration, the extent of change resulting over the period under study and

the impact of the CFI's funds, on a five-point scale. This approach allows for reliable and replicable ratings of diverse themes and for a transparent review process. During the on-site meetings, there are *in camera* working sessions in which expert panel members develop consensus ratings on the evaluation indicators for each outcome category. The expert panel chair drafts the expert panel report, drawing on the questionnaire results and other documentation furnished by the institution, the expert panel's discussions and assessments during their site visit and their consensus ratings on the outcome indicators. Following validation by the expert panel and the institution's review for accuracy, a complete expert panel report is produced for each OMS.

Attribution and incrementality

As noted above, CFI expenditures are part of an array of federal and provincial research funding programs that support each institution's research effort. In addition, each institution allocates funds from within its own operating budget to support research. Many projects also receive research funds from the private sector, private foundations (e.g. hospital foundations) and other non-governmental sources. One of the important challenges for the OMS methodology, and for the expert panels, is to identify the extent to which impacts, both within the institution and in the wider society, can be reasonably attributed to the CFI expenditures. The expert panels also look for evidence of synergies resulting from the interplay between CFI expenditures and other research funding programs. A number of items on the

questionnaire are designed to elicit information on this topic; for example, on complementary investments by the institution in the research theme, infrastructure investments in the theme from other funding sources, and the impact of CFI-funded infrastructure on research collaborations with external partners.

Expert panel members are charged with making qualitative assessments regarding, for example, impacts of CFI funding on the institution's ability to attract additional sponsored research funding, its ability to attract and retain faculty members, the degree of multi-disciplinarity at the institution, the quality of trainees and training, and the institution's research productivity. Importantly, the expert panels also attempt to assess the extent to which CFI-funded infrastructure has contributed to the institution's external networking, research partnerships and knowledge transfer, as well as broader societal impacts (e.g. evidence of an evolving industrial cluster). In this process, concrete and detailed examples are very important (see e.g. Grant *et al*, 2009: 61). The expert panel members' expertise and familiarity with similar national and international initiatives allow them to evaluate the data presented and compare outcomes in an international context.

The questionnaire asks for longitudinal data on many questions so that the expert panels can assess the incremental impacts of CFI funding over approximately a decade. While this time period is adequate to evaluate incremental impacts on the institution's research effort, it may well be inadequate to permit thorough assessments of societal impacts of basic research. These can take decades to materialize, as Martin and Tang (2007: 4), among others, have pointed out. Nevertheless, as demonstrated in the ensuing 'OMS Findings' section, the expert panels have been able to identify actual and potential societal impacts that can be attributed to CFI expenditures.

Collaboration in a learning partnership

The success of an OMS depends heavily on the commitment of the institution. The process is relatively resource-intensive and once the OMS is successfully completed, the CFI provides a one-time

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contribution of C\$10,000 to the institution. The CFI makes it very clear to participating research institutions that future CFI funding for research infrastructure is not contingent on the OMS results and that the results are not used for any ranking of institutions or research projects. Rather, the OMS is intended to serve as a learning partnership. The detailed expert panel reports are intended to provide both the CFI and the institution with important information for continuous improvement purposes. The reports are shared with the CFI Board of Directors and internally at the CFI. Although individual reports are not made public, periodic OMS summary documents (see Rank and Halliwell, 2008) are made public with the permission of institutions. Taken together, these summaries provide valuable data for addressing CFI accountability and transparency requirements.

Elements of the OMS process are used by other funding organizations in Canada and internationally. Among them are the R&D portfolio assessments that resemble the thematic approach (Jordan and Teather, 2007: 150–151 and Srivastava *et al*, 2007: 152–153) and program reviews by expert panels such as the NSF's Committees of Visitors <www.nsf.gov/od/oia/activities/cov/>. There are also particular similarities to the United States Department of Agriculture's portfolio review expert panel (PREP), a portfolio assessment tool that incorporates both a self study and an assessment review by an expert panel (Oros *et al*, 2007: 158–165). While several aspects of the OMS tool are familiar in the field of evaluation, the OMS is unique in its focus on medium- and long-term outcomes, its objective to serve as a learning exercise for both the CFI and the institution, its ability to administer a single assessment that encompasses a decade's worth of funding and projects, and its focus on the meso level of investigation. Moreover, because the CFI funds 40% of the cost of research infrastructure, there is an added level of complexity in assessing its contribution to research outcomes. The OMS approach allows for this kind of assessment while identifying complementarity or synergy with other partner funding.

The CFI developed the OMS in part to contribute to the expanding analytical frontier in public sector R&D evaluation. Table 2 compares the OMS methodology with other typical Canadian public sector evaluation approaches to indicate the niche this exercise fills and indicate where it might be considered by other Canadian or international organizations faced with similar needs.

OMS Findings

Findings from the 17 OMS visits conducted between January 2007 and February 2010 consistently show that CFI-funded infrastructure has had a significant impact on many aspects of the selected research themes. Perhaps the most significant overall findings

Table 2. OMS compared to other Canadian public service evaluation approaches

Common evaluation approaches	*Performance measurement/ dashboard indicators*	*Case studies/success stories*	*Expert review panels*	*Typical program evaluation/overall evaluation*	*Outcome measurement study*
Characteristics					
Defining traits	Organizational database; regular reporting from participants/clients	In-depth studies of particular participants/ recipients; often qualitative; typically purposefully selected; often interview-based	Expert opinion from panel who interpret results and data provided; typically report on a long period e.g. 5–10 years	Report based on surveys, interviews, and document review, often by independent consultant; usually covers a period of 2–5 years	Combines survey data and data from institutions database, with an expert panel review, using a unit of analysis based on cluster of actual activity in a theme
Strengths	Gives real-time data to managers; records what took place for future study	Detailed description/ narrative, with contextual analysis; may reveal unexpected mechanisms of change; outcomes; can have persuasive power for certain audiences	Informs high-level strategy and policy; brings in comparative knowledge from multiple contexts; can give seal of approval and validation to existing strategic directions	Provides input for major program-based decisions; can uncover impacts	Combines positive attributes of other methods: reflexive controls (i.e. before/after, longitudinal data), comparative use of natural variation between sites, ruling out alternative explanations for impact observed; validation by independent expert judgment; open format Q&A gives ability to detect unexpected mechanisms or outcomes; generalizability that increases after multiple visits
Weaknesses	Questions of impact or causation, rarely amenable to narrow quantitative definitions and may rely on un-validated self-reporting; may require significant resources from those reporting; can easily result in unwieldy quantities of data	Low generalizability; high bias; difficult to report in succinct format	Depends entirely on objectivity and expertise of expert panellists and quality of information supplied; findings tend to be high-level, vague; infrequent, based on regular planning schedule, not information needs	Success often relies heavily on external consultant expertise and knowledge; timing is often not aligned with timelines for impacts (especially in R&D funding); large scope can result in lack of depth on individual issues, focus on 'macro' level	Does not have the scientific rigour of randomized controlled experimental design; burden on those reporting needs to be considered
Relative cost	Low	Low	Medium/high	Medium/high	Medium
Ideal use	Statistics for reporting purposes and responsive management decisions; raw data for other evaluation approaches; accountability statistics	Exploratory studies where little is known about mechanisms of action or unintended effects; communication purposes; complementary to other studies	Strategic guidance; political credibility; public accountability	Responding to major program-level questions (continuation, re-design); accountability; organization-wide approach, appropriate where programs have shared objectives	Obtaining comprehensive validated information on results of interrelated programs and processes on the ground, along with the narrative of how and why the effects are or are not taking place

Note: Table 2 shows some common approaches and situates the outcome measurement study among them

were the 'facility' and 'organization' effects that were first identified following an analysis of the initial nine OMS visits (Rank and Halliwell, 2008). The 'facility' effect refers to the collective impact of integrated suites of state-of-the-art research equipment, whereas the 'organization effect' refers to the demonstrable impact of deliberate planning of diverse activities around such facilities. In several of the themes, the 'facility effect' was evident for integrated suites of research infrastructure that led to significantly increased multidisciplinary and cross-sectoral research cooperation. The impact of the 'organization effect' was manifested in the successful outcomes of institutions that deliberately focused their strategic research plans and translated them into their facility designs and related research, training, and knowledge transfer activities. In situations where the planning was less cohesive, the outcomes assessed were less pronounced than in those institutions that had a strong 'organization effect'. The key findings for the five outcome categories include the following.

Strategic research planning

By requiring institutions to have strategic research plans and by designing its funding programs to encourage institutions to think strategically about impacts and efficient use of infrastructure, the CFI has had a measureable effect on strategic planning at most of the institutions studied. Another driver of the institutional strategic plans is the partner funders, especially the science and technology priorities of the provincial governments. One striking example is the long-term and intensive collaboration between the University of Guelph and the Ontario Ministry of Agricultural and Rural Affairs. Through this collaboration, cutting-edge research to help improve food, health and environment is facilitated. This partnership and the training, testing and innovative research it supports help make Canada's agri-food sector more competitive at home and abroad. Coupled with CFI support for analytical equipment and facilities this shared vision has contributed to the university's international leadership in food sciences and cognate fields. The expert panel concluded that the overall impact of the CFI and its partners allowed the institution to 'think big' in novel ways that were not previously possible.

Research capacity

Prior to CFI expenditures, infrastructure-related research capacity in the OMS themes was rated by the expert panels as, on average, low. The expert panels assessed as very high the level of change in such capacity from pre-CFI to currently. As well, the CFI's impact on both the technical and operational capabilities of research infrastructure in most theme areas has been profound, with the majority of research equipment currently used rated as state-of-the-art. The number of faculty members in the theme areas increased in all cases, ranging from 1.5 to 3 times. All themes showed high levels of multi-disciplinarity, and some themes were also characterized by high levels of multi-sectoral interaction.

The OMS helped the CFI identify several successful examples of integrated suites of equipment in facilities that were explicitly designed to foster multi-disciplinarity and accessibility to multiple users. Such facilities include the 4D Labs, a materials research laboratory at Simon Fraser University in British Columbia that has close collaborations with the local industrial sector. Another example is the University of Guelph's Centre for Food and Soft Materials Science in Ontario that has strong research links to provincial government agricultural organizations and with industry in the area of food science.

Highly qualified personnel

The OMS revealed that there has been a significant increase between the pre-CFI period and the present in the number of HQP annually trained, at the masters, doctoral and post-doctoral levels. Higher-quality graduate training is indicated within several of the themes by the high proportion of students holding competitive graduate awards. For example, in nanotechnology at the University of Toronto over half of the Canadian graduate students were recipients of competitive scholarships. The OMS expert panels also observed that CFI-funded projects, along with the strategic research planning and the integrated nature of the facilities, have had a high impact on the quality of training of graduate and undergraduate students.

For all theme areas, the expert panels found that research knowledge was largely transferred through the training of HQP. In particular, the movement of individuals from academia to user organizations is a key mechanism for innovation. For example, upwards of 50% of the graduates in materials sciences and technology domains pursue careers in the private sector.

Research productivity and competitiveness

In nine of the 17 OMS visits, the researchers and their research programs were found to be internationally competitive, while in eight visits, they were at least nationally competitive. In several themes, there was virtually no research strength prior to the creation of the CFI. The expert panels found the impact of CFI-funded infrastructure on the quantity of research produced in the themes to be mostly medium-to-high, and the impact on the quality of the research to be high. Expert panels occasionally had concerns about the level of research productivity in particular themes or sub-themes, but noted that this could be explained by the initial demands on the time of project leaders to implement major CFI-funded projects and the time required for newly hired researchers (often foreign or repatriated Canadian researchers) to establish themselves. Networking and collaboration, an additional indicator of productivity, was assessed as high for most themes, with numerous collaborations within and beyond Canada, and with partners spanning the academic, private, and public sectors. There are many examples of informal and formal networks predicated on the CFI-funded infrastructure, among them a national network for atherosclerosis imaging, and partnerships between the University of New Brunswick's Canadian Rivers Institute and forest industries and hydroelectric companies throughout Canada.

Innovation

The OMS reports documented many specific activities and mechanisms aimed at innovation and the generation of socio-economic benefits. A variety of means linked researchers to external users, including the movement of HQP into user organizations, contract research, and provision of fee-for-service testing. Although traditional measures of technology

transfer were of high importance at most institutions, the expert panels expressed some concern that certain themes were not fully exploiting their potential in relation to patenting and licensing.

Social and economic benefits included:

- Improvements in health care (e.g. improved surgical treatment of brain tumours through pre-op MRI and intra-op ultrasound);
- Improved regulatory measures (e.g. for drinking water quality);
- New structural codes and standards in construction;
- New and improved products and processes (e.g. technologies for efficient oil recovery);
- Improved public policies (e.g. for food safety issues); and
- Environmental benefits (e.g. research support to the federal government's Environmental Effects Monitoring Program).

It is apparent that the means of knowledge transfer extend well beyond patenting and licensing and that the end-users encompass different sectors and segments of society.

Lessons learned and conclusions

On the basis of the 17 OMS visits, it is possible to highlight a number of lessons learned and conclusions regarding the strengths and challenges of the OMS.

First, the combination of quantitative and qualitative measures in the OMS, together with the use of multiple outcome categories and indicators, provides for a richness of analysis that is not possible with evaluations focused on a single outcome category (such as commercialization of research results), or that rely solely on either quantitative data or qualitative assessments of individual cases. For example, standard data on technology transfer outputs and outcomes seldom captures the full spectrum of knowledge transfer activities beyond traditional measures such as patents and licences. In several of the OMS reports and site visit presentations, the researchers reported other links with industry, such as pre-commercialization prototype product testing. This type of university–industry interaction would not necessarily have been identified through other evaluation methodologies.

An OMS expert panel report combines longitudinal data on a range of quantitative indicators (e.g. intellectual property data, faculty recruitment and retention data, student numbers, research funding data and survey data) with case studies and concrete examples of external impacts. As well, the reports provide for qualitative assessments by the expert panel members regarding, for example, the potential for non-economic societal impacts and the obstacles and challenges facing the institution in realizing these impacts. Furthermore, the OMS process can take into account contextual considerations and indirect or unintended impacts. At the same time, the inclusion of a large number of quantitative indicators can serve as a 'reality check' on expert panel perceptions of particular institutions, researchers, or types of research — one of the frequent criticisms of purely qualitative, expert or peer-based assessment methodologies (see e.g. the discussion in Butler, 2007: 569).

This combination of indicators leads to a rich analysis of the impacts of CFI funding, allowing the institution and the CFI to explore aspects that would not be possible otherwise. As well, the checks and balances incorporated into the OMS provide a comprehensive overview of outcomes and impacts without introducing the gaps and potential distortions that can be the result of a single methodological approach.

Second, we have learned in a very concrete way that the impacts resulting from CFI funding are as varied as the scientific endeavours encompassed by the OMS themes (ranging from health and life sciences, nano-sciences, environmental sciences, engineering, information and communications technologies to social sciences). Similarly, the OMS has highlighted the importance of different research contexts and environments, regional economic realities, varied research partners, and diverse rates of evolution of research impacts and knowledge transfer. Thus, there is no single gold standard for assessing research outcomes and impacts. On the contrary, the OMS reveals that there can be multiple and different modes of innovation and socio-economic impacts resulting from CFI-funded infrastructure. The OMS methodology allows for the capture and analysis of diverse research impacts, reflecting the CFI's investments across all disciplines, as well as the integration of such contextual considerations inherent in Canada's heterogeneous research environment.

The OMS has proven to be a generic tool that may be applied to the study of multidisciplinary and interdisciplinary research domains which span the fields of natural sciences and engineering, health and life sciences, and social sciences. The methodology was successfully applied to diverse thematic areas, each of which involved multiple projects with CFI funding ranging from a few thousand to tens of

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millions of dollars; infrastructure ranging from a single laboratory to major facilities infrastructure; stages of maturity ranging from newly created to well-established projects; and the involvement of diverse research groups ranging from a single project leader to large research groups from across disciplines and sectors.

There are, however, a few research scenarios that are not readily assessed using the OMS. It is challenging to use the methodology to study large regional or national endeavours, such as research platforms that serve hundreds or thousands of users. Assessment is particularly difficult with virtual resources such as databases, digital libraries, or high-performance computing. But despite these limitations, the OMS has demonstrated that its approach effectively assesses research outcomes for a diverse portfolio of research projects that span the funding spectrum and many disciplines.

Third, as a learning partnership tool, the OMS is proving useful for all participants. The CFI itself has built expertise on improving the assessment of the outcomes of its investments. For the institutions, the expert panel reports provide external, expert advice that can be taken into account as they evolve existing projects, plan for future CFI applications, and develop new strategic research plans. Importantly, institutional participation in an OMS tends to generate its own process effects on institutional behaviour. While, as Butler (2007: 571–572) notes, such behavioural effects can be a cause for concern in research evaluation exercises that are linked to future funding, they can be a desirable outcome of an exercise that is designed, in part, as a learning process. For example, in completing the OMS questionnaire and associated documentation, and in interacting with the expert panel, some institutional participants have identified new opportunities for further advancing research and research training in the theme area under assessment. They may discover that certain institutional data are not collected, and may opt to track such information in the future. Career paths, for example, are challenging to track once graduates leave an institution. However, they constitute an important indicator of the impact of research expenditures on the training environment and of the value of the skills and knowledge imparted to students and technical staff. The OMS can help in this regard.

In the course of the site visits, the expert panels stress the importance of links between the projects within a theme and the institution's strategic research plan, and they look for evidence of effective interactions both within the institutions and between the institution and external research and knowledge translation partners. This emphasis by the expert panels has led some institutions to pay greater attention to both strategic planning and the development of external partnerships. The OMS process and expert review can identify barriers to collaborative research and means to enhance collaborations within

or outside the institution. During one of the visits, for example, the expert panel recommended that a nanotechnology group explore collaborations with the medical sciences — an untapped link that the panel members felt had significant potential for knowledge and technology transfer. In other cases, researchers within multidisciplinary themes may themselves recognize new collaborative opportunities as they complete the data report or interact with expert panel members in the course of the OMS visit.

Fourth, the combination of two purposes — learning and accountability — of the OMS does involve some trade-off, as is common in evaluation. (For example, see Rossi *et al* [2004: 34], which outlines the differences in the approach typically required for evaluation for program improvement and evaluation for accountability.)The fact that the OMS results are not linked to future funding encourages institutions to be candid and comprehensive in their self-assessments. So too does the fact that the in-depth expert panel report is not made public. This, however, also means that the CFI is not able to make maximum use of the rich detail and analysis in the individual expert panel reports for public accountability and communications purposes. Nevertheless, the CFI does summarize, and periodically report on the overall trends of the OMS findings in public documents (see Rank and Halliwell, 2008).

Moed (2007: 576) argues that 'the future of research evaluation rests with an intelligent combination of advanced metrics and transparent peer review'; and Grant *et al* (2009: 57) observes that one of the challenges of any allocation system is to 'link performance to funding in the intended way in a transparent manner'. The OMS results are not linked to future funding and, therefore, the OMS is not part of an allocation system *per se*. The process and the results, however, are completely transparent for the participating institutions and the CFI. As Claire Donovan has noted, in Australia, a perceived lack of transparency in the assessment panel process may have contributed to the demise of the RQF before it even got off the ground (Donovan, 2008: 49). But unlike the OMS, the RQF results were to be linked explicitly to future funding allocations. In any case, the CFI has decided that the current balance between learning and accountability is the best approach because it allows the institutions to better understand the impacts of their research activities while providing the CFI with sufficient information to remain accountable.

Fifth, notwithstanding the trade-off discussed above, the OMS has proven to be an important complement to the set of accountability and performance measurement instruments that the CFI has developed and embedded in its integrated Performance, Evaluation, Risk, and Audit Framework (CFI, 2008). The most detailed and in-depth information at the institutional level is contained in the expert panel reports. While the quality of summary reporting is limited to

some extent by differences in data reporting across institutions, the summary data from the OMS studies are, nevertheless, indicative of overall directions in research and its impacts. The CFI is able to test conclusions from summary data against the conclusions drawn by the expert panels, institution-by-institution. As well, the use of ratings for each indicator, allowing for comparison of ratings across all reports, enables a further element of assessment consistency. Finally, the institutional data collected through the OMS questionnaire and validated by the expert panels can, to an extent, be used to corroborate information contained in the institutions' own project progress reports. These multiple validation pathways help to ensure a high-quality assessment process.

In conclusion, the OMS methodology has proven to be an effective vehicle for capturing the broad spectrum of research outcomes and impacts resulting from the use of CFI-funded infrastructure. Although a significant undertaking, it is a feasible process for both the CFI and institutions in terms of its demands on resources. As well, the OMS is a valuable complement to other evaluation activities and has proven important to the CFI in meeting its performance measurement and accountability requirements.

The dual learning and evaluation purposes of the OMS, its balanced quantitative/qualitative approach, its carefully selected categories and indicators, and its expert panel validation have made the OMS an innovative and valuable addition to the CFI's evaluation toolkit. Much remains to be gained by the CFI, the institutions, and partner funders. Added value arising from the OMS methodology will be the further engagement of the Canadian evaluation community in a discussion around this avenue of inquiry and the translation of the OMS findings into program and policy development.

Acknowledgments

Notes

1. For a complete list of the themes covered by the OMS see: <http://www.innovation.ca/en/evaluation/outcome-measurement-study-oms/oms-visit-schedule>, last accessed 1 November 2010.
2. CFI-funded institutions submit annual project progress reports

each year for five years following award finalization. The reports capture information on indicators in the five outcome categories outlined in Table 1.

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Research Evaluation