Indicators to Support Innovation Cluster Policy

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Paper prepared for a Special Issue of the
International Journal of Technology Management

"Innovation Networks and Knowledge Clusters in the Glocal Knowledge Economy and Society:
Insights and Implications for Theory and Practice"

20 May, 2007

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Abstract

The elaboration of a conceptually grounded and easily replicable set of indicators for gauging the current state and future prospects for cluster development is an essential aid for both policy makers and cluster advocates. Many different methods and techniques for analyzing clusters have been proposed in the literature, but no standardized approach has emerged, and numerous challenges exist in adapting these approaches to the analysis of emerging and established clusters in high technology industrial sectors. We propose here a parsimonious, generic cluster framework comprising six constructs and thirty-four variables, and we describe the process for using the framework in the analysis of clusters. Finally, we summarize the findings and implications from the analysis of the current state of eight cluster initiatives of the National Research Council of Canada. The framework and methodology have proven to be effective in analyzing clusters quickly, consistently, and cost-effectively.

Keywords

Clusters, innovation, indicators, framework, policy, analysis, strategic planning, methodology

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1 Introduction

Cluster theory suggests that competitive advantage derives not just from firm-based resources and capabilities, but also from the resources and capabilities located in the firm's geographically proximate business environment. Some empirical research has shown that clustering can produce significant positive effects on rates of new firm formation and firm productivity, innovation, profitability, and growth (Beaudry and Breschi, 2003; Boschma, 2005; Gordon and McCann, 2005; Rosenfeld, 2007). The pursuit of such benefits stimulated the acceptance of 'cluster theory' within public policy in the early 1990s when practitioners in the public, private, and academic sectors embraced the notion as an answer to the challenges created by increasing international competition and the growing importance of innovation in the knowledge economy. Governments at all levels have now adopted the concept as a tool for promoting national and regional competitiveness, innovation, and growth (OECD, 1999, 2002; Government of Canada, 2001).

Despite the fascination with clusters in both academic and policy circles, key aspects of the concept remain highly disputed. The rush to employ cluster ideas has run ahead of many conceptual, theoretical, and empirical issues (Martin and Sunley, 2003). In 1989, when cluster concepts were gaining traction in economic development circles, Thompson noted that prevailing theories of technology-based development were unable to distinguish between necessary and sufficient conditions for development, or between fixed and manipulable features, "both of which are important considerations for planners and policymakers" (Thompson, 1989). While a significant literature on clusters has appeared since that time, the definition of the concept is still contested, the means to identify and promote clusters are numerous, and the 'empirical case' for clusters is still in its early stages (Asheim, Cooke and Martin, 2006; Martin and Sunley, 2003). Reviews of the cluster research literature point out that the concept is too packed with divergent or contradictory meanings to be coherent (Benneworth et al., 2003; Boschma, 2005; Malmberg and Power, 2005; Martin and Sunley, 2003; Davies and Ellis, 2000). Knowledge of clusters is thus still highly fragmented, very descriptive, often qualitative, and inconclusive on many points.

If clusters are to be effectively fostered through public policy and private sector initiatives, there is a need for a systematic understanding of the factors that contribute to the creation and development of clusters, and the factors that will influence the success or failure of clusters and cluster policy. Quantitative indicators of both the presence and relative level of development of clusters are a necessary requirement for such an understanding. Yet much of the analytical and policy development work with clusters has relied upon a diverse set of quantitative measures that operate at widely varying conceptual and spatial scales (Raines, 2003). The elaboration of a conceptually grounded and easily replicable set of indicators for gauging the current state and future prospects for cluster development is an essential aid for both policy makers and cluster advocates working in this field.

Canada's National Research Council (NRC) has been a proponent of cluster-based development since the mid-1990s (National Research Council, 1996). NRC has launched a number of initiatives to support the growth of innovative enterprises clustered around

NRC research institutes in different regions of the country (National Research Council, 2002a). As part of the implementation of these initiatives, NRC has designed an approach to analyze the strengths and weaknesses of the clusters in which it is involved, to support policy and industry actions to foster the development of clusters, and to measure the progress of the clusters over time.

This paper explores some of the conceptual issues and methodological challenges encountered in analyzing the clusters supported by NRC. We begin by reviewing some of the challenges in defining innovation cluster indicators. We then propose a parsimonious, generic cluster framework comprising six constructs and thirty-four variables, and we describe the process for using the framework in the analysis of clusters. Finally, we summarize the findings and implications from the analysis of the current state of eight NRC cluster initiatives. Our intended contribution is conceptual as well as methodological. Our conceptual framework provides the context for our methodology, which is straightforward and replicable.

2 Cluster Indicators

Cluster analysis enables accurate and effective policy and management intervention. An understanding of a cluster's internal workings – components, structures, processes, routines and development pathways – is critical to support the development of a successful cluster.

And yet, systematic understanding of cluster dynamics and the mechanisms for effective strategic planning have been hampered by significant challenges. Foremost among these – indeed for science and technology indicators as a whole – has been the selection and collection of indicators. Official Science, Technology and Innovation (STI) statistics, cluster mapping techniques (which use official STI statistics), qualitative interviews with cluster actors, and purpose-designed surveys all entail certain limitations for analyzing clusters:

- *Official STI Statistics*. Numerous STI statistics are relevant for cluster analysis (e.g., investment in R&D, innovation, S&T human resources, patents, technology balance of payments), but such indicators are not sufficient on their own since they fail to capture basic structures and processes that are essential to understanding the state and performance of a cluster. For example, supply chain and forward market linkages, partnerships, knowledge sharing, social capital, and local sources of tacit knowledge are not reflected in these measures. Moreover, STI statistics are structured according to conventional industrial categories and usually do not capture new technology sectors. Also, STI statistics are frequently unavailable at the required level of geographical disaggregation for small clusters due to confidentiality restrictions.

- *Cluster Mapping*. Frequently, indices based on STI statistics are used to map the existence of clusters. For example, location quotients (the ratio of the regional industry's share of total regional employment to the national industry's share of total national employment) are commonly used to compare regional economies against other localities. A quotient higher than one indicates a high degree of specialization in the activities that comprise the cluster compared to other activities.

A more sophisticated version of location quotients is represented in the cluster mapping technique of Michael Porter's Institute for Strategy and Competitiveness at the Harvard Business School. The Cluster Mapping Project uses information drawn from the County Business Patterns data on employment, establishments and wages by four-digit SIC codes, plus patent data on location of inventor, to identify the core clusters in a region using the correlation of industry employment across geographic areas (Porter, Monitor Group, et al., 2001; Porter, 2003).

A different approach used by Bergman and Feser involves factor analysis of input-output tables to construct value-chain templates of the trading patterns within regional economies to identify clusters (1999). A related technique is the analysis of innovation interaction matrices, derived from surveys such as Statistics Canada's Innovation Survey or the Community Innovation Survey of Eurostat, to describe flows of innovations between innovation producers and innovation users.

However, all of these approaches share the sectoral definition and geographical disaggregation limitations of their underlying STI statistics, making their use problematic for small clusters in new technology areas.

- *Interviews*. Many analysts note that clusters can be studied by using expert opinion, self-identification, or other qualitative research techniques, including detailed interviews with a broad cross-section of cluster participants or ethnographic accounts of the cluster's dynamics by leading experts. The application of these techniques can provide a rich insight into how clusters operate. Most frequently this technique has been used to undertake a detailed study of an individual cluster, but recently it has been deployed in a series of comparative cross-cluster studies, such as Porter's study for the US Council on Competitiveness (2001) and the Innovation Systems Research Network's (ISRN) national study of clusters in Canada (Holbrook and Wolfe, 2005; Wolfe 2003; Wolfe and Lucas 2004, 2005). However, they rely on opinion, do not generally generate quantitative results, and are resource intensive.

- *Surveys of firms and innovation actors*. Survey techniques have often been applied in cluster analysis to generate a set of customized data about key cluster dynamics. The use of survey methods, as opposed to the use of the official STI statistics discussed above, means that the data collected are usually not comprehensive, i.e. they are from a sample, rather than from a full population. Also, lack of standardization in survey design means that results cannot be easily compared with studies conducted by other researchers. However, the custom design of the survey means that the cluster analysis is not dependent on existing generic statistical data sources or categories – stakeholders can be specifically targeted and the data gathered can be tailored to the specific issues of interest in the cluster analysis.

Given these considerations, and a review of Statistics Canada data for several clusters, NRC determined that the use of official STI statistics and derived indices would not be suitable for their purposes. Therefore, the NRC approach to cluster analysis, described below, relies primarily on interviews and surveys of firms and innovation actors.

3 NRC Cluster Initiatives

NRC has already played a key role in the growth of two of Canada's better known technology clusters: the biopharmaceutical cluster in Montreal, and the agricultural biotechnology cluster in Saskatoon (Niosi and Bas, 2000; Ryan and Phillips, 2003). Recognizing that stronger innovation performance in Canada's regions and communities is integral to national growth, and in response to the federal government's vision for innovation, commercialization and economic development, NRC launched a number of technology cluster initiatives to support the growth of new clusters. NRC has articulated the following four goals for these initiatives (NRC, 2002b):

- Creating a globally competitive research and technology base for cluster development at the community level;
- Supporting community leadership, champions and knowledge-based strategies;
- Working with stakeholders to leverage funding and new investment in community clusters;
- Stimulating the emergence of new firms, jobs, exports and investment growth.

Eleven locations across Canada are currently following this cluster approach. Initiatives include ocean technologies, e-business, IT and life sciences in Atlantic Canada; nanotechnology in Alberta; fuel cells and hydrogen in British Columbia; nutraceuticals and sustainable infrastructure in Saskatchewan; biodiagnostics in Manitoba; aluminum transformation in Québec; photonics in Ontario; and programs built upon NRC strengths in other regions (National Research Council, 2002a). Many of these cluster initiatives involve partnerships with local universities and regional development agencies.

Through its community focused approach, NRC and its partners encourage networked clusters of innovative firms, supported by strong research programs and technology assistance services. NRC research institutes and networks are important drivers, bringing local and regional interests together with groups of innovative companies around a common area of technology. These unique technology-based clusters are focused on matching local and regional strengths to national and global economic opportunities. The ability to measure the evolution of these clusters is vital to the planning of NRC's continuing activities.

4 NRC's Framework

NRC needs to monitor the progress of its initiatives to support reporting requirements to the federal government, to assist in program planning and management of current and future initiatives, and to aid communications with stakeholders within the clusters (industry and local government), the provinces, and the federal government. However, NRC has found few relevant sources of data to support their planning and performance measurement activities. As noted above, many different methods and techniques for analyzing clusters have been proposed in the literature, but no standardized approach has emerged, and numerous challenges exist in adapting these approaches to the analysis of emerging and established clusters in high technology industrial sectors, such as those that have been the focus of NRC's initiatives. Therefore, NRC commissioned the development of a *framework*, *process*, and *tools* for cluster analysis, which have now been applied to eight clusters.

In the absence of underlying theory and conceptual foundations, "a disparate array of indicators and measures" (Geisler, 2005) cannot provide a sound basis for rational policy action at the level of the cluster. Therefore, an underlying conceptual framework is necessary to structure cluster indicators. The NRC framework modifies and extends the previous work of Porter (1990, 1998), and it incorporates the findings of the Innovation Systems Research Network concerning clusters in the Canadian context.

The NRC framework is illustrated in Figure 1. It consists of two parts, Current Conditions and Current Performance. Current Conditions consists of three constructs that measure the cluster's supporting organizations (including NRC), the competitive environment of customers and competitors, and the factors in the environment of the cluster that influence all of these actors (e.g. availability of HQP, business climate, etc.).

Current Performance consists of three constructs that measure the cluster's significance in terms of the number and size of core firms, the breadth of their responsibilities, and their reach to distant markets; interactions within the cluster and with the rest of the world; and the cluster's dynamism in terms of innovativeness and growth. The performance of the cluster as a whole is dependent on the success of the individual firms and moderated by the cluster factors, supporting organizations, and customers and competitors. There is a temporal disconnect between Conditions and Performance in that current conditions impact future performance, and current performance is the result of past conditions.

'Supporting Organizations' in the framework is analogous to Porter's 'Related and Supporting Industries', although government-supplied services are included here. 'Competitive Environment' in the framework is analogous to the combination of Porter's 'Firm Structure, Strategy, and Rivalry' and 'Demand Conditions'. These are combined in our cluster model since local rivalry and local demanding customers are much less important in Canadian clusters than in clusters in the United States, which are typically larger and more self-sufficient. 'Cluster Factors' is synonymous with 'Factor Conditions' in the Porter Diamond.

However, in contrast to the Porter Diamond, the suite of 'Current Performance' indicators in the framework will permit cause (conditions) and effect (performance) relationships to be identified over time as longitudinal data are collected for individual clusters.

Also in contrast to the Porter Diamond, the framework is operationalized through specified indicators, as shown in Table 1. These indicators are developed through an interview guide and survey to collect information during the cluster analysis process.

Table 1: NRC Cluster Development Constructs and Indicators

Concepts	Constructs	Sub-Constructs	Indicators
Current Conditions	Factors	Human Resources	Access to qualified personnel
			Local sourcing of personnel
		Transportation	Quality of local transportation
			Quality of distant transportation
		Business Climate	Quality of local lifestyle
			Relative costs
			Relative regulations and barriers
	Supporting Organizations	Innovation and Firm Support	Contribution of NRC
			Contribution of other research organizations
		Community Support	Government policies and programs
			Community support organizations
			Community champions
		Suppliers	Local availability of materials and equipment
			Local availability of business services
			Local availability of capital
	Competitive Environment	Local Activity	Distance of competitors
			Distance of customers
		Firm Capabilities	Business development capabilities
			Product development capabilities
Current Performance	Significance	Critical Mass	Number of cluster firms
			Number of spin-off firms
			Size of cluster firms
		Responsibility	Firm structure
			Firm responsibilities
		Reach	Export orientation
	Interaction	Identity	Internal awareness
			External recognition
		Linkages	Local involvement
			Internal linkages
	Dynamism	Innovation	R&D spending
			Relative innovativeness
			New product revenue
		Growth	Number of new firms
			Firm growth

Because they are dynamically evolving systems, innovation clusters are moving targets for policy interventions (Raines, 2003). In particular, clusters have life cycles (Andersson et al., 2004). Therefore, the NRC framework has been situated within a four-stage cluster life cycle, defined as follows:

- *Latent* – A region has a number of firms and other actors that begin to cooperate around a core activity and realize common opportunities through their linkages. Indicators for a latent cluster will include a small number of firms, low internal awareness and external recognition of cluster activities, and few linkages among stakeholders.

- *Developing* – As new actors in the same or related activities emerge or are attracted to the region, new linkages develop. Formal or informal institutes for collaboration may appear, as may a ‘label’ (such as ‘Silicon Valley’) and common promotional activities for the region. Indicators for a developing cluster will include developing linkages, internal awareness of regional strengths and other actors, and high innovation.

- *Established* – A critical mass is reached. Relations outside of the cluster are strengthened. There is an internal dynamic of new firm creation through start-ups, joint ventures, and spin-offs. Indicators for an established cluster will include a large number of firms (many of which will be ‘spin-offs’ of other cluster organizations), external recognition of the cluster’s advantages, active linkages, and high innovation.

- *Transformational* – Clusters change with their markets, technologies, and processes. In order to survive, the cluster must avoid stagnation and decay. Transformation may be through changes in the products and methods, or into new clusters focused on other activities. Depending on the state of transformation, indicators may be mixed.

The needs and concerns of cluster players will differ depending on the stage of development of the cluster, and cluster policies must evolve accordingly. For example, in early stage clusters, salient issues include the development of specialized R&D infrastructure, the fostering of linkages, the development of firm capabilities, access to talent, and the elaboration of a shared vision. In growing clusters, the emergence of new firms may alter the strategic alliances driving the cluster’s R&D activities, or may require new strategies to meet the increased demand for skilled labour and risk capital. As the cluster firms expand their reach into national or continental markets, the availability of managerial talent with the skills needed to direct an enterprise of this increasing geographic scope can become a critical factor contributing to, or limiting, their growth potential. The emergence of foreign competitors or competing technologies may also require an internal restructuring to increase efficiencies or a new investment in R&D capabilities. This dynamism causes the cluster’s structure to change over time.

5 NRC’s Process

The data for the individual framework indicators are collected through a series of standardized firm-based surveys and structured interviews with a subset of firms and other core actors in the clusters. Where possible, data for these indicators are referenced against information provided by leading cluster organizations in the region and the NRC institutes. Since many of the benefits of clustering, such as the creation of local resources of tacit knowledge and social capital, and the promotion of collective learning, are intangible and therefore difficult to quantify, the cluster analysis process used by NRC includes in-depth interviews and stakeholder meetings in order to more fully understand the state of the cluster, and to validate the findings.

The cluster analysis process begins with a literature and document review of existing information regarding the state of the cluster. Next, based on the review, and in consultation with core cluster stakeholders, the scope of the clusters is defined. The scope is influenced by considerations of the cluster’s self-awareness (how do members of the cluster view themselves?), external recognition (how do others view the cluster?), and comparison (what definition will permit comparisons with similar clusters?). Then, given this cluster scope, cluster members are identified using lists obtained from the NRC institute, industry associations, economic development organizations, and other sources. Defining the cluster scope and identifying its members is often contentious and time consuming. Some stakeholders have vested interests in making the cluster look large and successful, so there is often significant pressure to broaden the cluster scope, in terms of both geography and subject matter. An introductory meeting is held to inform cluster stakeholders of the purpose of the study, the study approach, the requests that will be made of them, and the benefits to the cluster of their participation in the study. The cluster scope is reviewed with stakeholders at the meeting.

Interviews are conducted with stakeholder representatives of each cluster, segmented as firms, research organizations, supporting organizations, and service providers. The questions are structured according to the framework, and are open-ended, providing insight into the internal dynamics and workings of the cluster.

A survey of cluster firms provides data for quantitative analysis that is not available from other sources. We have experimented in administering the survey by telephone and on the web. Each method has its advantages and disadvantages – the telephone survey may have higher response rates, but possibly at the risk of annoying stakeholders; the web-based survey requires that stakeholders are Internet users (which may not be the case for all clusters). In either case, the involvement of the NRC institute in soliciting participation is critical to ensuring high response rates.

An important part of the survey is a question about interactions among cluster participants. This information is used in a social network analysis to gain a better understanding of the nature, extent, and quality of linkages in the cluster.

Finally, at a second cluster meeting, results are presented to stakeholders for validation and to provide the opportunity for feedback and discussion on the findings.

Quantitative results for each indicator from the survey are converted to a scale from 1 (low or poor) to 5 (high or good). Weightings are used to aggregate indicators to sub-constructs, and sub-constructs to constructs. Figure 2 shows an example of how indicators (on the right in the figure) are translated into measures of conditions and performance at the construct level (on the left in the figure).

The intent of this exposition is to provide a preliminary indication of a cluster's strengths and weaknesses. The ratings are based on what has been found to be important in many clusters across Canada and around the world. However it must be understood that a cluster is the sum of its parts and that any indicator must be assessed in the context of the other elements of that cluster. For this reason, care must be taken when comparing the performances of different clusters on any indicator.

A low indicator may or may not indicate a concern, depending on the circumstances of the cluster. For example, all NRC cluster initiatives that have been examined perform poorly on measures related to local activity – measures of the proximity of important competitors and customers. While the international literature stresses the importance of local competitors and customers, the research conducted by ISRN and NRC has shown that Canadian clusters are almost never large enough to have significant local market activity. They rather depend to a greater extent on exports than do, for example, United

States clusters. Firms' business development capabilities are important to the growth of Canadian clusters (Davis and Sun, 2006), and an assessment of these capabilities is included as a variable in our cluster model.

Another caveat is that the numbers are based on self-assessments by cluster firms. In some cases, these assessments may be optimistic, particularly with respect to firm capabilities and growth opportunities.

The process of measuring the indicators is, however, only the beginning of the story. To have value for policy makers and cluster stakeholders, the indicators must be interpreted and the findings must be assessed in the context of the cluster's stage of development.

6 Cluster Study Findings and Their Implications

NRC has undertaken cluster studies based on the previously described framework in eight clusters, each centred on an NRC research institute: fuel cells and hydrogen technologies in Vancouver, nanotechnology in Edmonton; functional foods and nutraceuticals in Saskatoon, sustainable infrastructure in Regina, biomedical technologies in Winnipeg, photonics technologies in Ottawa, aluminum technologies in Saguenay/Lac St. Jean, and nutrisciences and health in Prince Edward Island. These studies provide important insights into the cluster development process, lessons for NRC in refining its role in promoting the growth of clusters, and lessons for other stakeholders in addressing weaknesses that are beyond the purview of NRC.

The eight studies reveal clusters at very different stages of the lifecycle. Four of the clusters are clearly latent: Edmonton nanotechnology, Saskatoon functional foods and nutraceuticals, Regina sustainable infrastructure, and Prince Edward Island nutrisciences. Winnipeg biomedical is developing, and Vancouver fuel cells and hydrogen and Winnipeg medical devices are established clusters. The latter are both complicated by the existence of two sub-clusters in each: fuel cells and hydrogen in Vancouver, and medical devices and pharmaceuticals in Winnipeg. The two remaining clusters, Ottawa photonics and Saguenay aluminum, are undergoing a significant transition – from aluminum production to aluminum transformation in the Saguenay, and from photonics for telecommunications to photonics with broader applications in Ottawa.

A number of common 'bottlenecks' have been identified across the clusters that require policy responses and private sector actions to overcome, if the clusters are to improve their performance. Central among these are the processes by which firms grow. In all clusters, a lack of risk capital and investment-ready opportunities, and insufficient depth of management talent, were found to be critical weaknesses. This was a problem even in the Ottawa photonics cluster, the most internationally recognized cluster in the group, which was known as 'Silicon Valley North' during the technology boom at the turn of the century. Ottawa cluster firms recognize that while access to capital in Ottawa is as favorable as it can be in Canada, it is poor in comparison to previous years. Ottawa firms are also particularly cognizant of the need for more experienced management in assisting both the existing firms and the numerous startups in making the transition to a broader range of technology applications.

In the Edmonton nanotechnology cluster, where risk capital derived from the energy sector is abundant, technology firms point out that investors stick with known risks in the energy industry, rather than branching out into new areas. In the smaller prairie cities of Saskatoon and Winnipeg, providers of risk capital question whether the issue is lack of capital or lack of adequate deal flow, and point to the challenges of growing internationally competitive firms in these regions.

Another important issue for the clusters is the nature of existing innovation networks within and beyond the clusters. In both the Winnipeg biomedical and Edmonton nanotechnology clusters, linkages are primarily between firms and the research base as opposed to interactions among firms. This reflects the fact that these clusters are incipient and still emerging out of new areas of research; and that the firms in these peripheral regions are highly specialized and are attempting to cater to niches in global – or at the very least national – technology markets. In Saskatoon, where an established agricultural innovation system is evolving into a bio-economy cluster, the main local linkages are between the firms and input providers and technical service providers, especially growers and processing plants. Linkages with the research base are rarer. In the Vancouver fuel cells and hydrogen cluster, innovation networks are focused on individuals rather than on firms. The NRC Institute for Fuel Cell Innovation is attempting to develop these networks into inter-firm networks by leading collaborative R&D projects involving multiple firms. Similar initiatives may be necessary in other clusters to increase interaction among firms and with the research base.

A social network analysis of the linkages that firms have with other firms and organizations (universities, colleges and training institutions, other research institutions, economic development organizations) found that the large majority of firm linkages in all clusters are with organizations located within participants' own province or elsewhere in Canada. Most linkages are with local universities and training institutions, and linkages are weakest with economic development organizations. In all eight clusters, customers and competitors are not local, and are usually foreign. Forward market linkages, found to be essential in the cluster research undertaken by ISRN (Wolfe and Lucas 2005), are relatively underdeveloped, and senior marketing management skills are lacking.

Even within the broad cluster framework presented above, the clusters differ significantly in terms of their underlying technology base, their geographical location within the country, and the nature of the relationship between the NRC institute or facility and the firms within the cluster. These unique cluster attributes pose additional challenges that must also be taken into account in defining the actions needed to promote growth within the clusters, and the appropriate roles for cluster champions. NRC must clearly refine the role it plays in the individual clusters to accommodate the specific developmental stage and unique attributes of each.

The cluster studies reinforce the fact that the cluster approach, encompassing as it does a wide range of heterogeneous actors in the public, private, and not-for-profit sectors in addition to a core group of firms, implies complex governance (coordination) mechanisms – mixtures of markets, firms, alliances, associations, public-private organizations, and public organizations, with no *a priori* structurally superior solution (De Langen, 2003). In each cluster, stakeholders must determine what needs to be done, and what their appropriate roles should be. An important lesson from the cluster studies is the limited influence than any one stakeholder, including research institutes such as those of NRC, can have on cluster conditions. Empirically grounded cluster analysis is required to support the foresight, strategic planning, performance measurement, and social knowledge management functions of cluster governance. For example, stakeholders can use the findings provided by cluster analysis to support social knowledge management activities that enhance communication between actors within a cluster system, thus coordinating and generating commitment to action. Critical to the success of such social knowledge management exercises is the ability to involve key stakeholders and sources of knowledge that can formulate a strategic vision for the cluster and use the intelligence generated by the cluster analysis (Gertler and Wolfe, 2004).

7 Conclusions and Recommendations

NRC has developed a framework and methodology to analyze clusters quickly, consistently, and cost-effectively. The framework articulates a suite of indicators of cluster development. It includes indicators of the features of clusters that NRC can influence through the services it provides, and the pathways such influence can take. It also highlights the aspects of clusters that are beyond NRC's purview, but of relevance to other cluster actors. The process was initially driven by policy relevance for measuring success, reporting on results, and facilitating decision making by NRC in its cluster strategy going forward. Additional areas of relevance have been identified for cluster strategic planning processes involving local stakeholders. Key lessons learned to date regarding the framework and indicators include:

- First, interaction between theory and practice can continually improve cluster theory (and associated indicators) and policy and management practices.

- Second, cluster policymakers and managers must understand innovation pathways and cluster dynamics in order to design and execute effective policy interventions and management strategies.

- Third, policy relevant cluster indicators can support social knowledge management activities in a cluster environment that features a diversity of policy stakeholders with varied interests and information requirements. No single organization can make a cluster work, and establishing the mechanisms and processes for cluster governance is a challenging task.

- Fourth, all cluster players should support the production of accurate and up-to-date indicators for a particular cluster, with support from senior levels of government.

Both the overall conceptual framework, and the specific indicators derived from it, provide NRC and its institutes and programs with an appropriate set of tools for gauging the level of development of its individual cluster initiatives. The analyses conducted to date using the framework and indicators provide valuable insights into the key challenges and potential obstacles confronting the clusters. As such, they can serve as invaluable guides to NRC and other key actors in the clusters as part of a broader strategic planning exercise, in charting future directions for the clusters.

Acknowledgements

The authors would like to acknowledge the National Research Council, Western Economic Diversification, Canada Economic Development, and the stakeholders of clusters in Vancouver, Edmonton, Saskatoon, Winnipeg, Ottawa, and the Saguenay for their funding and assistance during the studies that were the foundation for this paper.

Disclaimer

The views and opinions of the authors expressed in this paper do not necessarily state or reflect those of the National Research Council.

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Figure 1: NRC Cluster Framework

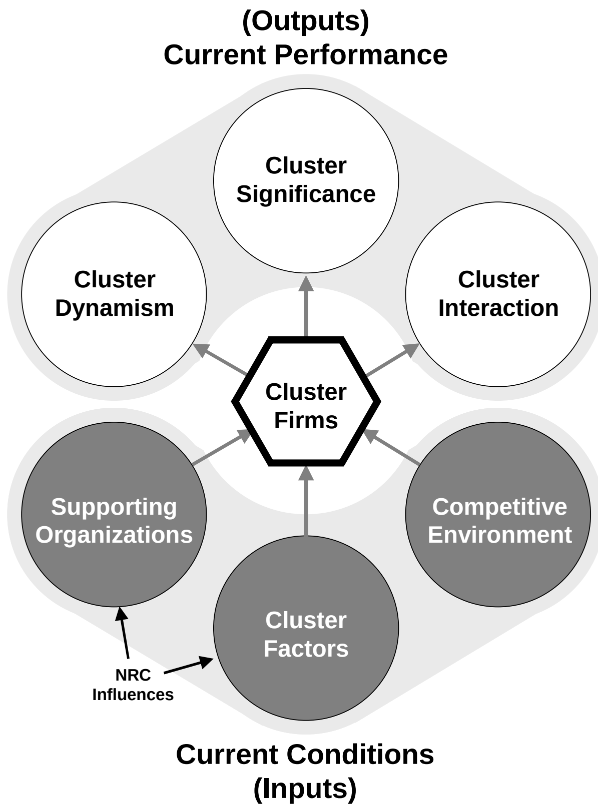

Figure 2: NRC Cluster Constructs and Indicators

Current Conditions

Construct	Value	Sub Construct	Weight	Value	Indicator	Weight	Value
Factors	3.94	Human Resources	0.50	3.94	Access to qualified personnel	0.60	3.43
					Local sources of personnel	0.40	4.70
		Transportation	0.20	3.12	Quality of local transportation	0.30	3.00
					Quality of distant transportation	0.70	3.17
		Business Climate	0.30	4.48	Quality of local lifestyle	0.20	3.57
					Relative costs	0.50	2.71
					Relative regulations and barriers	0.30	3.00
Supporting Organizations	2.93	Innovation Support	0.25	3.29	Contribution of NRC	0.50	3.01
					Contribution of other research organizations	0.50	3.57
		Community Support	0.25	2.74	Government policies and programs	0.50	2.57
					Community support organizations	0.25	3.00
					Community champions	0.25	2.80
		Suppliers	0.50	2.84	Local availability of materials and equipment	0.20	3.50
					Local availability of business services	0.30	3.33
					Local availability of capital	0.50	2.29
Competitive Environment	3.32	Local Activity	0.20	1.87	Distance of most important competitors	0.30	2.42
					Distance of most important customers	0.70	1.63
		Firm Capabilities	0.80	3.69	Business development capabilities	0.70	3.43
					Product development capabilities	0.30	4.29

Current Performance

Construct	Value	Sub Construct	Weight	Value	Indicator	Weight	Value
Significance	3.08	Critical Mass	0.50	2.46	Number of cluster firms	0.50	2.36
					Number of spinoff firms	0.25	3.29
					Size of cluster firms	0.25	1.83
		Responsibility	0.15	3.66	Firm structure	0.50	2.46
					Firm responsibilities	0.50	4.86
		Reach	0.35	3.72	Export orientation	1.00	3.72
Interaction	3.57	Identity	0.50	3.06	Internal Awareness	0.30	3.84
					External recognition	0.70	2.72
		Linkages	0.50	4.09	Local Involvement	0.40	4.44
					Internal Linkages	0.60	3.86
Dynamism	2.63	Innovation	0.35	4.00	R&D spending	0.25	4.59
					Relative innovativeness	0.50	3.71
					New product revenue	0.25	4.00
		Growth	0.65	1.89	Number of new firms	0.50	2.43
					Firm growth	0.50	1.36