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OUTPUT-BASED PERFORMANCE MEASURES FOR THE NORTH CAROLINA ALLIANCE FOR COMPETITIVE TECHNOLOGIES

> *"In the long run, men hit only what they aim at."*
> —Henry David Thoreau

INTRODUCTION

The North Carolina Alliance for Competitive Technologies (NC ACTs) is an organization operated by the state of North Carolina to coordinate technology development and deployment activities in the state. The mission of NC ACTs is to apply innovation, technology, and technical resources to promote economic growth in the state. NC ACTs will operate as a central, strategic organization to guide existing resources and to develop new resources when necessary.

To accomplish its mission, NC ACTs must coordinate institutions and organizations that currently offer technology development and deployment into a rational, customer-driven system that measures and rewards results. Timely, reliable assessment and evaluative feedback will be essential to managing these programs effectively. A well-designed system for performance assessment and evaluation can fill a number of management needs (Shapira, Youtie, and Roessner, 1994):

- Monitoring the progress of NC ACTs and its components in accomplishing their missions;
- Measuring and improving customer satisfaction;
- Identifying the most promising strategies and understanding why they are effective;
- Rewarding and reinforcing positive results;
- Allocating resources to their most effective uses; and
- Demonstrating accountability and value to program sponsors.

The design of an evaluation plan is critical in public institutions. While sponsors of public programs demand measures of performance and effectiveness, typical market indicators of success (i.e., market share, profit, stock price) are not applicable. Therefore, the evaluation plan must use credible techniques, reliable data, and consistent methodologies without draining organizational resources. To meet these standards, an evaluation plan must be developed during the genesis of the organization. Early assessment allows program managers to adopt the evaluation system as part of the overall management strategy and provides data for program assessment at critical early stages of operation. For this reason, NC ACTs has designed an

output-based performance measurement system as part of the NC ACTs operating plan for its first year.

The NC ACTs will be acting through affiliated independent organizations rather than through its own service efforts. The services and direction provided by NC ACTs are intended to *add value* to the existing technology development and deployment services in North Carolina by assuring that

- The total package of technology services available in North Carolina follows a comprehensive strategy and that the activities of the program components are coordinated so that they play their recognized role in that strategy;
- The total package of technology services offered through NC ACTs meets the technology needs of the firms in the target industries that are not effectively met in the private market without duplicating services;
- The needs are prioritized so that those most urgent and most likely to lead to positive economic outcomes are given first priority and public investment is steered toward the most important and successful initiatives; and
- Each program receives feedback regarding its success so that it can adjust its approach to fill its role in the overall strategy more effectively.

In short, NC ACTs will add value by formulating a comprehensive strategy, communicating that strategy to its affiliates, and influencing the behavior of its affiliates toward their clients, the small- and medium-sized manufacturers. Measuring this contribution is a difficult task complicated by the diversity of missions, customers, and services represented by the affiliated organizations.

The remainder of this paper discusses our plans for measuring the effectiveness of NC ACTs. Some features of the evaluation design are typical of the data collection efforts being conducted by many of the Manufacturing Technology Centers (MTC's) and Manufacturing Outreach Centers (MOC's). However, due to the unique design and mission of NC ACTs, we have deviated somewhat from the usual set of performance metrics for technology deployment organizations. This paper focuses on two of those features: measuring organizational influence and measuring technological influence. The second section contains a discussion of the overall design of the data collection, analysis, and reporting system being planned for NC ACTs. The third section focuses on how NC ACTs will measure its influence on the quality and direction of the technology services available in the state of North Carolina. The fourth section discusses a strategy for analyzing the influence of NC ACTs on the use of efficient core technologies emphasizing environmental technologies. The final section contains a summary.

OVERVIEW OF THE NC ACTS EVALUATION STRATEGY

The core of the NC ACTs evaluation strategy is the Outcome-Based Performance Measurement and Feedback System (OBPMFS). As its name suggests, the OBPMFS uses outcomes as the primary performance metric for NC ACTs and its affiliated technology service providers. While many performance assessments measure the inputs of a program, such as staff and other resources, the OBPMFS has been designed to focus on the quality of services NC ACTs provides to its clients and the impacts of those services on the clients and on the North Carolina economy. The system emphasizes the target populations and core technologies identified through a Target Industry Needs Assessment. As shown in Figure 1, the OBPMFS is designed to provide continuous feedback to the NC ACTs decision structure. This assures that NC ACTs can build, maintain, and continually improve upon the quality of the services it delivers directly and those delivered by its affiliated organizations. The OBPMFS will be executed in five stages:

1. Design information infrastructure (hardware, data, software, knowledge of methodologies) for assessing success in meeting these objectives.

2. Extend this infrastructure to affiliate organizations and implement a system for collecting data from affiliate organizations.

3. Compile and analyze data from affiliate organizations, using the methodologies developed in Step 1.

4. Use this analysis to make strategic investment decisions in technology development and deployment.

5. Report the analysis results—including implications for the NC ACTs strategic plan—to stakeholders.

The comprehensive technology strategy developed by NC ACTs will be executed through the affiliate organizations and the services they provide to their clients, with the aim of achieving the greatest regional impact for the available resources. Thus, NC ACTs can measure its impact at each of three levels of influence: affiliate organization, client, and state economy. This impact-level progression follows a time frame over which impacts might be observed, as shown in Figure 2. In the short run, NC ACTs will affect the activities of its affiliate organization, and therefore, short-term indicators of effectiveness will focus on the affiliates' reaction to NC ACTs. Over the medium term, changes in the mission and focus of the affiliate organization should filter through to the clients of the affiliates and affect their technological sophistication and performance. In the long run, the policies and actions of NC ACTs will be felt regionally as the technology strategy is enacted throughout the state

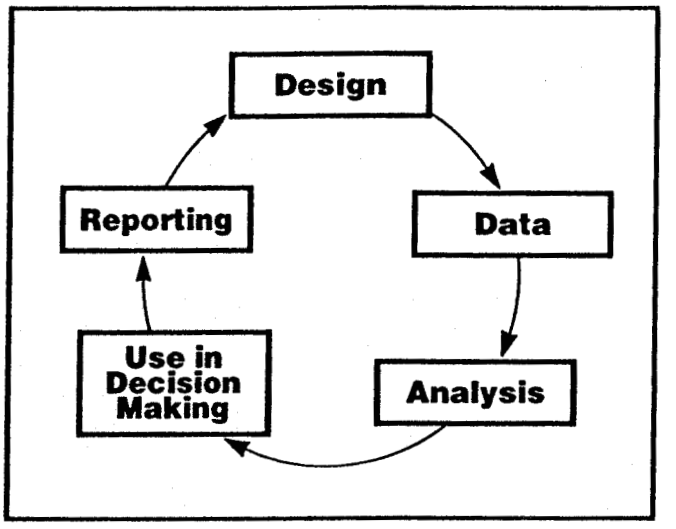

Figure 1. The NC ACTs Outcome-Based Performance Measurement and Feedback System (OBPMFS)

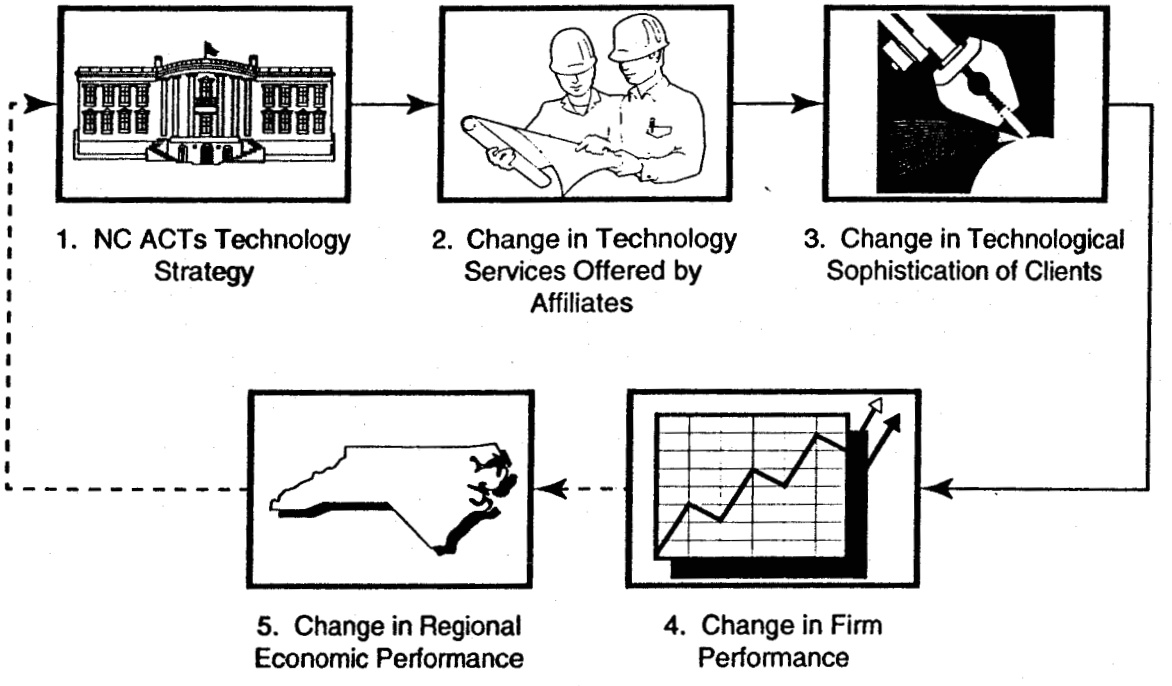

Figure 2. The Linkages Between NC ACTs and Firm and Regional Performance

ORGANIZATIONAL EFFECTIVENESS

Much has been written in the last few years about the data and methodologies that are or should be used to assess the impact of technology deployment organizations.[1] Before the National Institute of Standards and Technology's (NIST's) recent emphasis on developing and diffusing widely recognized, credible evaluation methodologies, most evaluations of technology programs were ad hoc and lacked analytical rigor. Much of the literature bemoaned the lack of meaningful criteria for judging the success of technology programs, and recognized the difficulty of finding methodologies that were plausible given the difficulty of gathering data and the political influences on the evaluation process (Feller, 1988). More recently, important steps have been taken to develop and diffuse credible, defensible methodologies and metrics that assist us in examining the success of technology transfer organizations rigorously. (This workshop is a good example of that effort.)

However, these methodologies are not entirely appropriate for NC ACTs, given the uniqueness of its mission and structure. Therefore, it seems appropriate to consult the academic literature on organizational effectiveness for guidance regarding more appropriate metrics.

The only consensus emerging from the literature is that there is no consensus. There are many theoretical models of organizational effectiveness, almost as many as there are definitions of an organization. The empirical literature provides no better guidance. In his investigation of 24 studies of organizational effectiveness, Cameron (1978) found that 80 percent of the criteria used to judge effectiveness did not overlap.

But this variety of models is not negative. Cameron and Whetten (1983) assert that the diversity of the models provides greater insight. Similarly, lack of definitive criteria regarding organizational effectiveness allows for the empirical flexibility required to judge a wide variety of organizations as effective, even when they have different characteristics.

Thus, we have chosen to use several models of organizational effectiveness to develop our criteria for the effectiveness of NC ACTs. Although these models have implicitly influenced the development of existing evaluation criteria for technology transfer organizations, the models have not been specifically cited. Keen observations and common-sense analysis of the technology deployment process have contributed to the derivation of the metrics. Because observation is the root of all theoretical models, the resulting list of metrics is jointly derived from these models and from shrewd observation.

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[1] For a review of this literature, see Shapira, Youtie, and Roessner, 1994.

The Goal Model

The goal model of organizational effectiveness views the organization as machinery for achieving a set of goals. Thus, the effectiveness of that organization is judged by the extent to which those goals are met. The goal model is inherent in many evaluations of technology extension activities, as reported by Shapira and his colleagues (1994). One of the most widely cited problems with using the goal model for program evaluation is that goals are usually quite broadly defined, or else are so numerous that measuring progress toward them is difficult or impossible. One approach often taken to mitigate this problem is defining goals more narrowly, which presents a problem. The goals of an organization change over time; if goals are defined too narrowly, the evaluation criteria will become irrelevant after only a short period of time.

Despite these difficulties, we find that measuring results against goals can be quite useful when the goals can be easily defined and progress toward them can be measured. We take this approach in our process metrics of the impact of NC ACTs on its affiliated organizations, as explained below.

The Systems Resource Model

The systems resource model (Seashore and Yuchtman, 1967) is based on the idea that an organization is effective if it is able to exploit its environment to acquire the resources required to sustain its functioning. However, there is a danger in this view of confusing inputs with outputs. While resource acquisition itself may be a subgoal of organizations, resources are not acquired for their own sake, but for the purpose of achieving the goals that might be attained by using them. A useful variation on this model developed by Milnar and Rogers (1976) contends that distribution of resources from a public organization is an appropriate effectiveness indicator. As explained below, we view resource distribution as one of the mechanisms by which NC ACTs might influence its affiliates, and therefore, a useful metric of effectiveness.

The Strategic Constituencies Model

Strategic constituencies are individuals or groups who have a substantial stake in the organization (Cameron and Whetten, 1983). Examples of strategic constituencies include resource providers, customers, employees, groups whose cooperation is essential to the organization, or people whose lives are significantly affected by the organization. These constituencies generally are in a mutually dependent relationship with the organization. The strategic constituencies model assumes that the assent of the strategic constituencies is therefore

important to the organization's effectiveness. Thus, one component of organizational effectiveness is the viewpoints of strategic constituencies.

We have included indicators of strategic constituencies' satisfaction in the performance measurement system for NC ACTs. However, we cannot rely entirely on these viewpoints to judge the effectiveness of NC ACTs. Different constituencies may hold different views of what would constitute effectiveness. These differences of opinion would force us to either choose the opinions of one constituency as most indicative of the effectiveness of the organization, or to develop some weighting scheme.

A more reasonable approach is to combine measures of strategic constituency satisfaction with other indicators. Actually, the strategic constituency model is related to the goal model, because mutual goal agreement is an important component of the satisfaction of strategic constituencies. Furthermore, the strategic constituencies model is related to the systems resources model in that organizations must acquire resources sufficient to be instrumental for their constituencies. Thus, we combine metrics derived from each of these models of organizational effectiveness.

Organizational Effectiveness and NC ACTs

Each of the models described can be useful for deriving metrics of the effectiveness of NC ACTs. At each of the three levels of influence—affiliate organization, client firms, and regional economy—NC ACTs can measure its effectiveness in three ways:

- with program monitoring and process evaluation techniques (using the system resource model and the goal model);
- with stakeholder satisfaction assessment (using the strategic constituencies model); and
- with program impact assessment (using the goal model).

In Year 1, NC ACTs will develop its technology strategy and build the infrastructure through which this strategy will be communicated and enacted; thus, measures of its influence at the affiliate organization level will be most relevant.

AFFILIATE INFLUENCE

Process Measures

Developing a comprehensive technology strategy and communicating that strategy to its affiliates is the first step to building the NC ACTs organization and executing its mission. Thus,

the first set of process metrics proposed for NC ACTs measures progress towards completing the products through which it will develop and communicate that strategy:

- a Technology Audit and System Capacity Review;
- a Target-Industry Needs Assessment;
- a Technology-Extension Incentive Fund; and
- a Centers of Excellence Strategy.

Development of these products has been set forth in the NC ACTs Operating Plan as important goals for Year 1. As shown in Table 1, NC ACTs will monitor progress towards the completion of these products quarterly. This somewhat qualitative variable can be quantified by estimating the percentage of tasks (or percentage of total effort) that has been completed. Detailed workplans for each product have been developed to facilitate the monitoring and reporting of these estimates.

Drawing on the system-resource model of organizational effectiveness, Milnar and Rogers (1976) measured the amount of resources distributed by a public agency. Because financial resources are an important tool for influencing the missions and activities of the affiliates, we will use the number of proposals received, the number of awards made, and the total dollars awarded from the Technology-Extension Incentive Fund and the Centers of Excellence Strategy Fund as metrics for Years 2 and beyond.

Interaction with affiliates is a prerequisite for communicating the technology strategy. Furthermore, the participation of the affiliates in carrying out the NC ACTs strategy is an important resource for NC ACTs. Thus, another process measure of affiliates' influence is the amount of interaction that NC ACTs has with its affiliates. This interaction is an indicator that the cooperation of the affiliates is being solicited, and, to some extent, is being gained. However, this interaction is difficult to track and measure. There are two countable metrics that will serve as proxies for the level of interaction between NC ACTs and its affiliates: the number of cooperative service agreements signed and the number of organizations in the NC ACTs Organizational Linkages Directory (OLD).

The OLD will be an important component of the information infrastructure developed by NC ACTs. This directory will track each affiliated organization; its level of cooperation with NC ACTs; and specific information about the affiliate's mission, target industries, and/or technologies. An entry in this directory indicates that NC ACTs has developed an understanding of the mission of that organization and its target industries or technologies.

TABLE 1. OUTCOME-BASED PERFORMANCE METRICS FOR NC ACTs

Metric	Description	Source	Reporting Period
Organizational Metrics			
System Capacity Review: Progress	Percent of tasks completed	Task force reports	Quarterly
Industry Needs Analysis: Progress	Percent of tasks completed	Task force reports	Quarterly
Technology Incentive Fund: Progress	Percent of tasks completed	Task force reports	Quarterly
Technology Incentive Fund: Proposals	Number of proposals	Bidders	Quarterly
Technology Incentive Fund: Funding Awarded	Dollars of funding awarded	Budget	Quarterly, Years 2 and 3
Technology Incentive Fund: Projects Awarded	Number of projects awarded	Budget	Quarterly, Years 2 and 3
Centers of Excellence Strategy: Progress	Percent of tasks completed	Task force reports	Quarterly
Centers of Excellence Strategy: Centers Proposed	Number of centers proposed	Bidders	Quarterly
Centers of Excellence Strategy: Centers Funded	Number of centers funded	Budget	Quarterly, Years 2 and 3
Centers of Excellence Strategy: Dollars Awarded	Dollars awarded, by source of funds	Budget	Quarterly, Years 2 and 3
Number of Cooperative Service Agreements	Number of agreements signed	Affiliates	Quarterly
Number of Organizations in the Organizational Linkages Directory (OLD), by Type	Number of organizations	Organizational Linkage Directory (OLD)	Quarterly
Organizational Influence	Case studies of organizational input	Survey or interview of affiliate	Quarterly
Coordination Among Affiliates	Change of organizations in affiliate (OLD)	Affiliate (OLD)	Annually (Year 2)
Affiliate Satisfaction Index	Satisfaction with NC ACTs activities	NC ACTs Affiliate Survey	Annually

(continued)

TABLE 1. OUTCOME-BASED PERFORMANCE METRICS FOR NC ACTs (CONTINUED)

Metric	Description	Source	Reporting Period
Organizational Metrics (continued)			
Impact of Affiliate Mission (technology deployment)	Change in target firms served	Affiliate activity reports	Quarterly (as implemented)
Impact of Affiliate Mission (technology development)	Change in funding, core technologies	Affiliate activity reports	Quarterly (as implemented)
Client Metrics			
Target Firms Served, by Industry Type	Number of firms served by affiliates	Affiliate process reports	Quarterly
Core Technology Services, by Technology Type	Number of services by affiliates	Affiliate process reports	Quarterly
Number of Accredited Service Professionals, by Technology	Number of staff skilled in each technology	Affiliate process reports	Quarterly
Client Satisfaction, by Program Type	Client Satisfaction Index (see text)	Affiliate client satisfaction surveys	Quarterly
Regional Metrics			
Total Number of Firms Served, by Industry	Total number of firms	NC ACTs longitudinal database	Years 2 and 3
New Technology Development in Core Technologies	Qualitative description of new developments	Affiliate process reports	Annually
Percent of Target Industries Served	Number of firms served ÷ total firms	NC ACTs longitudinal database	Annually, Years 2 and 3
Change in Use of Core Technologies	Change, percent of firms using core technologies	Survey of environmental and telecommunications technologies	Annually Years 2 and 3
Change in Survival Rate of Firms in Target Industries	Survival rate, 1997 – survival rate, 1994	NC Employment Security Commission	Every 3 years

In some cases, NC ACTs and the NC ACTs technology strategy will have a substantial impact on the mission or activities of an affiliate. For example, an opportunity to receive matching funds through NC ACTs might influence a technology organization to target new industries or to hire additional staff so as to achieve expertise in a core technology. These instances will be reported as case studies and included in the quarterly report to NIST.

NC ACTs will encourage its affiliates to maintain their own OLD and to provide it to NC ACTs along with the Affiliate Activity Reports, explained below. The number of entries in the affiliates' OLDs will serve as an indicator of the extent of cooperation and coordination of technology services across the state and track the growth of that cooperation as NC ACTs grows. Other measures of this cooperation will be discussed and agreed upon by a group of affiliate representatives. Candidates include the number of referrals, number of cooperative research agreements, and number and size of consulting contracts among affiliates.

Stakeholder Satisfaction

The affiliate organizations are a strategic constituency of NC ACTs. A questionnaire will be designed and implemented to gauge the impact of the information and guidance provided by NC ACTs, and the affiliates' assessment of the effectiveness of NC ACTs. The questionnaire will be designed in cooperation with the stakeholders and will be pre-tested on a group of affiliates to assure that it provides an adequate opportunity to evaluate the quality of the information and services they receive from NC ACTs, to describe the nature of the influence of NC ACTs on their organization and operations, and to make suggestions for improvements. This questionnaire will be administered annually and will provide a short-term indication of NC ACTs' impact on its affiliates' operations; longer-term indicators of this influence are discussed below.

Impact Measures

Since NC ACTs will act primarily through existing technology organizations in the first year, an important subsidiary goal of NC ACTs is to influence the mission, objectives, and quality of the affiliates, as well as the resources that the affiliates are willing to commit to the NC ACTs mission. A short-term indicator of the influence of NC ACTs will be provided by the stakeholder satisfaction survey, as explained above. However, a more objective measure will be the actual change in the types of services provided, the types of firms assisted, and the nature of the technologies transferred to the affiliates' clients. This information will become available to

NC ACTs as its affiliates adopt the information infrastructure (i.e., software, data collection instruments, data analysis methodology, and reporting protocols) developed by NC ACTs and provide quarterly Affiliate Process Reports.

In particular, NC ACTs' influence will be measured by the change in the attention its affiliates give to the target industries and core technologies. For example, for technology service providers, the NC ACTs influence might be measured by the change in the number of target-industry firms assisted or by the number of client services that involve the core technologies—telecommunications, electronics, and environmental technologies. For technology development firms, NC ACTs' influence might be measured by changes in funding directed toward core technologies.

CLIENT INFLUENCE

NC ACTs will measure its influence on the firms in North Carolina primarily through its affiliates. Thus, NC ACTs will not have primary access to data about the affiliates' clients and the services they are provided. To obtain this information, NC ACTs will extend the information infrastructure for collecting, analyzing, and reporting data to its affiliates. In exchange, the affiliates will be asked to file Affiliate Activity Reports to NC ACTs containing metrics of the affiliates' processes, satisfaction of their clients, and impacts on their clients. This information will be aggregated by NC ACTs to provide an accurate picture of the technology services being provided throughout the state, the satisfaction of firms in North Carolina with the services they are receiving, and the impact of technology services on firms in North Carolina, particularly on the target industries.

As affiliates sign cooperative service agreements with NC ACTs for information exchange, NC ACTs will begin to build a longitudinal database of client firms. This database will contain a single record for every firm that is a client of NC ACTs' affiliates. This record will contain basic information about the firm's operation, firm-level performance metrics for a baseline year and for subsequent years, dates and type of service provided, and other characteristics that might affect the extent to which technology services impact the operations of the firm. This database will be used to calculate process, satisfaction, and impact measures as explained below. The progress that NC ACTs makes towards developing a comprehensive picture of the impact of technology services on firms in North Carolina will critically depend on the number of cooperative agreements signed in the first year.

Process Measures

The process measures that NC ACTs will collect from its affiliates will closely follow the NIST reporting requirements. The activity reporting will include the number and types of firms served, the types of services provided, the type of technology implemented to serve the client, and the resources used to provide those services. NC ACTs will examine these statistics to monitor service to its target industries and deployment of core technologies.

NC ACTs will also ask the affiliates to provide a Staff Skills Directory, which will be updated quarterly. This directory will provide input to the Technology Audit and System Capacity Review and will serve as a benchmark from which to measure changes in the skill mix of the technology services professionals in the state. NC ACTs will track changes in that mix, hoping to observe changes that favor knowledge of and skills in the core technologies and industries.

Satisfaction Measures

NC ACTs will work with the affiliates to develop a questionnaire of client satisfaction. A meeting of affiliate representatives will be convened to discuss the appropriateness of the survey for measuring the level of satisfaction of the affiliates' clients, starting with the NIST-recommended survey instrument as a model. Once developed, the affiliates will implement these surveys after services are provided; results from these surveys will be reported to NC ACTs. NC ACTs will compile them to provide an overview of the comparative satisfaction of customers with different technology service delivery models and mechanisms.

Client satisfaction with technology services has a number of dimensions: response time, agent's knowledge of the industry and technology, appropriateness of the advice, and ability to communicate effectively, among others. With the affiliate organizations, NC ACTs will develop a weighting to produce a single index of customer satisfaction. These indexes may be specific to the technology deployment or development organization, depending on its mission. For example, one service provider might emphasize quick-turnaround service on simple design problems. Another might consider their mission providing a complete package of business and technical services to improve the overall competitiveness of the firm. These two affiliates might favor different weighting schemes for their client satisfaction index.

Impact Measures

While the ultimate mission of NC ACTs is to promote economic growth in North Carolina, the instrument through which economic growth is achieved is the application of

technologies. Figure 2 shows that technology services provided to clients begin a process of improvement in firm practices which leads to improvement in the firms economic performance. To measure NC ACTs' influence on the client firms, we will examine changes in both technology utilization and economic performance. Our plan for measuring technology impact will be explained in detail in the next section.

Economic Impact

One section of the client satisfaction survey will ask clients to estimate the impact of the assistance received on bottom-line measures of performance, such as sales, cost, and profit. Other impact measures might include capital investment, capital avoidance, changes in order delivery time, and changes in inventory turns. However, an additional, more specific set of metrics will be developed for the target industry. These metrics will be collected from the client firms by the affiliates and included in the longitudinal database. With this information, along with data on the amount and type of service provided, NC ACTs will be able to associate technology services with client performance. In order to investigate carefully the causality between service and performance, NC ACTs will plan to develop a control group for the target industries. The NC ACTs longitudinal database will be expanded in the second and third years to include firms that do not have contact with affiliate service providers. This database will provide the information needed to fulfill NIST requirements for reporting 2-year changes for each client in the following nine measures:

- scrap rate,
- percent of employees using computers or programmable machine controllers at least weekly,
- overall inventory turns (sales/inventory),
- sales per employee,
- manufacturing lead time,
- sales,
- employment, and
- income growth.

This record will contain firm-level metrics for the baseline year and for subsequent years as explained below.

REGIONAL ECONOMIC IMPACTS

Ultimately, NC ACTs hopes to have a substantial impact on the economy of North Carolina by improving the performance of firms in the target industries and by advancing the

development and application of core technologies. As shown in Figure 2, the linkages between firm performance and regional economic performance are complex and often emerge only in the long run. Furthermore, causality between intervention at the firm level and regional performance is difficult to establish because of the many confounding regional and industry factors. Theoretically, it is expected that improvements in the performance of North Carolina firms will lead to economic prosperity for the state as firms expand, hire new workers, build new facilities, widen their profit margins, pay their workers higher wages, and contribute more to state revenues. However, establishing those linkages empirically is difficult. NC ACTs will measure its influence on the North Carolina economy with process measures and impact measures.

Process Metrics

The process metrics are intended to estimate the overall effort level of the combined technology resources in the state. The extent to which the NC ACTs' mission is being executed will be measured by the total number of firms served by NC ACTs; the percent of the firms in the target industries served; total research funding for core technologies; new technology development in the core technologies, as identified in the needs analysis; and the percent of manufacturing facilities using core technologies.

Impact Metrics

The ultimate measure of the impact of NC ACTs is the change in the economic viability of its target industries compared to firms in that industry that have not benefited from NC ACTs technology planning and coordination. To factor out some regional and industry-specific factors, regional performance variables for the target industries in North Carolina over time will be compared with those of other states. The NC ACTs target industries and the industries using the core technologies are expected to experience a greater improvement in overall economic performance than these same industries in other states over the same period of time. The economic performance of these target industries will be measured by the new firm survival rate, the percentage of change in employment, and the North Carolina market share in that industry. For North Carolina, this data will be gathered from the North Carolina Employment Security Commission, along with comparable data from similar agencies in other states.

TECHNOLOGICAL IMPACT: ENVIRONMENTAL TECHNOLOGIES

Economic development strategies that include technology development and technology transfer are based on the theoretical causality between the use of advanced technologies and the bottom-line economic performance and survivability of firms. The trend towards technology-

based economic development has driven improvements in data that documents the use and diffusion of technologies, such as the Survey of Manufacturing Technology, a survey of firms in Standard Industrial Classification (SIC) codes 34 through 38 (U.S. Department of Commerce, 1989). Studies using this data have provided empirical support for the theoretical contention that investments in advanced technology improve the survivability and growth of manufacturing firms (Doms, Dunne, and Roberts, 1994).

One of NC ACTs' first-year goals is to develop a strategy for improving the technological sophistication of North Carolina firms. An important part of the development of this strategy is an industry needs analysis and a "roadmap" for core technologies. These roadmaps will present a picture of the current position of the core technologies and their diffusion in North Carolina firms and provide a strategy for both advancing the technology in a strategic direction and for diffusing that technology. This process will provide excellent input to the evaluation system.

An important measure of NC ACTs' influence will be changes in the technological sophistication of North Carolina firms with respect to the core technologies, and, in the longer run, the impact of those technologies on their economic and environmental performance. Thus, in the first year, a baseline study will be conducted to determine the relative performance of North Carolina manufacturers with respect to the core technologies. In subsequent years, we will measure the progress of manufacturers in North Carolina with respect to the technological indicators.

A preliminary list of core technologies has been identified as generically relevant across industrial sectors: telecommunications, environmental management technologies, advanced materials, software systems, and manufacturing technologies that include advanced sensors and automated integration technologies. These enabling technologies are important for two reasons: they will impart distinct competitive advantage to those firms that optimize their use, and they are the basis for emerging industry sectors.

Plans are currently underway to conduct technology roadmapping studies in telecommunications and environmental technologies. For environmental technologies, a study has been initiated by a coalition led by the North Carolina Department of Environmental Health and Natural Resources (DEHNR). This study will provide a baseline measure of the status of firms in North Carolina relative to best-practice technologies in environmental management. This baseline will provide information for the technology roadmap as well as input to the evaluation system.

Methodology

This study will be similar in some respects to a benchmarking study. Most benchmarking studies, including several recent environmental management benchmarking studies (AT&T Bell Laboratories QUEST Organization, 1993), identify "Best-in-Class" firms through a combination of qualitative and quantitative analysis. The facilities chosen as Best in Class are then interviewed about the factors underlying their success. Analysts then compile their findings in a systematic way to provide guidance to facilities that aspire to match the Best-in-Class performance.

By contrast, our approach is less qualitative, more data intensive, more specific to each industry, and more inclusive of the entire industry. We will identify Best-in-Class facilities using a single indicator of environmental efficiency, which is explained below. We will measure the environmental efficiency of all establishments in the study against the Best-in-Class firms, and we will identify the technologies that are correlated with best performance. We will further examine the importance of those technologies to the environmental efficiency of firms (i.e., how much variation in environmental performance is attributable to these technologies). We will then describe distribution of these technologies, identifying factors that influence their adoption and segments of the industry that might derive the most benefit from adoption of these environmental technologies.

This study poses several important methodological challenges. First, there is no generally accepted or identifiable set of technologies recognized as being state-of-the-art environmental management technologies. Second, existing measures of environmental performance fall short of providing reliable, comparable, quantitative, unambiguous performance data that truly reflect the environmental cost of specific manufacturing technologies. We address the first problem by utilizing the expertise of environmental technology experts in designing the survey. The second challenge is addressed by developing a unique method for choosing best-practice firms and technologies that is far more quantitative than traditional benchmarking methodology.

The study will be conducted in six tasks:

1. Develop a survey instrument including a list of candidate technologies that may be considered environmental technologies in each of the chosen industries.

2. Collect economic, technological, and waste-generation data.

3. Determine which firms are "best practice" with respect to environmental performance and calculate the environmental efficiency of each firm relative to best practice.

4. Determine which technologies are associated with the best environmental performance (best-practice technologies) and model the performance variation among firms as a function of technologies and other explanatory variables.

5. Describe and analyze the diffusion of the best-practice technologies among firms in the state.

6. Repeat the diffusion study in subsequent years, analyzing the diffusion of the best-practice technologies and noting changes in the best practice.

Each of these tasks is briefly described below.

Developing the Survey Instrument

Three types of data must be collected from establishments in the study: economic, environmental, and technological. Economic data and environmental data will both be used to construct a measure of environmental performance that is normalized by the establishment's economic activity, as explained below. The technological data will be collected to identify the practices and technologies that the plant is using to improve its environmental performance.

One challenge to the design of the survey instrument will be to assure that the instrument will elicit from manufacturers the correct information about their environmental technologies so that the best-practice technologies can be identified. An environmental management technology can be any practice, process, or equipment that facilitates the reduction of waste, the conservation of resources, or the restoration of damaged environments. These technologies can include simple practices such as inventory management as well as more sophisticated and capital-embodied technologies such as on-site waste recovery equipment (Hunt, 1993). The most successful environmental technologies are likely to differ between industries and even between specific types of manufacturing processes.

The inexactness of the best-practice definition complicates the data collection process. We must anticipate which technologies might be best practice and assure that they are included in the survey. Therefore, we will consult with industry experts to develop a list of candidate technologies for each of the industries targeted for the survey. These experts will include representatives from industry and from technology deployment services, including the North Carolina Office of Waste Reduction, the North Carolina State University Industrial Extension Service, and the Center for Environmental Technologies and Center for Environmental Analysis at Research Triangle Institute. Each of these organizations provides environmental technology assistance to manufacturers.

Collecting Environmental, Economic, and Technological Data

We will collect economic, environmental, and technological data from a sample of firms in each of the target industries. The economic and environmental data are required to rate each firm's environmental performance. While performance for manufacturing firms is generally defined by productivity, efficiency, or profits, environmental performance is generally measured by waste generation, weighted by some measure of output. The definition of this measure is discussed in detail below.

While facility-level economic and waste-generation data are available from other sources, these are inadequate for our purposes. The U.S. Environmental Protection Agency Toxics Releases Inventory is inadequate because it does not cover all important chemicals or industries, and because it focuses on release volume without accounting for differences in toxicity (Wells et al., 1992). Establishment-level economic data is collected by the Census Bureau, but difficulty in accessing this data and limitations of the data about small establishments[2] limit the usefulness of this data for our purposes.

We will use a stratified sample of manufacturers in each of the target industries, (these industries have not yet been determined), based on a list of all manufacturers in that industry obtained from the North Carolina Department of Employment Security. The stratification variables will be chosen so as to assure that sufficient data are obtained from manufacturers of different sizes and locations.

We will take several steps to increase the response rate to the survey. First, we will carefully develop and pre-test the survey to assure that the survey questions are clear, that they are relevant to the recipients, and to minimize the amount of time required to complete the survey. Second, we will enlist the support of industry trade associations to promote the study and encourage its members to participate. In order to provide the trade associations some interest in the success of the project, we will provide them an opportunity to provide input to the design of the survey instrument. We will also conduct follow-up procedures, including setting up a help line, second wave mailings, and follow-up phone calls to non-respondents. Finally, we will offer the respondents a benchmarking report as an incentive for returning the survey.

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[2]Establishment-level economic data collected by the Census Bureau is available through the Longitudinal Research Database (LRD), which was developed and is maintained at the Center for Economic Studies. Due to disclosure regulations, this data can be accessed only for approved research, on-site at the Census Bureau. Any results derived from research performed with the LRD is subject to disclosure analysis before it can be published or otherwise removed from the premises of the Census Bureau. For small establishments, much of the economic data are imputed from administrative records from the Internal Revenue Service and the Social Security Administration, and while this has little effect on the aggregate data, establishment level data for the small manufacturers can be very unreliable. For more information about the LRD, see McGuckin (1988)

Determining the Best-Practice Facilities and Measuring Environmental Performance

The data collected from the survey will enable us to find a best practice frontier and calculate relative environmental efficiency for each establishment. As developed by Joyce Smith (1994), environmental efficiency is an adaptation of the engineering concept of technical efficiency, which was first proposed in the economic literature by M.J. Farrell in 1957. Intuitively, technical efficiency is the degree to which the greatest amount of output possible is produced from a given input vector, or equivalently, the degree to which as few inputs as possible are used to produce a given output level. An environmental interpretation of the concept is that environmental efficiency is the degree to which the greatest amount of output is produced given a vector of wastes, or equivalently, the degree to which as little waste as possible is generated from production of some specific amount of output.

Figure 3 provides an example for the second definition. Consider a manufacturing process that produces one output and generates two wastes. The x axis measures the amount of Waste 1 generated per unit of output; the y axis measures the amount of Waste 2 generated per unit of output. Each point represents an observation. For example, P_2 represents a firm that generates 0.48 units of Waste 1 per unit of output and 0.16 units of Waste 2 per unit of output. The efficient frontier is constructed by joining the points to form the outer envelope of the observed points. Any point to the northwest of this frontier represents a production process that generates more of at least one type of waste than the technology represented by the frontier.[3] The efficiency of other firms is measured relative to this frontier. A point such as P_4 is technically inefficient because it lies to the northwest of the frontier. To produce a unit of output, it generates more of both types of waste than does process P_2. A radial contraction of all wastes from P_4 meets the frontier at point C, at which production is accomplished with the same proportions of waste as at point P_4. Environmental efficiency equal to OC/OP_4: the ratio of the vector of wastes generated at C to that used at P_4.[4]

Determine Best-Practice Technologies and Model Environmental Performance

After estimating environmental efficiency for each establishment, we will model environmental performance as a function of a number of variables, including environmental technologies. This will provide an indication of which technologies are associated with the most

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[3]For a formal definition of technical efficiency and construction of the efficient frontier, see Lovell and Schmidt (1987)

[4]Actually, Joyce Smith's definition of environmental efficiency is the sum of releases efficiency, which I have described here, and risk efficiency, which is conceptually akin to the economic notion of allocative efficiency. Risk efficiency takes into account the relative risk of the wastes to the environment, in a fashion similar to the consideration of input prices in determining allocative efficiency.

environmentally efficient firms. There will likely be other variables that affect environmental performance, including the size of the firm, the location (especially whether it is in a nonattainment area), and whether or not the firm has received assistance from a pollution prevention outreach program. We will try to explain the variation in environmental efficiency as a function of these variables. One of the outputs of this task will be a list of the best practice technologies by industry.

We also plan to analyze the relationship between environmental efficiency and economic performance. Because most pollution prevention and environmental management technologies reduce waste and therefore decrease the use of raw materials, we expect that environmental efficiency and economic performance will be correlated.

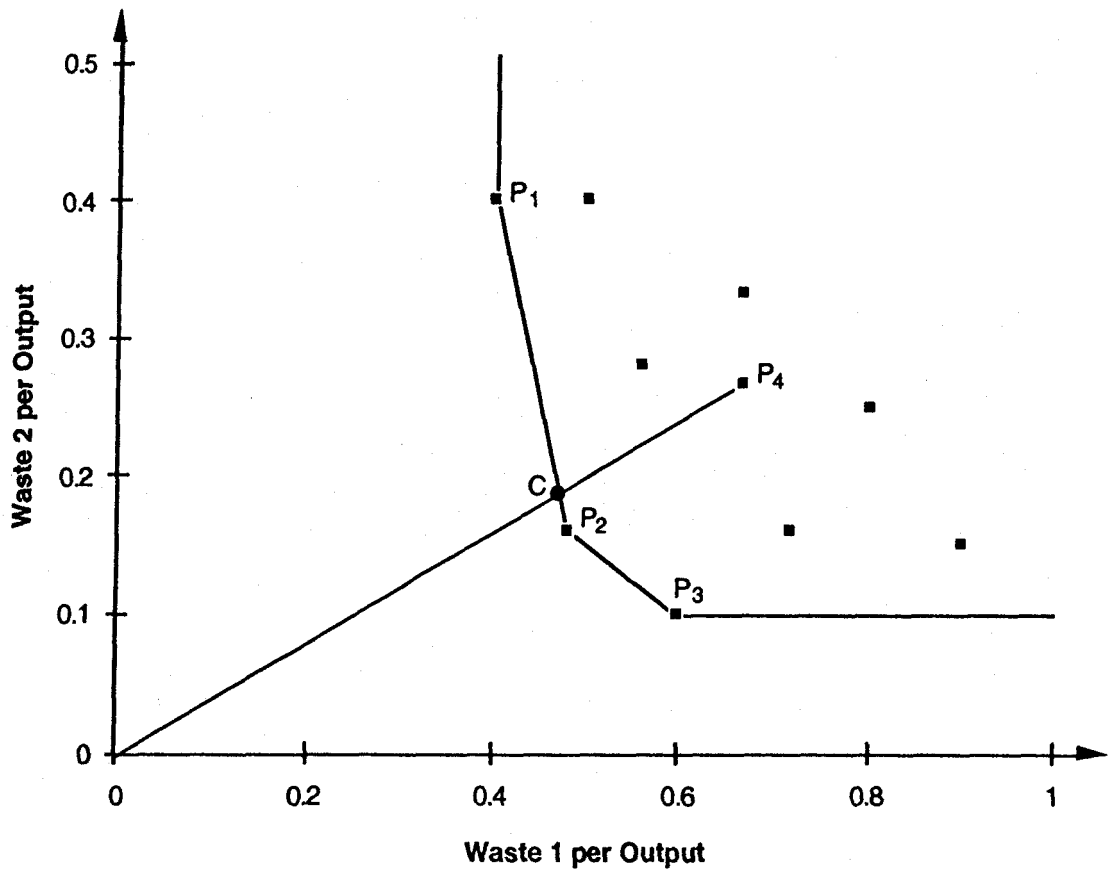

Figure 3. The Environmental Best-Practice Frontier and Relative Environmental Efficiency

Describing the Status of the Use of the Best-Practice Technologies

We will analyze patterns of use of the best-practice technologies, with the intent of identifying which regions or industry segments could benefit most by a proactive extension effort.

Repeating the Study in Subsequent Years

Preliminary plans call for the repeat of the study, particularly the technology usage survey, to analyze the diffusion of environmental technologies among firms in the state. This will provide a measure of the effectiveness of NC ACTs in promoting the use of environmental technologies throughout the state. The follow-up survey will contain questions assessing the influence of North Carolina technology programs in their decision to adopt the technology.

SUMMARY

NC ACTs will provide value added to the existing technology development and deployment agencies in North Carolina by enunciating a technology strategy and by coordinating the efforts of its affiliates in executing that strategy. The effectiveness of NC ACTs must be measured by how well it influences its affiliates to execute that strategy, by how apparent that strategy is in services offered to client firms, and, ultimately, by the progress that is made in the core technologies and target industries that are chosen by NC ACTs.

Because NC ACTs is unique among technology development and deployment organizations, we have sought guidance from the organizational effectiveness literature for developing metrics of the impact of NC ACTs. We have found that the metrics currently being developed by NIST and adopted by many technology transfer organizations have a theoretical base in models of effectiveness. By considering the application of these models to NC ACTs, we have developed metrics that indicate the impact of NC ACTs on its affiliated organizations, on the affiliates' clients, and on the North Carolina economy.

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