1. Introduction

Several methodologies fall under the umbrella of continuous quality improvement (CQI), such as: Total Quality Management (TQM), Six Sigma, the Shewhart/Deming Plan-Do-Check-Act Cycle, and the Capability Maturity Model Integration (CMMI). Some of these methodologies have been in use for decades, and they all have a common feature – they rely on the use of data and statistical thinking. Dransfield et al. (1999) has discussed the role of statistics and statistical thinking in improving organizational performance.

However, statistical organizations seem to have a blind spot when it comes to applying statistical thinking to improve their own processes. While CQI has been given prominence in publications about statistics (e.g., Biemer et al. (1994) and Morganstein et al. (1997)), CQI efforts in statistical organizations have not been widespread. Eurostat’s Handbook on improving quality by analysis of process variables (Aitken et al., 2004, referred to as “the Eurostat Handbook”) listed 15 statistical processes, but was able to discuss only eight of them. The team writing the Eurostat Handbook could not discuss the other seven statistical processes because they could not find “examples of suitable process quality work in these areas” in their national statistical institutes.

Further, the few CQI methods documented almost invariably are applied to production-type operations, such as interviewing, data entry, and clerical editing or coding – what Morganstein calls, “repetitive processes.” For example, Biemer described a CQI project to reduce errors identified during the quality control (QC) of the operation to assign industry and occupation codes from text responses. We found only one example of CQI in what Morganstein calls a “creative process,” writing statistical reports for a pharmaceutical company in Pikounis et al. (2001). Examples of other creative processes include designing samples, developing questionnaires, and analyzing data.

We contend that CQI efforts in statistical organizations are limited in part because organizations have difficulty measuring process quality and performance. They use a flawed approach to select process measures by looking for data they already have or data that are easy to obtain, rather than identifying the organizational goals to determine the measures they actually need.

A symptom of this flawed approach is the difficulty statisticians have in measuring creative statistical processes. We think CQI efforts focus on repetitive processes because “researchers often select a process because it is easy to measure, rather than choosing a more important but harder-to-measure process,” as Morganstein noted. Most of the repetitive processes where CQI has been applied generate process data as a by-product of a QC system. The project Biemer described used data generated by the QC system.

* Any views expressed are those of the authors and not necessarily those of the Census Bureau.
When process data are not automatically generated, often no data are obtained. Sundgren (2001) pointed out, “Up to now, it has not been common for statistical offices to collect, organise, and analyse process data in a systematic way. With a growing interest in systematic quality work, such as Total Quality Management (TQM) the needs for such efforts have become more and more evident.” Unfortunately, even one of the most basic measures, cost, can be hard to obtain. De Vries (1999) noted, “Efforts to compare the cost of specific, rather comparable statistical operations (such as the Labor Force Survey or the Consumer Price Index) in a few countries of the European Union have so far been unsuccessful.” On this same topic, De Vries also commented, “It is very difficult to measure the ‘productivity’ of statistical workers and even more so to compare ‘productivity’ between different statistical offices.” Haselden et al. (2001) remarked, “It is hard to find ways to measure the quality of a report.”

A statistical organization should measure process quality and performance for all their important processes, not just those that are easy to measure. To be fair, we recognize that data collection and clerical processing operations are not only easy to measure, but also account for a large part of an organization’s costs, so the Pareto Principle would suggest putting more emphasis on these processes. Although the costs of processes carried out by statisticians may be small relative to the costs of collecting and processing data, the importance of these creative statistical processes is disproportionate to their costs. For example, if the processes for analyzing data and generating reports need improvement, the organization’s information products will have longer cycle times and fewer products can be delivered. Late reports and reports that have to be recalled and corrected can hurt an organization’s credibility and hinder completion of its mission. Another consideration is opportunity costs. If weak creative processes generate errors and limit productivity among statisticians, the limited resources of statisticians cannot be assigned to improving the repetitive processes that account for the bulk of the organization’s costs.

This paper demonstrates a systematic approach for setting up process measurement systems based on the method described in Goal-Driven Software Measurement – A Guidebook, (Park et al., 1996). For the rest of this paper, we will refer to this document as the Guidebook. Written for software engineers, the Guidebook uses a ten-step approach that explicitly links the organization’s business goals with the information and measurements about the products, processes, and resources needed to meet those goals. We applied these goal-driven process measurement principles to the process of writing statistical reports, but simplified the approach by removing repetitive steps.

This demonstration illustrates how to measure process quality and performance in both repetitive and creative processes. As with any process improvement approach, management must provide resources and active support for it to succeed.

2. The goal-driven approach to defining process measures

Our demonstration uses the goal-driven approach to identify some of the measures needed to improve the process of “writing statistical reports.” To set the context before starting this example, consider the various processes involved in producing a statistical report:

1. Planning the analysis.
2. Obtaining the needed data files.
3. Preparing the data for analysis and producing estimates and statistical models.
4. Analyzing the data and determining results.
5. Writing (and re-writing) the report.
6. Reviewing, commenting, and approving the report.
7. Disseminating the report.
Our demonstration concentrates on Process 5, “Writing the report.” However, because Process 6, “Reviewing and approving,” provides some of the measures of the performance of Process 5, we include it in our discussion.

Figure 1 summarizes Processes 5 and 6. See Pikounis for a detailed flow chart of a report writing process.

![Figure 1. Report Writing Process Model](image)

While our demonstration focuses on writing the report, measurements on the report writing process might point to improvements needed in earlier processes because output from these processes are used in report writing. For example, mistakes in analyzing the data (Process 4) can carry over to the written report, so an improvement project might aim to reduce analysis errors.

The Guidebook calls for identifying the individuals or groups whose concerns the measures will address. Their concerns should provide the perspectives used in completing the steps to create the measures. Our demonstration uses the perspective of the managers responsible for the report writing process, so the measures should provide these managers with the information they need to manage and improve the process. If the measures don’t help the managers achieve their goals, the managers won’t use them. The best way to reflect the managers’ perspectives is to have them participate in developing the measures. An alternative is to interview these managers to get input on the data they need to manage the process.

1) Identify the business goals

The first step in the goal-driven approach is to identify the organization’s business goals. The manager responsible for the processes must be involved in identifying these goals. As mentioned earlier, if the measures don’t help the organization achieve its goals, they won’t be used and the resources needed to collect and report them will be wasted.

The business goals should be stated at a high level. We identified two business goals for our CQI project: 1) Reduce the costs (i.e., staff hours) needed to write statistical reports and 2) Reduce the cycle time for writing statistical reports.

2) Document the process and identify the entities

To improve a process, that process must first be defined and ideally, it should be documented. According to Basili (1995), “Measurement must be defined in a top down fashion, based upon the goals for measurement and our models of understanding. A bottom-up approach doesn’t work. The reason is that there are a large variety of software metrics … But which metrics does one use and how does one interpret them without the appropriate models and goals surrounding them?”

One of the first steps of a quality improvement project should be to document the processes to be improved, if they aren’t already documented. A documented process promotes consistency and predictability. Without documented processes, what Morganstein called “current best methods,” variability in cost, schedule, and product quality will be higher than necessary. Kristensen et al.
(1995) said regarding documented processes, “It goes without saying that it will be impossible to obtain continuous improvements if best practice is not standardized and communicated to everybody concerned.”

When the process is documented, it is easier to identify the important entities (objects of interest) in the process. These entities become candidate objects of measurement. The Guidebook suggests creating informal “mental models” of the processes in question to identify the important entities in the processes, but we want to emphasize the importance of formal documentation.

The Guidebook lists four kinds of entities important to processes:
- Inputs and resources (e.g., elements that are used or consumed)
- Activities and flow-paths (e.g., the structure of the process)
- Products and by-products (e.g., outputs)
- Internal artifacts (e.g., inventory or work in process)

Figure 2 lists many of the important entities in the report writing process.

<table>
<thead>
<tr>
<th>Inputs and resources</th>
<th>Activities and flow paths</th>
<th>Products and by-products</th>
<th>Internal artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authors</td>
<td>Drafting the report</td>
<td>Reports</td>
<td>Reports being drafted</td>
</tr>
<tr>
<td>Reviewers</td>
<td>Submitting paper for review</td>
<td>Errors</td>
<td>Reports needing review</td>
</tr>
<tr>
<td>Data and estimates</td>
<td>Reviewing the report</td>
<td>Reviewer feedback</td>
<td></td>
</tr>
<tr>
<td>Statistical test results</td>
<td>Providing feedback to the author</td>
<td>Approvals</td>
<td></td>
</tr>
<tr>
<td>Procedures</td>
<td>Correcting errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report templates</td>
<td>Approving the report</td>
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<td>Reviewer templates</td>
<td></td>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reviewer staff hours</td>
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<td></td>
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</tr>
</tbody>
</table>

Figure 2. Entities in the report writing process

3) Identify sub-goals

Sub-goals restate the high-level business goals as specific desired outcomes for the process being improved. To develop the sub-goals, we asked how we could improve the entities of the report writing process to achieve the business goals. These sub-goals support both business goals:
- **Reduce errors in initial draft reports** – Achieving this goal will reduce rework, saving both time and money.
- **Reduce the iterations in the review of reports** – Achieving this goal will again reduce rework, saving time and money by making a more efficient review process.
- **Reduce the effort needed to produce the initial draft report** – Achieving this goal will improve efficiency in preparing the first draft.

Before proceeding to the next step, validate and prioritize the sub-goals with the process’s managers to ensure that the goals address their concerns.

4) Develop quantifiable questions and indicators

For our demonstration, we selected the sub-goal, “Reduce errors in initial draft reports.” We used brainstorming techniques to generate and select quantifiable questions about the entities in the process that would be most likely to help achieve this sub-goal. If answered, they would help us manage the report writing process to meet our sub-goal. These questions ask about attributes of the entities and have numerical answers.

1. How many errors are identified?
2. What types of errors occur in each type of report?
3 Which processes generate the errors?
4 Which steps of the review process detect each type of error?
5 How many staff hours does it take to fix the errors?

Question 5 does not directly support the sub-goal “reducing errors,” but it provides information on whether the sub-goal and the business goal are being achieved – if staff hours needed to fix the errors have been reduced, the business goal, “reduce costs,” is being achieved.

After developing quantifiable questions, the second part of this step is to construct useful “indicators” to address the questions. “Indicators” communicate the answers to the quantifiable questions. The Guidebook suggests creating visual displays (e.g., tables, charts, or graphs) because they help clarify exactly what needs to be measured. We came up with these indicators to communicate the answers to the questions:

1 Distribution of errors by type.
2 Distribution of errors by report type (see Figure 3).
3 Distribution of errors by the process that generated them.
4 Distribution of errors by the review step that found them.
5 Staff hours to fix the errors by report type.

Figure 3 is an example (using hypothetical data) of an indicator for quantifiable question #2 in Step 4. For this demonstration, we used four types of report: news releases, publications, professional papers, and working papers. We grouped the types of error into five categories: editorial errors (e.g., grammatical or typographical errors), computational errors, statistical methodology errors (e.g., comparisons that are not statistically significant reported as significant), nonconformance with standards or policies, and other errors (e.g., errors within the data set used to prepare the report). Developing the indicators is useful because thinking about how you will communicate the data helps you catch hidden assumptions and improve the effectiveness of the operational definitions of the data elements that make up the indicator.

5) Identify and define the data elements

The data elements are the measurements that must be collected to construct the indicators developed in the previous step. This step has two parts: a) Identify the data elements and b) Create the operational definitions of the data elements. Based on the indicators shown in Step 4, we identified six data elements:

1 Number of errors
2 Type of error
3 Type of report
4 Number of staff hours
5 Type of review
6 Type of process

The second part of this step is to create the operational definition for each data element. Good operational definitions clearly communicate what is being measured, how it is measured, and what the measure includes and excludes. They should enable users of the data to interpret the measures correctly and apply them to make valid conclusions. They also promote reproducibility of the measures – anyone using the definition should be able to carry out the measurements and get essentially the same results.

We used detailed checklists to record the operational definitions of the data elements, as the Guidebook recommends. They help ensure that the definitions capture exactly what must be done to collect the data associated with each measure. This step can seem tedious because the checklist must go into a great deal of detail – it has to cover all the issues associated with each element and record what should be included or excluded from the measure. Even using a checklist, when actually carrying out the measurements, it is possible to discover that the definition needs revision to account for issues that were overlooked during the initial definition. Figure 4 is an example of a checklist for defining the data element “errors.” Finally, to help prioritize the data elements, it helps to map the data elements to the indicators, as in Figure 5. The data elements used in more indicators generally are more helpful because they address multiple questions.

<table>
<thead>
<tr>
<th>Data Element</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Number of errors</td>
<td>X</td>
</tr>
<tr>
<td>Type of error</td>
<td>X</td>
</tr>
<tr>
<td>Type of report</td>
<td>X</td>
</tr>
<tr>
<td>Number of staff hours</td>
<td>X</td>
</tr>
<tr>
<td>Type of review</td>
<td>X</td>
</tr>
<tr>
<td>Type of process</td>
<td>X</td>
</tr>
</tbody>
</table>

**Figure 4. Definition Checklist for Errors**

6) Develop a measurement plan

Finally, after identifying the data elements to be collected, it is time to develop a measurement plan to implement the measures. This step has four parts: a) Gather information about the existing data that might provide the measures needed to attain the sub-goal; b) Identify any changes to the existing data or any new data that may be needed including any changes that should be made to ex-
isting processes to collect those data; c) Plan the actions needed to implement the measures; d) Document the measurement plan.

a) Gather information.

Sometimes data are already collected in an organization’s processes. Two noteworthy examples are productivity measures in data collection and accuracy or reliability measures from the QC of clerical processing. To help in gathering information about existing data, the Guidebook suggests asking questions like:

• What data elements are required for my goal-driven measures?
• Which data elements are collected now?
• How are they collected?
• What are the processes that provide the data?
• How are the data elements stored and reported?

A common mistake is to begin with this step – determining what data are available or easy to get and trying to make those data work, rather than identifying business goals and figuring out what data are needed to work toward those goals.

b) Identify any changes to existing data or new data needed.

This part of developing the measurement plan involves determining what existing data meet your need as-is, what data need to be modified, what new data are needed, and finally, how you need to change your processes to provide the data that you need. If the existing data meet all the measurement needs, no changes may be needed. Generally, the existing data will not meet all your needs and new data will need to be collected or the existing data may need to be collected, processed, stored, or accessed differently. This means that changes must be made to at least some existing processes.

c) Plan the actions needed to implement the measures.

This step involves describing what activities must be carried out to meet the measurement needs. The Guidebook lists several activities to address in the plan:

• Describe the products to be generated and the tasks to be performed.
• Define the methods that will be used to collect and report the data.
• Identify the tools that will be required to support collecting, reporting, and storing the data.
• Set the time and frequencies of the measurements.
• Determine the schedule and the resources needed to implement the plan, including who is responsible for which tasks and products.
• Determine how progress will be monitored.
• Determine who will use the data.
• Describe how the data will be analyzed and reported.

d) Document the measurement plan.

The Guidebook provides a template for the measurement plan, so we will simply summarize key elements that the measurement plan should address. The plan should include sections that describe:

• The background and purpose behind the measurements.
• The scope of the plan.
• The goals that the measures will support (the business goals and sub-goals).
• The assumptions underlying the plan and the risks to implementation, and how the risks will be handled.
• How the measurement processes will operate on a production basis to collect, process, store, and use the data to support the goals.
• How the measurement activities relate to other processes in the organization.
• All the actions needed to implement the measures (described in Step 6c).

7) **Implement the measurement plan**

Carry out the plan using standard project management practices for monitoring progress and taking corrective actions to stay on schedule. In some cases, the plan may need revision to account for unexpected developments.

Implementing the measurement plan must be given enough priority so that resources are not shifted from measurement to regular production activities – or at least not shifted too often. Process improvement activities are often deferred when resources become tight or when emergencies crop up.

3. **Conclusion**

The primary point to remember from this paper is that an organization’s business goals should be the foundation for any process measures. Basili says “The process of setting goals and refining them into quantifiable questions is complex and requires experience.” The goal-driven approach to process measurement is not easy to do and we struggled with it at first. However, if organizations take the time to follow this approach, it will ensure that the measurements developed support their business goals.

The second point is related – do not take measurements simply because they are convenient. Too many organizations focus on process data that are convenient, rather than determining data needs based on the organization’s goals. If measurements do not ultimately support an organization’s business goals, they will not be used and will generate costs with no corresponding benefits. You also should resist the temptation to rely too heavily on customer satisfaction surveys – those surveys measure symptoms and will not reveal the root causes that must be addressed in a quality improvement project.

Finally, when creating operational definitions, using a definition checklist is important. Even with such a checklist, when people make the measurements or try to analyze them, clarification probably will be needed because the definition did not cover one point or another.

Continuous quality improvement requires measurement, to determine the current condition, to identify root causes, and to assess whether the improvement steps are actually working. This paper demonstrates how to apply the methods used in another field – software engineering – to processes in statistical organizations. We hope this paper assists statistical organizations in using a structured approach to determine the measures they need. We also hope the ability to develop useful measures will encourage statistical organizations to tackle CQI in processes they often overlook.
REFERENCES


2005. Measuring Performance and Benchmarking Project Management at the Department of Energy. Washington, DC: The National Academies Press. doi: 10.17226/11344. Â—.Â Performance measures used as a management tool need to be broadened to include input and process measures. One approach is to use an array or scorecard composed of multiple measures. The Balanced Scorecard is one such approach that assesses an organization and its programs from four different perspectives: customer, employee, process, and finance. â€œThe scorecard creates a holistic model of the strategy that allows all employees to see how they contribute to organizational successâ€. 