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# Quality Control Processing System for Survey Operations[1]

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ABSTRACT

The methods used to control the quality of Statistics Canada's survey processing operations generally involve acceptance sampling by attributes with rectifying inspection, contained within the broader framework of Acceptance Control. Although these methods are recognized as good corrective procedures, they do little in themselves to prevent errors from recurring. As this is of the utmost importance in any quality program, the Quality Control Processing System (QCPS) has been designed with error prevention as one of its primary focuses. Accordingly, the system produces feedback reports and graphs for operators, supervisors and managers involved in the various operations. The system also produces information concerning changes in the inspection environments which enable methodologists to adjust inspection plans/procedures in accordance with the strategy of Acceptance Control. This paper highlights the main tabulation and estimation features of the QCPS and the manner in which it serves to support the principal quality control programs at Statistics Canada. Major capabilities from a methodological and systems perspective are discussed.

KEY WORDS: Quality control processing system; Process control; Acceptance sampling; Acceptance control; Skip-lot sampling.

## 1. INTRODUCTION

This paper deals primarily with the features of the Quality Control Processing System (QCPS) that is presently being used at Statistics Canada. However, in order to show how this system fits into the overall quality picture for surveys, the paper begins with a brief discussion of the survey process and the role that quality assurance and quality control play in this process. The paper then identifies the specific quality control methods and strategies that are used for processing operations at Statistics Canada and how the QCPS serves to support this activity. The paper then proceeds to describe the system features and provides a summary of its major achievements.

### 1.1 The Survey Process

The requirement of ensuring quality in the overall survey process has always been considered a high priority at Statistics Canada. In a very general sense, it may be viewed as being achieved through the application of a series of quality assurance (QA) and quality control (QC) measures at the appropriate stages of a survey process. It is important to distinguish between these two activities since in our environment, they involve very different approaches and procedures that are normally applied at different points in the process. A simplified overview of the survey process at Statistics Canada includes the following stages:

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- planning
- design
- implementation
- processing
- publication.

It is important to note that every one of these stages is subject to some error. It should also be realized that the further into the survey process the errors are discovered, the more impact they have on survey timeliness, cost and accuracy. Therefore, it is good practice to put a strong emphasis early in the process, on the development of measures and procedures that would prevent or reduce their occurrence. This should occur at the planning and design stages of the survey process. These measures and procedures are also known as quality assurance.

### 1.2 Quality Assurance

A general approach to establishing quality assurance is to try to anticipate problems very early in the survey process and take appropriate steps to prevent or minimize them. The anticipation can be based on experience, reviews, evaluations, debriefing exercises, feasibility studies, *etc.* The steps could include improving sampling frames/designs, modifying data collection methods, improving questionnaire design, providing clearer processing procedures, *etc.* A comprehensive list of such steps may be found in Statistics Canada's Quality Guidelines (1987).

This approach is extremely important since effectively it moves quality upstream and thereby helps to prevent many potential problems from occurring. Furthermore, in so doing, it assures better quality at the least cost by "getting it right the first time". Despite our best efforts however, there are some situations when error levels continue to be unacceptably high. In these situations we consider the use of quality control.

### 1.3 Quality Control

In contrast with QA, statistical quality control has been found to be highly applicable at the processing stage of the survey cycle. At this stage, the work usually has the following characteristics:

- labour intensive and repetitive in nature;
- assigned to individuals or operators with varying abilities;
- normally grouped into batches or lots of similar work units.

As such, these survey operations are more prone to the occurence of errors. Examples of these operations include:

- coding/transcription
- manual editing/reviewing
- data capture/entry
- corrections/reconciliation
- updating/profiling, *etc.*

For many reasons, which include complexity of tasks, abilities of operators, turnover of staff, *etc.*, the amount and significance of error varies between operations, between operators within an operation, and at times within operator. Statistical quality control is used to identify and reduce this variability and ensure that the outgoing quality of each operation falls within acceptable levels.

## 2. QUALITY CONTROL STRATEGY

### 2.1 Methods of Quality Control

Of the two main methods of quality control available, namely, process control charts and acceptance sampling, we have found the latter methodology applied in the broader context of Acceptance Control, to be the more appropriate method for *on-line* quality control of survey processing operations. The reasons for this are as follows:

- prior control or stability of process cannot be assumed initially nor always attained in the long run;
- assignable causes of error are not always known since we are dealing with people (*vs.* say machines);
- processes cannot readily be stopped and adjusted for assignable causes, even if they are known;
- with many operators and large "between operator" variabilities, many individual control charts requiring immediate updating (*i.e.*, after each sample observation) would be required on-line to the survey operation; this would be operationally difficult to achieve.

Therefore our quality control strategy generally consists of using varying acceptance sampling procedures (with rectification) applied at the operator level, as a screening device for correcting substandard quality, with the aim of continually reducing inspection as the inspection results support this action. This is coupled with an emphasis on operator and supervisor feedback to establish error prevention. In this manner both error correction and subsequent prevention are exercised at the error source, where they can have their greatest impact. Furthermore, between operator variations are automatically dealt with as each operator is effectively treated as a process in the following sense. During a period of low to moderate stability, acceptance sampling is applied to each lot processed. During a period of high stability coupled with good past inspection results, less acceptance sampling and even spot checking may be applied under the broader strategy of Acceptance Control.

### 2.2 Acceptance Control

After a quality control program has been operating for some time, operator processing abilities tend to improve and in many cases, a stabilization of quality occurs. In an effort to take advantage of this improved situation and to enable our quality control designs to be more economical, we have adopted the strategy that Schilling calls Acceptance Control (1982). Under this approach, acceptance sampling procedures are continually modified and adapted as changes in the inspection environment are identified. This is in accordance with one of QC's main pioneers, H.F. Dodge who states (1950):

> "A good product with a history of consistently good quality requires less inspection than one with no history or a history of erratic quality. Accordingly, it is good practice to include in inspection procedures provisions for reducing or increasing the amount of inspection, depending on the character and quantity of evidence at hand regarding the level of quality and the degree of control shown."

In fact the ultimate aim of acceptance control is to continually reduce inspection to the level of spot checks or process controls as the quality history improves and stabilizes. At Statistics Canada, two specific approaches are used to achieve this principle:

- *Graduated Inspection Plans.* These are obtained by raising or lowering the quality index for the sampling plan as changes in the process average are observed and then closely monitoring the impact on the resulting average outgoing quality estimates.
- *Cumulative Results Plans*, more specifically Skip-Lot Sampling (Stephens 1982). Here, the extent of skipping lots depends on the stability and level of expected incoming quality.

Both approaches are part of our acceptance control strategy and require a good quality history which would indicate not only the underlying level of processing quality (*i.e.*, at the operator level) but also the extent of stability (*i.e.*, degree of control) that can be expected in the process. Accordingly, the inspection process must provide:

- good data (accurate error estimates);
- quick results (monthly, weekly, daily);
- incentive for improvement (feedback reports);
- quality history (time series of error quality).

Essentially these have been the motivating influences in developing the Quality Control Processing System (QCPS). It should be noted that changes are currently being made to the system to expand the existing operator quality history. This should provide the data to enable greater implementation of spot checks and/or process control for selected operators with exceptional and stable performances.

## 3. SYSTEM DESCRIPTION

Based on the strategy identified above, the QCPS has been developed to achieve the following objectives:

- process any single acceptance sampling transaction;
- provide output by operator where each operator can be treated as the error source;
- provide feedback to four levels of staff with current and historical quality control information;
- support the acceptance control strategy by enabling the processing of skip-lot sampling results and providing an extensive operator quality history;
- support the major QC objectives of error correction and prevention while enabling inspection costs to continually be minimized.

### 3.1 Methodological Features

#### a. Inspection Schemes

The system can process any quality control transaction resulting from the application of *single* acceptance sampling. This naturally includes normal, reduced and tightened plans as well as any skipped lots resulting from skip-lot sampling. The system will also process any lot whose plan designation is 100% inspection.

#### b. Lot Status Codes

The system determines the treatment of incoming QC transactions by using lot status codes which indicate the state of completeness of the intended inspection. There are codes for the following lot situations:

- sample inspected and accepted;
- sample inspected and rejected (remainder inspected);
- 100% inspected;
- any of the above not completed (3 codes);
- no sample inspection due to skip-lot.

**c. Attributive Quality Measures**

The system will produce estimates for various quality measures which include percent defective, defects per hundred units and weighted error equivalents. For the latter quality measure, the system allows errors to be weighted according to a pre-defined error seriousness classification scheme. Typically, under these more complex measures, errors are categorized and assigned weights from 0 to 1 depending on their relative magnitude and seriousness. For purposes of simplicity, no more than four error categories are generally defined, as follows:

| Category | Weight |
|---|---|
| Critical | 1.0 |
| Major | 0.4 - 0.6 |
| Minor | 0.2 - 0.3 |
| Insignificant | 0.0 - 0.1 |

**d. Estimates**

The system provides estimates and their associated standard errors (where applicable) for many key quality control indicators. The most important of these are:

(i) *Error Rates*

Error rates are calculated which relate to the individual operator, a specific sampling plan or the overall application. These estimates are provided for various time frames (*e.g.*, daily, weekly, monthly, quarterly, *etc.*), and various subsets of the application, such as specific lot categories (*e.g.*, rejected lots) or sub-groups (*e.g.*, regional offices).

(ii) *Operator Process Average*

An estimate of an operator's processing ability at any particular point in time is provided by the operator process average. This estimate is calculated using an empirical Bayes approach (MacMillan and Mudryk 1988) which essentially shrinks the current operator sample error rate estimate part way towards the grand average error rate of the last four periods for that operator. The basis of shrinkage is determined by the ratio of the sampling variance of the current sample estimate to the total variance of the grand average estimate. This quantity has been found to produce good estimates for qualifying operators onto minimum inspection sampling plans.

(iii) *Rejection Rates*

Actual and expected rates of rejection are calculated for each sampling plan for purposes of statistical comparison and operational evaluation. The expected rates are obtained assuming Poisson probabilities.

(iv) *Inspection Rates*

Inspection rates are calculated at various levels as a general indicator of relative costs. These rates are determined with and without skip-lot effects on an actual and expected basis. The expected rates are a natural extension of the expected rejection rates discussed above.

(v) *Average Outgoing Quality*

An estimate is provided of the Average Outgoing Quality (*i.e.*, AOQ) rate resulting from the application of quality control to the operation. This estimate projects the observed error rate at the operator level to the uninspected volume for that operator, and then aggregates all operators to determine the overall estimate.

**e. Analysis**

The system provides tabulations and outputs which enable analyses to be performed at various levels which help to subsequently fine tune the application parameters and/or modify the plans. These include:

- operator profiles that enable a sampling plan/procedure qualification analysis;
- individual sampling plan evaluations that provide an overall QC plan analysis;

- summaries of key indicators that enable a QC cost-benefit analysis;
- a Pareto analysis of operator and error code contributions;
- group charts of operator process averages that provide an operations performance analysis.

**f. Reports**

The system produces 8 reports and 5 graphical outputs (through its link to SASGRAPH) for each application run. Tabulations can also be produced for specified sub-groups (*e.g.*, Statistics Canada's regional offices) with a summarizing feature over all sub-groups of each report.

Each set of output reports is designed for and disseminated to four levels of staff, namely: operator, supervisor, manager and QC designer. Examples of the output reports are available from the author.

## 3.2 Software Features

**a. Operator Capacity**

For each application, the system can handle up to 108 operators in its historical file, each containing up to three previous periods of error information. A unique self-maintaining feature of this file is that any operator who has not been active during at least one of the last 4 consecutive months of processing is dropped. This makes room for new operators on the file and thereby increases the effective file capacity.

**b. Historical Updates**

The system updates each operator error quality history (of up to 4 consecutive periods) with new information as it becomes available. This is currently being increased to 6 consecutive time periods. If an operator has not processed during a particular month, blank data for that month is inserted. Likewise, application year-to-date and quarterly totals are updated with the addition of each new month of QC data.

**c. Year-End Rollover**

Most of the QCPS applications are maintained on a calendar year basis. When this option is specified, the system will zero out the previous monthly totals and commence a new application time series (usually starting in January). The quarterly totals and the operator error quality time series however, are not re-set at this time and continue to be maintained as usual.

**d. Recovery**

If a tabulation run is made and errors are subsequently discovered, another run can be made using the recovery feature with the corrected data, to automatically produce the corrected outputs.

# 4. SYSTEM BENEFITS

The QCPS is aimed at servicing the needs of four levels of staff which interface with each QC application. Accordingly, the major achievements of this system can best be described under these same headings:

**a. Operator Level**

The QCPS provides extensive feedback to the individual processing operators on their current and historical performance. The operators are then able to track their own progress, compare their own performance with that of their peers, and identify explicitly where their errors are being made. The result of this feedback generally leads to:

- improvement in operator processing ability;
- increased motivation with respect to peers;
- greater quality consciousness;
- higher operator morale.

**b. Supervisor Level**

The system provides operational information to the supervisors which enables them to better manage their operation in terms of:

- effective resource allocation and work distribution;
- identifying problem operators and/or areas;
- determining training needs.

**c. Management Level**

The system provides data summaries on key quality control indicators for management which enables them to:

- receive an assurance of quality;
- track the progress of the application in terms of quality and costs;
- recommend changes to operational objectives.

**d. QC Design Level**

The system provides extensive information (*e.g.*, estimates, quality histories) which is used to analyze the quality control design and fine tune or enhance the methods and procedures of each application. When this data has been established and maintained over a sustained period of time, it can lead to:

- improvements in QC methodologies and procedures;
- sampling plan and/or inspection procedure adjustments;
- minimization of inspection costs.

## 5. CONCLUSIONS

The QCPS is being used at Statistics Canada to support the Quality Control programs of many production oriented survey processing operations. As the ultimate aim of each program is to exercise error prevention to the extent possible, as well as, to progressively reduce inspection to the level of spot checks, a good and flexible processing system is essential. The QCPS achieves these objectives by providing good data and quick results to the various levels of staff that are involved in each operation, as well as, supporting the various inspection methods that fall under the general strategy of Acceptance Control.

The system is particularly attractive to our user community since it can easily handle large volume operations involving many operators, quickly and at a low cost. Furthermore, by treating each operator individually, the system focuses attention to each relevant error source and supports this with necessary feedback to the appropriate levels of staff. In this manner the system enables our quality control methods to be both preventive and corrective in an efficient and economical manner.

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## REFERENCES

DODGE, H.F. (1950). Inspection for quality assurance. *Industrial Quality Control*, 7(1), 8.

MacMILLAN, J.H., and MUDRYK, W.V. (1988). A non-parametric Empirical Bayes approach for estimating a process average in quality control. Paper presented for the Section on Physical and Engineering Sciences, American Statistical Association Annual Meeting, New Orleans, Louisiana.

MUDRYK, W.V., and BOUGIE, R.W. (1987). Quality control processing system (QCPS) - Users Manual. Internal document. Statistics Canada, Ottawa.

SCHILLING, E.G. (1982). *Acceptance Sampling in Quality Control*. New York: Marcel Dekker.

STATISTICS CANADA (1987). *Quality Guidelines*. 2nd Edition, Ottawa, Canada.

STEPHENS, K.S. (1982). *How to Perform Skip-Lot and Chain Sampling*. Volume 4, ASQC Basic References in Quality Control: Statistical Techniques. American Society for Quality Control, Milwaukee, Wisconsin.