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STATISTICAL QUALITY CONTROL AT STATISTICS CANADA

by

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Key Words: acceptance sampling; attributes; statistical quality control; acceptance control; quality control processing system; average outgoing quality limit.

ABSTRACT

Over the past several years statistical quality control methodologies at Statistics Canada have evolved from formal Product Control (ie Acceptance Sampling By Attributes) to a more complete use of all quality control information obtained to achieve what is now called Acceptance Control. The use of this additional information allows us to continually adapt our quality control methods to the existing conditions of survey operations. In this context this paper reviews the general approach to statistical quality control and its relation to survey processing operations in Statistics Canada.

INTRODUCTION

At Statistics Canada, quality control efforts have mainly been oriented to the statistical quality control (SQC) of survey operations involving manual processes rather than to research into new methods. Thus our experience is predominantly related to the selection and implementation of relevant statistical quality control methods to specific survey operations. Generally we utilize methods and techniques that have evolved in parallel with and resemble those proposed by various authors in texts, journals and research papers.

Our developmental work has been restricted, firstly, to the evaluation of design options and secondly, to the continuing improvement in the implementation and maintenance stages of quality control operations. Over the last three years greater emphasis has been placed on the incorporation of preventive measures based on the use of data from inspection and, as a result of this, Statistics Canada has moved towards what Dr. Edward Schilling calls Acceptance Control (11).

These preventive measures require the maintenance of accurate time series data on inspection results for each quality control operation and the use of these data to improve the design. The latter involves developing sampling plans that are more tailored to each operator's performance, providing appropriate feedback of information to all levels of staff (operators, supervisors, managers), and establishing and continually updating the data base that will be used to analyze the design and fine-tune the methods. Most of these measures are supported by software improvements in our Quality Control Processing System (QCPS) which will be described in more detail below under the heading of Quality Control Maintenance Requirements.

Increased efficiency resulting from the use of this QCPS has allowed the same monitoring staff to maintain more quality control operations for other areas. In total, the number of new operations now using quality control methods has more than doubled.

This paper will begin with a brief overview of the quality environment in Statistics Canada. This will cover the Bureau's products, their use, the importance of quality, how we attempt to achieve quality and lastly, how quality and statistical quality control relate to our survey processing operations. Next the major considerations underlying the design, implementation and maintenance stages of our quality control operations will be described. The benefits that are derived from the greater use of inspection results will be underlined.

BUREAU'S PRODUCTS

At Statistics Canada the major activity is the production of Information that relates to all social and economic facets of Canadian society. This information is disseminated in the form of publications, through CANSIM, on summary tapes, by custom tabulations, etc. These products are the result of censuses (i.e. a complete coverage of a specific universe, with the Census of Population being the most important example), sample surveys, use of administrative records or a combination of these data sources. In sample surveys, data are collected from a probability sample of a particular target population which permits calculation of estimates and of quality indicators that allow inferences to be made. These estimates may be at the Canada level or they may relate to provincial or sub-provincial levels.

Censuses or surveys may be either cyclical or special collections with the majority falling into the cyclical category. The cycle can vary from every five to ten years for censuses to annual, quarterly or monthly for sample surveys.

PRODUCT USES and IMPORTANCE OF QUALITY

Governments (federal, provincial, municipal), industry, academia and the public make use of the information Statistics Canada produces in their decision making processes (e.g. where to build a school or plant, which segment of the population or which industry provides marketing opportunities, etc.). It is essential that all these users have confidence in the information published and that its quality is sufficient for their purposes. The following sections will summarize how quality is built into the design of Statistics Canada censuses and surveys and the part that statistical quality control plays in this.

ACHIEVING PRODUCT QUALITY

It is widely accepted that quality products can only result from quality processes and that quality cannot be "inspected into" a product. Quality must be considered at the design stage so that appropriate procedures are developed and implemented. Having said this let us briefly look at how the survey design and implementation activities relate to product quality.

In general one could say that survey design is a preventive approach to product quality. It is at the design stage that one considers how to minimize or avoid the effect of both weaknesses in available lists or frames intended to cover the population of interest, and the various sources of errors that are known to occur during the implementation of a survey.

The art of overall survey design is essentially concerned with identifying an optimum balance between the costs and errors of individual survey operations. Since the quality of the final statistical output will be a function of errors introduced at all stages of the survey, control of error at these stages is crucial. Statistical quality control is therefore an essential ingredient to overall survey design.

SURVEY OPERATIONS AND SQC

Our survey operations can be divided into two main types, namely, those that are manual and those that are computer oriented. The computer oriented operations are not as subject to error since they will be fully tested to ensure that they meet their specifications and objectives.

Manual operations can include data collection, editing, coding, transcribing, data capture and correction processes. In most of these, the work is usually grouped into work units called batches or lots which are then assigned to individuals or operators for processing.

It is in these manual activities that errors can and will be introduced into the survey data. The number and importance of these errors in any specific survey operation will vary not only between operators but within operators over time. The between operator error variability is generally found to be considerably greater than the variability within an operator.

When the cumulative effect of errors in a survey operation is excessive (i.e. greater than the quality objective for that operation) then the application of statistical quality control methods is often the best way of bringing this error variability under control. At Statistics Canada, product control (or acceptance sampling) by attributes is generally the chosen method.

Before covering the major considerations of quality control design, implementation and maintenance, there are two important points that should be noted:

- Quality control techniques should only be implemented when they are justified. Normally the first task is to evaluate the data quality of an existing survey operation and then recommend management actions and/or quality control techniques if they are needed;
- At Statistics Canada the resources assigned to a specific survey operation are generally fixed while the number of people that need to be assigned to the inspection function may fluctuate. It is these fluctuations that will often lead the survey manager to consider sacrificing quality requirements in order to meet production deadlines. To cope with these situations the acceptance sampling procedures must be flexible enough to accommodate such operational fluctuations and constraints.

MAJOR DESIGN CONSIDERATIONS

1. Lot Formation

Care must be taken to consider several constraints when estabishing the rules for lot formation (4, 6). Generally speaking, the larger the lot size, the smaller the required percentage of inspection while, on the other hand, the more difficult it is to select a representative sample. Furthermore, larger lots present additional work distribution problems in their preparation and in their inspection if the lot happens to be rejected. Thus a balance must be struck among these conflicting constraints.

2. Sampling Plans

Associated with each acceptance sampling plan is a sample size and an acceptance number which can be calculated in different ways depending on the quality and inspection objectives. Although there are many standard types of quality protection available (eg. Average Quality, Lot Quality, Specific Quality Levels or MIL-STD-105D Tables), the sampling plans used most often at Statistics Canada are those that provide

Average Quality Protection with minimum inspection at a specific processing error level - i.e. the features that best meet the needs of survey managers. With rectification these plans are called Average Outgoing Quality Limit (AOQL) minimum inspection sampling plans which follow the Dodge-Romig Model (1). These plans are calculated to be optimum for each individual operator or group of operators processing the work.

Many operational constraints, such as the survey process itself and the logistics of work flow, must be considered when selecting an appropriate sampling plan or set of plans.

Most of our quality control operations are associated with monthly survey processes where, in general, the work is grouped into batches and then processed by individuals. As already mentioned, for these operations we generally use the Dodge-Romig minimum inspection AOQL plans. However, when resources become an operational constraint, adjustments may be made either by using reduced inspection plans for the better qualified operators or by adjusting the AOQL specification upwards and then tightly monitoring the estimated AOQ to ensure that it is always within the original design specification.

However, the above approach is not always possible, and alternative methods must be considered. In one operation, where the work is segmented and continuous in nature, the Wald-Wolfowitz Continuous Sampling Plan (13) is being used. In another operation, work batching is impossible and the data flow is by individual units. For this operation the use of the DODGE-CSP1 Continuous Sampling Plan (2) has been recommended.

It is interesting to note that Table 19.2 of Dr. Edward Schilling's recent book (11) recommends the use of the same sampling plans in similar work flow situations.

3. Sampling Schemes

Although theoretically there are inspection economies to be realized with double, multiple or sequential sampling schemes, at Statistics

Canada, experience has indicated the importance of keeping operations simple (3), so normally single sampling methods are used.

4. Level of Sampling Plans

In most quality control operations, a sampling plan is designed for each operator based on his or her calculated processing average. In some cases, operators falling in a small specified range of processing average are considered as an homogeneous group for which the sampling plan is designed. In both cases, the inspection is minimized per operator or per group since the between operator variability in process quality can be ignored. It is by exercising control at this operator level that we achieve control of the overall operation in an economical manner.

5. Seriousness Classification of Error

For the most part, multiple items of a sampling unit are treated as true attributes. However, for purposes of lot decision and error calculation when certain items of a sampling unit carry less or greater importance than others, these are treated within the context of a seriousness classification system as described by Juran (6). It is important to note that for economical reasons, a common sampling plan (ie for different classes of defects) is always used.

6. Operator Qualification

Every month each operator is allocated to a sampling plan based on his or her estimated processing average. With each individual having a sampling plan, it is important to have good estimates of process averages to achieve minimum inspection. Estimation methods have changed over the last few years from a moving average approach to a regression method and currently to a Bayesian approach (i.e. making use of past relevant data). These changes have resulted from an ongoing review of research papers (5, 10) and evaluation of techniques using our own data. With each change, the stability of estimates of individual operator processing averages has improved.

7. Sample Selection

Methods of sample selection for inspection vary among operations and depend on certain operational considerations. Since inspection resources are limited and experience has shown the benefit of keeping procedures simple, random sampling is rarely used. In cases where the production of a lot is limited to less than one half-day, cluster sampling is normally used under the assumption that lot quality is homogeneous. On the other hand, for large lots whose production spans several days, systematic sampling (with a random starting point) is preferred to achieve good lot representation. Sometimes combination methods are used (eg. multiple clusters).

In each case, care is taken to achieve reasonably good lot representation in a simple, timely and efficient manner. From time to time evaluations are carried out to verify whether or not the underlying homogeneity assumptions are being violated.

8. Method of Verification

Although independent verification methods are generally accepted to be more accurate than dependent methods (7, 8, 9), resource constraints and operational simplicity have a great influence on the method that is ultimately selected. In our data capture operations, the sample records are independently rekeyed but the final decision on all mismatches is made on a dependent basis. In most of our manual coding operations we incorporate dependent or combined verification methods. In general, our experience with completely independent methods is that they are too expensive and complicated to be sustained. This has been particularly the case in a period of continuing budgetary restraint. We do feel, however, that independent methods are less subject to verifier bias and given sufficient resources, they should be encouraged.

9. Automated vs. Manual Quality Control Systems

Over the past few years there has been a tendency for survey data capture to move from a centralized operation to decentralized operations on mini computers in program areas. In the centralized operation, the specified lot data are manually recorded on a lot control card. These data include administrative information, sampling information, recording of different errors as well as whether the decision was to accept or reject the lot for complete verification. When these operations were moved onto mini computers, advantage was taken of the opportunity to automate the quality control procedures.

In this new environment a computer program drives the verifier by identifying the start of sample inspection and continues to present subsequent sample records until the required sample size (specific for the lot and operator) is completed. During this process, the software keeps track of all errors that are identified (and corrected) and when the verification is completed it tells the verifier whether the lot has been accepted or rejected. If rejected the system then forces the verifier to verify the remainder of the lot. For each lot processed, the software also maintains a statistical record of the results. Essentially this automated system eliminates the need for manual sample selection, record keeping and decision making on the lot. The resulting statistical records are then accumulated and processed through our Quality Control Processing System (QCPS).

QUALITY CONTROL IMPLEMENTATION

There are two major tasks associated with the implementation of quality control operations. First, detailed quality control procedures are developed for each operation. Then formal training sessions are held to ensure that the production staff fully understands the quality control system and can follow the procedures.

For each manual quality control operation the procedures that are developed would contain information on the following:

- guidelines for batching the units into work lot assignments;
- specifications for obtaining the relevant sampling information;
- procedures for selecting the sample units to be verified;
- rules for recording and correcting errors;
- lot decision and rectification rules.

Detailed training material is then prepared on the reasons for quality control and importance of following the prescribed procedures. Training sessions include test situations to check that the staff understands and correctly interprets the application of all procedures. Refresher training sessions are given when requested or when an operator's performance indicates it is needed.

The critical role that proper training plays in each quality control application cannot be over-emphasized. Experience indicates that without proper training the chances of successful and effective implementation diminish substantially.

QUALITY CONTROL MAINTENANCE REQUIREMENTS

Acceptance sampling is a good corrective procedure that screens out bad work and with rectification ensures acceptable levels of outgoing quality. However, this by itself, does not constitute an effective quality control program, since errors may continue to recur and high levels of inspection would continually be required to "correct-in" quality.

An effective quality control program should include steps aimed firstly at detecting errors and secondly at providing appropriate feedback, retraining or other measures for their future prevention. In fact this should be the primary objective of a quality control program since success in prevention will reduce the amount of inspection required in correction. This prevention may be realized by providing timely feedback to all production, management and design levels concerned, and by ensuring that appropriate follow-up actions are taken. (ie this may involve management action)

Recognizing the importance that feedback and good use of inspection results can play in a successful quality control program, software has been developed in a special system that provides feedback information tailored to the needs of staff at all levels involved with each program, namely:

- operators who process the work;
- supervisors who manage the operation;
- management that is responsible for overall data quality;
- methodologists who design, update and maintain the Q.C. Program;
- methodologists involved in the overall survey design.

The system that provides this information is the previously mentioned Quality Control Processing System: QCPS (12) which produces reports and graphs, usually on a monthly basis, for each of the various staff involved. It should be noted that it is through the effective and timely use of this information that Statistics Canada has moved closer to realizing the important concept of "Acceptance Control". The QCPS system thus provides the information needed by various staff to achieve Acceptance Control.

A description will now be given of the particular outputs generated by QCPS and how each can help staff in bringing about improvements for the benefit of the overall operation.

1. Personal Operator Information Report

   This report is sent to each operator on a monthly basis and it provides both the individuals' and the group's performance levels for the current and last three processing periods (months). Operators whose current performance is better than the group average are identified on the report to give them positive recognition. The potential benefits of this report are:

   . improvement in operator processing abilities;
   . increased motivation with respect to peers;
   . instilling quality consciousness;
   . promotion of operator morale.

2. Supervisor Summary Report

   This report provides information on the quality performance of each individual and of all operators. As well, it provides data on overall inspection levels, rejections and their expected rates. The supervisor can make use of this information to better manage the operation in terms of:

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

Increasingly, graphical outputs are also being provided, since graphs are often more illuminating.

3. Year-to-date Summary Report to Management

   This report provides summary data on volume, inspection levels and the overall incoming and outgoing quality levels of the operation for each month of the calendar year, as well as, quarterly and year-to-date summaries.

   With this report, survey and senior managers can readily see whether their quality requirements are being met. Management decisions and/or changes may subsequently result from a review of this report.

4. Analysis Reports to Designers

   There are several reports which provide detailed information on the performance of operators, verifiers, and individual sampling plans for survey and quality control designers. Comparisons can be made of actual against expected rejection rates for each sampling plan utilized. Current and historical error rates for each operator (including their variances) along with other summary data relating to the overall operation are provided.

   These data are used primarily to analyse the quality control design and to fine-tune the methods used in each operation. When data are maintained over a sustained period, this analysis can lead to:

   - changes in methodology;
   - improvements in procedures;
   - sampling plan modifications;
   - reduced inspection/skip-lotting/spot checking.

The most important aspects of our Quality Control Program, are the active participation and co-operation of production, management, and quality control staff, and the QCPS system with its provision of feedback reports and results to all levels concerned. Both are key to achieving Acceptance Control.

EXAMPLES of Q.C. OPERATIONS

Table 1 provides a summary of all quality control operations that are subject to the methods described in this paper. This does not include, for example, applications in the Census of Population and Housing, which utilize quality control for field enumerator's work, manual coding and data capture operations. Seven program areas encompassing 16 different survey operations are serviced. Two of these operations are decentralized in 8 Regional Offices across Canada.

CONCLUSION

The most significant change in quality control practice at Statistics Canada in recent years has been the move towards Acceptance Control supported by the introduction of a computer based Quality Control Processing System. The latter has allowed the doubling of the number of quality control operations in the last two years with no increase in the size of the staff responsible for quality control design, implementation and monitoring.

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TABLE 1

Q.C. OPERATIONS - 1984 SUMMARY

Name of Survey Operation	Type of Manual Operation	No. of Sub-groups*	Total No. of Operators	Annual Volume (Units)	Overall Inspection Rate (%)	Sample Rejection Rate (%)	AOQL %	Est. AOQ %
1. LABOUR FORCE SURVEY								
a) Form 05	Oata Capture	8	69	1,484,054	14.0	4.2	3	0.7
2. TAX RECORO ACCESS								
a) T1 Transcription	Coding & Trans.	1	10	207,582	8.8	1.0	10	3.5
b) T2 Transcription	Coding & Trans.	1	11	38,051	24.3	5.2	10	5.2
c) T1 & T2 Keying	Oata Capture	1	34	462,919	19.9	6.9	4	2.0
3. BUSINESS REGISTER								
a) PO-20	Coding & Trans.	2	26	125,707	30.1	5.9	5	2.9
b) CBS-718	Coding & Trans.	3	26	42,682	54.7	4.5	5	1.4
4. INTERNATIONAL TRAVEL								
a) Form E62	Oata Capture	1	15	271,884	15.0	5.8	5/7	3.4
b) Quest. Group 2	Coding	1	12	45,935	15.5	3.2	8	3.4
c) Quest. Group 3	Coding	1	4	17,262	10.0	0.0	8	5.4
d) Quest. Group 4	Coding	1	9	30,954	12.9	1.4	8	4.6
5. HEALTH								
a) Quarterly Hospital	Editing	1	6	10,641	19.8	NA	NA	1.1
b) Therapeutic Abortions	Oata Capture	1	3	16,501	26.7	0.0	3	1.8
c) Oisability Survey	Coding/Capture	1	9	70,372	7.7	0.5	3	0.5
6. R.O. OPERATIONS (Business)								
a) SEPH	Editing	8	107	193,310	33.2	8.4	5	1.2
7. BUSINESS FINANCE								
a) LTC	Data Capture	1	19	188,839	19.8	7.9	3	1.7
b) SIC	Coding	1	13	102,048	15.2	1.6	5	3.2
TOTALS	16 Operations	33	373	3,308,741	17.3	4.8	-	-

* Where an operation has more than one production staff, it is called a sub-group.