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Sampling procedures for inspection by attributes — Two-stage sampling plans for auditing and for inspection under prior information

Règles d'échantillonnage pour l'inspection par attributs — Plans d'échantillonnage à deux niveaux pour l'audit et l'inspection des lots en exploitant l'information a priori

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 69, *Application of statistical methods*, Subcommittee SC 5, *Acceptance sampling*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document addresses several application domains: financial auditing, lot inspection, quality auditing, functional testing, conformance inspection and acceptance testing. In all these domains, users are concerned with the decision problem of accepting or rejecting an inspection target.

The two-stage sampling scheme suggested by this document addresses three areas of inspection practice:

a) adjust sample sizes to prior information on the status of the inspection target;

b) enable a rapid decision by samples of small size if the population submitted for inspection is actually in very good or very bad condition, and enforce higher sample sizes only if the population submitted for inspection is actually in a medium condition;

c) protect against both errors of

   1) erroneously rejecting a tolerable inspection target, and

   2) erroneously accepting an intolerable inspection target.

To satisfy a), the sampling plans in this document are indexed in the parameter Trust with levels low, mid, high, where increasing Trust level reduces sample size. To satisfy b), this document imposes two-stage sampling plans with small sample sizes in the first stage and higher sample sizes in the second stage, where ordinarily a decision is reached already in the first stage if the population submitted for inspection is somewhere in-between.

The sampling scheme in this document is particularly suitable for financial auditing, both for auditing the internal control system (ICS) and for usage in tests of details as a tool of substantive procedures in financial auditing. ICS auditing and test of details are usually based on sampling instead of screening procedures. The relevant standard ISA 530 requires that sampling enable conclusions on the full population. Conclusively, statistical sampling schemes are indispensable.

Previous inspection results will be an important basis for the choice of the trust level for later inspections. Thus, the continued use of the sampling scheme in this standard will serve as an incentive for the providers of the respective targets, e.g. the responsible authorities for the ICS in a company, to improve upon the quality of the target populations.

The decision procedure of the sample is kept simple for immediate implementation. In particular, the user is not requested to evaluate mathematical formulae.

The target population is considered as acceptable (tolerable) if the proportion nonconforming does not exceed a specified tolerance p_0, otherwise it is considered as unacceptable (intolerable). Correspondingly, the objective of sampling inspection is to enable a decision between the alternatives of "acceptance" and "rejection". In different application domains, acceptance and rejection have different practical interpretations, see the explanations in Clause 5.

The sampling inspection procedure starts with a first sample of size n_1 with the following rule: accept if and only if no nonconforming units are found among the n_1 sampled units; reject if and only if at least Re_1 (stage 1 rejection number) nonconforming units are found among the n_1 sampled units; proceed to the second stage if and only if at least one and at most Re_1-1 nonconforming units are found among the n_1 sampled units. In the second stage, sample n_2 units, and decide "accept" if and only if the number of nonconforming units in the combined first and second sample is smaller or equal to the stage 2 acceptance number Ac_2, otherwise reject. The two-stage decision procedure can be expressed equivalently by comparing the limits of a two-sided confidence interval of nominal level (γ) for the proportion nonconforming with the tolerance p_0.

The sampling plans are indexed by three quantities:

i) the tolerance p_0;

ii) the nominal confidence level (γ), which is respectively either 0,7, 0,8, 0,9, 0,95 or 0,99;

iii) three levels, low, mid, high, of a scale called Trust.

The Trust levels express the user's degree of confidence into the status of the target population.

The objective of this document is to provide procedures that enable a decision quickly and economically if the proportion nonconforming is particularly low or high. In the latter case, the inspection procedure will in most all cases terminate in stage 1 with small sample sizes n_1. Only under intermediate values of the proportion nonconforming in the target population, the likelihood of proceeding to a second sample is high. The two sample sizes in stage 1 and stage 2 are chosen so as to minimize the expected sample size under the specified confidence level and Trust level.

Sampling procedures for inspection by attributes — Two-stage sampling plans for auditing and for inspection under prior information

1 Scope

This document specifies two-stage (double) sampling plans by attributes for inspection for a proportion of nonconforming items in a target population of discrete units, in particular:

a) the proportion of nonconforming items in a lot of product items;

b) the proportion of nonconforming function instances of an internal control system (ICS);

c) the proportion of misstatements in a population of accounting entries or booking records;

d) the proportion of nonconforming test characteristics of an entity subject to an acceptance test, e.g. in product and process audits.

The plans are preferable to single sampling plans where the cost of inspection is high or where the delay and uncertainty caused by the possible requirement for second samples is inconsequential. The statistical theory underlying the plans, tables and figures are provided in Annexes A through K.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2859-2, *Sampling procedures for inspection by attributes — Part 2: Sampling plans indexed by limiting quality (LQ) for isolated lot inspection*

ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2859-2, ISO 3534-1 and ISO 3534-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
acceptance number
Ac
largest number of nonconformities or nonconforming items found in the sample by *acceptance sampling* (3.1.2) by attributes that permits the acceptance of the lot, as given in the *acceptance sampling plan* (3.1.3)

[SOURCE: ISO 3534-2:2006, 4.4.2]

3.1.2
acceptance sampling
sampling after which decisions are made to accept or not to accept a lot, or other grouping of products, materials or services, based on sample results

[SOURCE: ISO 3534-2:2006, 1.3.17]

3.1.3
acceptance sampling plan
plan which states the sample size(s) to be used and the associated criteria for lot acceptance

[SOURCE: ISO 3534-2:2006, 4.3.3]

3.1.4
Conditional risks

3.1.4.1
conditional risk type I
conditional type I
conditional probability that $H_0 : p \le p_0$ be accepted by the test, given that $p > p_0$

Note 1 to entry: The conditional type I error is also addressed as the conditional type I risk.

Note 2 to entry: In an auditing context, the conditional type I risk evaluates the extent in which the purpose of auditing is failed. Hence, the type I risk can also be considered as a conditional measure of audit effectiveness.

Note 3 to entry: For a detailed mathematical explanation of this conditional risk, see Annex D.

3.1.4.2
conditional risk type II
conditional type II
conditional probability that $H_0 : p \le p_0$ be not accepted by the test, given that $p \le p_0$

Note 1 to entry: The conditional type II error is also addressed as the conditional type II risk.

Note 2 to entry: In an auditing context, good lots are rejected in this case. So, the conditional type II risk is a measure for economic loss. Hence, the type II risk can also be considered as a conditional measure of auditing efficiency.

Note 3 to entry: For a detailed mathematical explanation of this conditional risk, see Annex D.

3.1.5
confidence interval
interval calculated from the sample, which specifies a range of plausible values of the unknown parameter p

Note 1 to entry: The reliability of the confidence interval as an interval estimate for p is measured by the actual coverage probability, i.e. the probability that the interval contain the true value of p. For a confidence interval of nominal level γ, the actual coverage probability has the lower bound γ pointwise in p. The length of the confidence interval corresponds to the precision of the statistical inference on p. Thus, interest is in shortest confidence intervals.

Note 2 to entry: See Annex A

3.1.6
coverage probability
probability that a random confidence region contain the true value of p

Note 1 to entry: For a detailed mathematical explanation of the coverage probability, see Annex G.

3.1.7
financial statement
formal record that reports about an entity's financial activities and position, related to one point in time or to changes within a period in time

3.1.8
inspection by attributes
inspection by noting the presence, or absence, of one or more particular characteristic(s) in each of the items in the group under consideration, and counting how many items do, or do not, possess the characteristic(s), or how many such events occur in the item, group or opportunity space

[SOURCE: ISO 3534-2:2006, 4.1.3]

3.1.9
integrated average sample number
I.ASN
number measuring the average sample size resulting from a sampling plan under a given proportion nonconforming p, weighted according to prior information on p

Note 1 to entry: For a detailed mathematical explanation of *I.ASN*, see Annex F.

Note 2 to entry: If costs for sampling single units are given, the *I.ASN* can be used to estimate average sampling costs of the two-stage plan $(n_1; n_2)$.

3.1.10
integrated second stage probability
$\boldsymbol{I.p_{2nd}}$
probability of requiring the second step

Note 1 to entry: For a detailed mathematical explanation of $I.p_{2nd}$, see Annex E.

3.1.11
lot
definite part of a population constituted under essentially the same conditions as the population with respect to the sampling purpose

[SOURCE: ISO 3534-2:2006, 1.2.4]

3.1.12
misstatement
difference between the required amount, classification, presentation or disclosure of a financial statement and the actual observed one

3.1.13
nonconforming item
nonconforming unit
item or unit with one or more nonconformities

[SOURCE: ISO 3534-2:2006, 1.2.12, modified — "unit" has been added to "item".]

3.1.14
nonconformity
non-fulfilment of a requirement

[SOURCE: ISO 3534-2:2006, 3.1.11]

3.1.15
operating characteristic
OC
probability of reaching the decision "acceptance" by a sampling plan, considered as a function of the true value of the proportion nonconforming p

Note 1 to entry: See Annex B.

3.1.16
OC matched
sampling plans that have the same operating characteristic

Note 1 to entry: See Annex C.

3.1.17
prior information
knowledge about a parameter before the actual sampling evidence is taken into account

Note 1 to entry: Sources of prior knowledge are, for instance, historic audits and the assessment of the company environment.

3.1.18
population
totality of items under consideration

[SOURCE: ISO 3534-2:2006, 1.2.1]

3.1.19
rejection number
Re
smallest number of nonconformities or nonconforming items found in the sample by acceptance sampling by attributes that requires the lot to be not accepted, as given in the acceptance sampling plan

[SOURCE: ISO 3534-2:2006, 4.4.1]

3.1.20
sample
subset of a population made up of one or more sampling units

[SOURCE: ISO 3534-2:2006, 1.2.17, modified — Note 1 to entry deleted.]

3.1.21
substantive procedure
audit procedure with the objective of detecting misstatements at the assertion level

Note 1 to entry: There are two types of substantive procedures:

a) tests of details (of classes of transactions, account balances, and disclosures); and

b) substantive analytical procedures.

3.1.22
test of controls
audit procedure with the objective of assessing the operating effectiveness of controls in preventing, or detecting and correcting, material misstatements at the assertion level

3.1.23
tolerance proportion
largest value p_0 of the proportion nonconforming such that the target population is considered as acceptable

3.2 Symbols and abbreviated terms

n_i	sample sizes in stage i
n_{match}	one stage sample size with same OC as two stage sampling plan
x_i	number of misstated items (nonconforming items) found in n_i
D	confidence interval for the proportion of misstatements (nonconforming items)
p	proportion of misstatements (nonconforming units)
p_{L}	lower limit of D
p_{U}	upper limit of D
p_0	tolerance proportion
I.cp	integrated actual coverage
γ	nominal confidence level
a, b	shape parameters of the beta distribution
Ac_i	acceptance number in stage i
Re_i	rejection number in stage i
c.type I	conditional probability of erroneous acceptance
c.type II	conditional probability of erroneous rejection
$I.p_{2\text{nd}}$	integrated probability of entering the second stage
I.ASN	integrated average sample number
N	lot size
OC	operating characteristic function
P_a	probability of acceptance (OC function at a specified value p)

4 Selecting and operating a two-stage sampling plan under prior information

4.1 General

Table 1 to Table 5 in Clause 7 provide two-stage sampling plans $(n_1,(\text{Ac}_1;\text{Re}_1),n_2,(\text{Ac}_2;\text{Re}_2))$ indexed in the parameters p_0 (tolerance proportion), γ (confidence level), and in the level of prior information (trust).

The aim of the application of a two-stage sampling plan is two-fold:

a) enable a decision on whether or not the actual proportion nonconforming p exceeds the tolerance proportion p_0. In statistical terminology, the decision problem can be considered as a test of the hypothesis $H: p \le p_0$ versus the alternative $K: p > p_0$;

b) provide a confidence interval for the actual proportion nonconforming p.

The design of the sampling plans assures that the probabilities of both decision errors 1) erroneous rejection of *H*, and 2) erroneous acceptance of *H* are bounded.

4.2 Selecting a sampling plan

Sampling plans can be obtained from Table 1 to Table 5 in Clause 7. The cell entries Table 1 to Table 5 display:

a) upper left: n_1 sample size in stage 1;

b) upper right: $(\mathrm{Ac}_1;\mathrm{Re}_1)$ acceptance and rejection number in stage 1;

c) lower left: n_2 sample size in stage 2;

d) lower right: $(\mathrm{Ac}_2;\mathrm{Re}_2)$ acceptance and rejection number in stage 2.

The sampling plans are indexed in p_0 (tolerance proportion), γ (nominal confidence level), and in the Trust level.

The nominal confidence level γ determines the reliability of the conclusive decision as taken according to the algorithm in 5.3 in the sense that the coverage probability $P(p \in D)$ exceeds γ for a wide range of actual values p, except a small interval around p_0, see the coverage probability graphs in Figures G.1 to G.5. Correspondingly, the probabilities of both decision errors 1) erroneous rejection of $H: p \le p_0$, and 2) erroneous acceptance of $H: p \le p_0$ are bounded by 1-γ for a wide range of actual values p.

The level of prior information shall be specified on an ordinal scale named Trust, by choosing among the values {low, mid, high}. The Trust level low shall be used if no prior experience or bad prior experience with populations submitted for inspection exists. The Trust level high shall be used if there is strong evidence of good performance. The Trust level mid shall be used if there is weak evidence of good performance or strong evidence of in-between performance.

See Annex H for further technical background on the prior information model and the Trust scale.

4.3 Sampling and decision procedure

The decision by a two-stage sampling plan $(n_1,(\mathrm{Ac}_1;\mathrm{Re}_1),n_2,(\mathrm{Ac}_2;\mathrm{Re}_2))$ shall proceed according to the following algorithm with $\mathrm{Ac}_1 = 0$:

Stage 1:

Draw a random sample of size n_1, determine the number x_1 of nonconforming units among the n_1 sampled units. Decide according to the subsequent cases a), b), and c):

a) $x_1 \le \mathrm{Ac}_1$: Acceptance of the hypothesis $H: p \le p_0$, i.e. p is considered not to exceed the tolerance p_0;

b) $x_1 \ge \mathrm{Re}_2$: Rejection of the hypothesis $H: p \le p_0$, i.e. p is considered to exceed the tolerance p_0;

c) $\mathrm{Ac}_1 < x_1 < \mathrm{Re}_1$: No decision in stage 1, go to sample stage 2.

Stage 2:

If, in stage 1, the case c) occurs and enforces entering stage 2, proceed as follows:

Draw a second random sample of size n_2, determine the number x_2 of nonconforming units among the n_2 sampled units. Decide according to the subsequent cases a) and b):

a) $x_1 + x_2 \le \mathrm{Ac}_2$: Acceptance of the hypothesis $H: p \le p_0$, i.e. p is considered not to exceed the tolerance p_0;

b) $x_1 + x_2 \ge \mathrm{Re}_2$: Rejection of the hypothesis $H: p \le p_0$, i.e. p is considered to exceed the tolerance p_0.

4.4 Estimation of the actual proportion nonconforming

The sample proportion nonconforming is

$$\hat{p} = \begin{cases} \frac{x_1}{n_1}, \text{ if the decision procedure terminates in stage1,} \\ \frac{x_1 + x_2}{n_1 + n_2}, \text{ if the decision procedure terminates in stage2.} \end{cases}$$

$\hat{p}$ is an unbiased estimator of the actual proportion nonconforming p in the population. The sampling uncertainty inherent in the estimator p is expressed by a confidence interval. A two-sided confidence interval $D = [p_L; p_U]$ of a nominal level γ satisfies the inequality $P(p_L \leq p \leq p_U) \geq \gamma$, i.e. with a probability of at least γ, the actual proportion p lies between p_L and p_U. A two-sided confidence interval D for the actual proportion p of misstated items (nonconforming items) can be obtained from the confint function in the ISO 28596 package from the following input quantities: 1) nominal confidence level γ and level of *Trust* chosen for selecting the sampling plan; 2) number x_1 of misstated items (nonconforming items) found in stage 1; 3) if stage 2 was entered: number x_2 of misstated items (nonconforming items) found in stage 2.

5 Application paradigms: lot inspection and financial auditing

Details of two standard application paradigms for the two-stage decision procedure are described below:

— for the inspection of lots of discrete product items, see 6.1

— financial auditing, with two targets: for testing for the compliance of an internal control system (test of controls), and test of details in the course of substantive procedures, see 6.2

5.1 Lot inspection

5.1.1 Sampling

Samples shall be drawn from the lot by simple random sampling. When the lot consists of sub-lots or strata, identified by some rational criterion, representative sampling shall be used in such a way that the number of items sampled is proportional to the number of items in the sub-lot or stratum.

5.1.2 Acceptance of loss

All items in the sample shall be inspected and the nonconforming items shall be counted.

Acceptability of a lot shall be determined by the use of the obtained sampling plans. If the number of nonconforming items found in the sample is equal to or less than the acceptance number Ac_1 and Ac_2, respectively, the lot shall be accepted, otherwise the lot shall not be accepted.

5.1.3 Disposition of non-accepted lots

The disposition of lots not accepted shall be agreed in advance by all interested parties.

5.1.4 Lots with one or more nonconforming units

If a lot has been accepted, the right is reserved not to accept any item found nonconforming during the acceptance sampling inspection that led to lot acceptance.