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# THE INFLUENCE OF SAMPLING AND INSPECTION LEVELS ON SHIPMENT ACCEPTANCE

Davor DONEVSKI, Diana MILCIC, Petar MALISA

Faculty of Graphic Arts, University of Zagreb, Croatia

***Abstract:***

*Acceptance sampling is a method used to decide whether the shipment of some product should or should not be accepted. For inspection by attributes, the probability of acceptance of a shipment with some quality level and given the agreed acceptable quality level is based on binomial distribution. The aim of this research was to compare the calculated probabilities of acceptance with simulated empirical values. These values were obtained from measurement data of solid ink densities (SID) of cyan ink on print run of 8500 copies. A simple computer program was used to select 1000 random samples at different inspection levels of MIL-STD-105E sampling plans. The proportion of accepted lots was compared to the values calculated by the formula. It was noted that these values differ to greater extent for smaller sample sizes although they should be better approximated by binomial distribution.*

***Keywords:***

*acceptance sampling, sampling plans, print production*

## 1 INTRODUCTION

Acceptance sampling is used to decide whether the shipment of a certain product should or should not be accepted. It is used to reduce the inspection costs or when the inspection method destroys the inspected unit. Although it has important advantages and is necessary in most cases, it does not assess the quality of the lot [1]. The most general types of acceptance sampling plans are those for inspection by variables and for inspection by attributes. The sampling plans for inspection by attributes have the advantage of being able to take into account more than one quality characteristic as the unit is evaluated as either being conforming or nonconforming [2]. Their acceptance probabilities are distributed by the hypergeometrical distribution, and can be approximated by the binomial distribution when lot size $N$ is much larger than sample size $n$ [3].

This paper compares the probabilities of acceptance calculated using the binomial distribution formula (1) with the empirical data collected by taking a large number of samples. The most important issues concerning the use of sampling plans are inspection costs and risks [4]. Taking a larger sample from the lot increases the inspection costs, but reduces the α (supplier's risk of valid shipment being rejected) and β (customer's risk of invalid shipment being accepted) risks. Therefore, for a given AQL (acceptable quality level, i.e. acceptable proportion of nonconforming units in the lot), sampling plans such as MIL-STD-105E [5] which was used in this experiment, offer different levels of inspection. The experiment conducted in this research consisted of taking many random samples at given AQLs' and inspection levels and comparing the proportions of accepted lots to acceptance probabilities calculated by the formula (1).

$$\sum_{x=0}^{k} \binom{n}{x} p^{x} q^{n-x} \qquad (1)$$

## 2 EXPERIMENTAL

The experiment was conducted on a print run of 8500 envelopes. They were printed in single spot color which had the highest proportion of cyan ink. Therefore, the control variable that was used was solid ink density measured for cyan ink by a densitometer. A 100% inspection was carried out, and the measurement results were recorded. With no colorimetric data available, solid ink density tolerances could not be determined for a given tolerated $\Delta E$. Therefore, two experienced press operators evaluated sample prints visually and agreed that the acceptable visual difference corresponds to ±6,5% of the aim solid ink density value. The nominal value was D=1,10, the lower specification limit $D_{min}$=1,03, and the upper specification limit $D_{max}$=1,17. The 100% inspection determined that 2,788% of measured values falls outside the specified limits, therefore being considered as nonconforming. In order to compare the accuracy of different sampling plans to the results obtained by 100% inspection, many random samples would have to be taken from the lot. As this is practically impossible, a simple computer program was written to randomly select samples from the values obtained by 100% inspection. MIL-STD-105E sampling plans for inspection by attributes were used. Sampling was carried out for three different AQLs', smaller than, close to and larger than the proportion of nonconforming units in the lot. For each of the three AQLs', three inspection levels (reduced, normal and tightened) were used. The purpose was the comparison of different sampling plans performances on a shipment of a known quality level and the selection of appropriate sampling plans with respect to inspection costs.

## 3 RESULTS

Results of 100% inspection revealed that 2,788% of measured SIDs' were outside the specification limits. Figure 1 shows the distribution of measured SID values. It can be seen that SIDs' are approximately normally distributed.

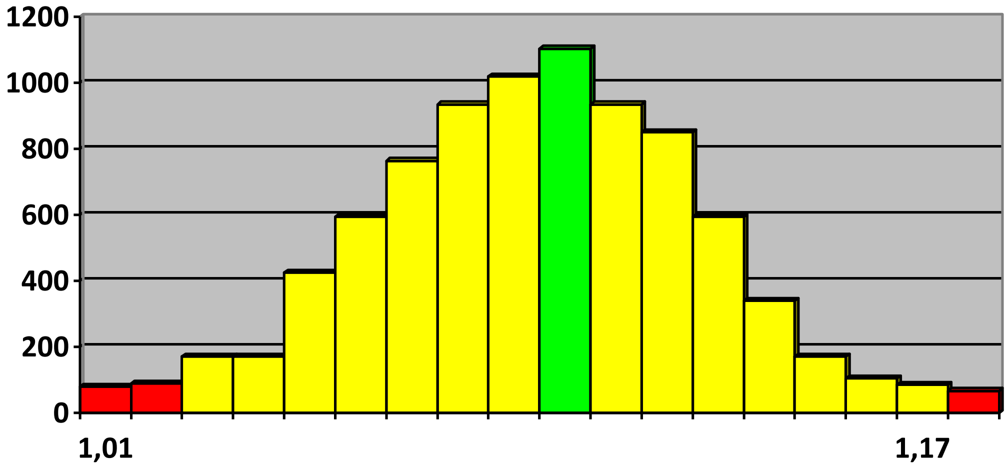


*Figure 1: Histogram of measured SIDs'*

Table 1 shows the results of taking multiple random samples from the lot, i.e. the proportions of accepted lots at different AQLs and inspection levels, as well as probabilities of acceptance calculated by the binomial distribution formula.

*Table 1: Calculated and empirical acceptance probabilities at different AQL's and inspection levels*

| AQL | | Reduced | Difference | Normal | Difference | Tightened | Difference |
|---|---|---|---|---|---|---|---|
| 1,5 | Calculated | 81,52% | 3,72% | 80,20% | 4,70% | 73,28% | 7,28% |
| | Empirical | 77,80% | | 75,50% | | 66,00% | |
| 2,5 | Calculated | 97,55% | 0,85% | 97,43% | 1,53% | 96,71% | 1,51% |
| | Empirical | 96,70% | | 95,90% | | 95,20% | |
| 4,0 | Calculated | 99,82% | 0,22% | 99,94% | 0,14% | 99,99% | 0,01% |
| | Empirical | 99,60% | | 99,80% | | 100,00% | |

Figure 2 is a graphical representation of results from Table 1. It shows more clearly how the differences between the calculated and the empirical acceptance probabilities are reduced as AQL gets close to and becomes greater than the lot's proportion of defectives. It can also be noted that in almost all cases (except AQL=4, tightened inspection) the calculated acceptance probabilities were higher than the proportion of lots accepted on the basis of samples. Even the AQL=4, tightened inspection case would likely behave in this manner if the number of samples was greater than 1000 (its calculated acceptance probability was 99,99%).

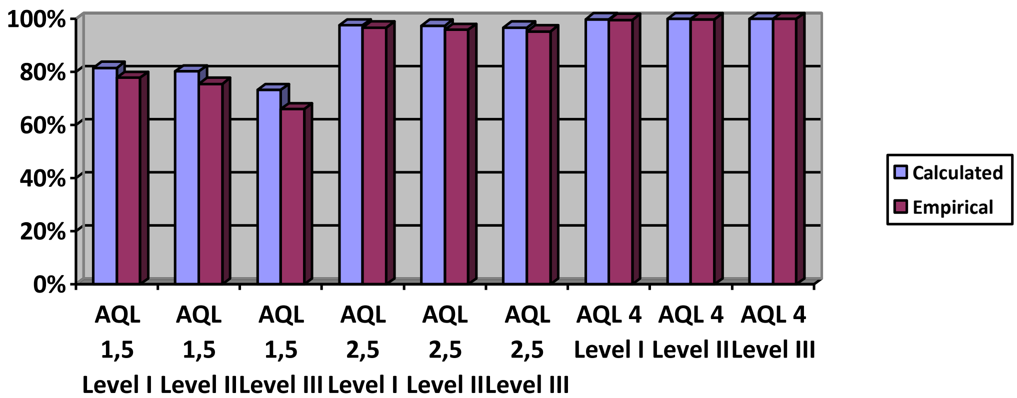


*Figure 2: Bar chart of acceptance probabilities*

## 4 DISCUSSION

As can be seen from Table, the probability of acceptance is higher for higher AQLs. This is well known and easy to understand. If the proportions of defectives in a lot is smaller than tolerated proportion, the lot is more likely to be accepted. The proportion of defectives *p* detected by 100% inspection equaled 2,788%. For AQL=1,5 *p*>AQL, the probabilities of acceptance are relatively small for all inspection levels. However, greatest differences occur between inspection levels in both calculated and empirical acceptance probabilities. It can be noted that the greatest difference between calculated and empirical probabilities occurred at AQL=1,5 and tightened inspection. An abrupt drop in acceptance probabilities occurred between normal and tightened inspection levels. For the empirical values, this can be explained quite simply. The larger the sample, its proportion of defectives is more likely to be similar to that of the lot. Calculated values exhibit similar behavior, but the differences between calculated and the empirical values increase with inspection levels. These differences occur due to imperfect approximation by binomial distribution. It approximates acceptance probabilities fairly well when lot size is much greater than sample size, $N >> n$. However, as $n$ increases, it gives poorer approximation and hypergeometrical distribution should be used in those cases. In cases where ALQ is similar to (AQL=2,5; $p$=2,788) or larger than (AQL=4; $p$=2,788) the proportion of defectives in the lot, calculated and empirical values do not differ significantly (within or between). It is interesting to note that for AQL=2,5 (AQL<$p$) the probabilities decrease as inspection gets tighter (as was the case for AQL=1,5), while for AQL=4 (AQL>$p$) they increase. This confirms that the collected data and results obtained in this experiment do not exhibit abnormalities.

## 5 CONCLUSION

As sampling plans are commonly used tool, but require the customer-supplier consumer agreement on the ALQ and the inspection level, several recommendations can be formulated from the results of this experiment. Firstly, the agreed AQL should be higher than the proportion of defectives normally output from a certain production process. This ensures that even in cases when process outputs were slightly worse than normal, or even slightly worse than the agreed AQL, reduced and normal inspection levels will both yield satisfactory results. If, however, the process output is significantly worse than normal, as was the case in this experiment for AQL=1,5; $p$=2,788, severe consequences can be noted. The difference between normal and reduced inspection level in such a case is not significant. They both perform poorly, and normal inspection performs just slightly better than the reduced inspection. Only employing tightened inspection yields satisfactory results in such cases. The results obtained in this study suggest that provided the AQL<$p$ or AQL≈$p$, reduced inspection level performs quite well considering the increased inspection costs when normal inspection is used. In order to avoid costs imposed by shipment rejection, supplier and consumer should agree on the AQL sufficiently larger than $p$, and use the benefits of reduced inspection level which performs well in such cases.

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**Corresponding author:**

Davor DONEVSKI
Department of Graphic Machines, Faculty of Graphic Arts, University of Zagreb
Getaldiceva 2
10000, Zagreb, Croatia
phone: +385 1 2371 080 fax: +385 1 2371 077 e-mail: davor.donevski@grf.hr