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Sequential Analysis: A Methodology for Monitoring Approval Plans

Sequential analysis is a statistical method based on drawing sample items one at a time, with a decision at each stage whether further sampling is necessary to reach a conclusion. This methodology is shown to provide a convenient and appropriate method for investigating the performance of a library approval plan. The sequential approach minimizes the investment in staff time, by delaying, until a title is chosen for the sample, the determination of its status in the approval plan. Application of the methodology at an academic library is reported in detail, and adaptations to other library situations are explained.

ALTHOUGH APPROVAL PLANS have become widely used in the last ten years as an important acquisitions mechanism, doubts have been expressed regarding the reliability of such plans. McCullough, Posey, and Pickett note that

> looming largest among these [shortcomings] is the uncertainty factor. . . . Except in a minority of cases, it is difficult to guarantee that a specific book will be produced by an approval plan.[1]

Dudley has indicated that

> one of the charges against an approval plan, based on experience and the literature, is the uncertainty of knowing whether a specific book will arrive. . . .[2]

Librarians using approval plans must contend with two major problems: (1) receipt of unwanted material and (2) nonreceipt of wanted material. Receipt of unwanted books is admittedly troublesome and entails some expense.

However, failure to receive desired material poses, by far, the more serious consequences. To the degree that the approval plan breaks down and wanted books are not received, (1) the library staff must attempt to fill the gaps on a title-by-title basis, a difficult task when it is impossible to predict what will and will not arrive on approval; and (2) gaps discovered by patrons frequently result in complaints and poor evaluation of library service.

Approval plans are beneficial only to the extent that staff time and paperwork associated with the selection and acquisition of material are reduced. Any attempt to monitor approval plans on a title-by-title basis in order to overcome the "uncertainty factor" defeats the purpose of approval plans as staff time devoted to selection and searching is not significantly reduced.

Monitoring of approval plans is important, for much of the uncertainty surrounding the receipt of approval material appears to stem from differing expectations and interpretations on the parts of vendors and of librarians. An objective monitoring plan, coupled with detailed analysis, can do much to reconcile differing interpretations. To date, however, most reports concerning the

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monitoring of approval plans have been informal and descriptive.[3,4]

Librarians frequently retain a subjective impression of approval plan performance as a result of user complaints and time spent supplementing the plan; however, librarians seldom have facilities for collecting and analyzing quantitative data.

Sequential analysis refers to a statistical method in which sample items

> are drawn one by one . . . and the results of the drawing at any stage decide whether sampling is to continue. The sample size is thus not fixed in advance but depends on the actual results and varies from one sample to another. The sampling terminates according to predetermined rules which are decided by the degree of precision required.[5]

Sequential analysis offers several advantages:

1. It requires a minimun of staff time and essentially no other expense.
2. It can be used for a single evaluation or for periodic monitoring.
3. It yields quantitative data of value in explanations to patrons and to administrators.
4. It should lead naturally to analysis and correction of any weaknesses found in the approval plan.

In a recent study at Kansas State University (KSU) Libraries a sequential analysis was performed to find how well the library's interpretation of an approval plan, particularly the profile, coincided with that of the vendor. Sequential analysis, in other words, was used to investigate whether the percentage of "defects" (that is, books that the library expected to receive on approval but did not) was low enough to indicate good performance (Accept rate), or whether adjustments were indicated (Reject rate).

Sampling, rather than 100 percent screening, was necessary as a practical matter because of the number of titles involved and the limited amount of staff time that could be devoted to the project.

The purpose of the sampling experiment was to allow statistical inference as to the degree of conformity between the interpretation of librarians and the interpretation of the vendor's book selectors. Each instance in which the library expected to receive a book on approval but did not was counted as a "defect," with an "Accept" result for a low percent defective and a "Reject" result for a high percent defective.

Once a decision was made to conduct a sampling experiment, the next decision was whether to use a fixed-size sampling plan or a sequential plan—whether to choose the sample size in advance or to sample until enough evidence is accumulated to warrant an inference. A sequential approach was especially advantageous in this study because of the difficulty of determining the necessary sample size for a fixed sampling plan in advance.

When conclusions are generalized from a statistical sample, there are risks that an atypical sample (sampling "error") will lead to the wrong conclusion. It is especially difficult to decide in advance on some fixed number of titles to sample when the variable is "percent defective" as in the KSU study. The problem is that the sample size necessary to achieve reasonable risks depends on the variability from sample to sample, and the variability depends, in turn, on the unknown percent defective. Fortunately, this circularity can be avoided by use of a sequential plan whenever, as in the approval monitoring application, it is convenient and economical to draw and inspect one item at a time.

As noted above, in a sequential sampling plan the size of the sample is not determined in advance of the experiment as it is in a fixed sampling plan. Sampling, in a sequential plan, simply continues until an "Accept" or "Reject" conclusion is supported by the evidence. So long as the evidence is inconclusive, the investigator continues to draw additional sample items.

It should be pointed out that, as suggested by capitalization, the words "Accept" and "Reject" are used in a technical sense. "Accept" and "Reject" do not refer to acceptance or rejection of the approval plan as a whole, and at no time was rejection of the entire approval plan under consideration by the KSU Libraries. Nor do the terms refer to acceptance or rejection of specific books. Rather, sequential analysis was used as a device to "tune" the approval plan.

In a sequential analysis plan the sample size that will be necessary to reach a conclusion is not known definitely in advance.

However, the average sample number (ASN) can be calculated for various actual defect rates. If the actual defect rate is very high, a conclusion follows quickly, on the average. Similarly, the ASN for a very low actual defect rate is small. The largest ASN values occur at intermediate percentages. The saving in sample size (and therefore in time and money) in a sequential plan over a fixed-size plan often amounts to 50 percent. For that reason, sequential plans are in wide use in production quality control and acceptance sampling. Details of sequential plans are available in several references.[6,7,8]

Methodology

The choice of a particular plan amounts to the choice of an "Accept" defect rate p_1 with a related risk α, and a "Reject" defect rate p_2 with a related risk β. In the KSU study the "Accept" rate, that is, the acceptable level of conformity between the interpretations of librarians and vendors, was set at $p_1 = 2$ percent defective, with a ("producer's," i.e., vendor's) risk of $\alpha = 5$ percent of an atypically bad sample leading to an error. The "Reject" rate was set at $p_2 = 10$ percent defective, with a ("consumer's," i.e., librarian's) risk of $\beta = 10$ percent of an atypically good sample leading to an error. Other values, adapted to the needs of other libraries, can easily be substituted for the ones used here.

The sequential sampling chart shown in figure 1 was drawn according to specifications in standard references for the set of values $p_1 = 2$ percent, $p_2 = 10$ percent, $\alpha = 5$ percent, and $\beta = 10$ percent, used in the KSU study. As explained below, critical line boundaries separate the two decision regions, "Accept" and "Reject," from the region of continued sampling.

The 1977 edition of *American Book Publishing Record*[9] was used as a source of titles for sampling. Five-digit sequences were drawn from a large random number table (uniform distribution),[10] entered randomly and read in a predetermined order to avoid bias. Since individual titles are not numbered in the *American Book Publishing Record*, an estimate was made of the number of titles per page. Each random sequence was decoded to represent a page number and then the number of a specific title on the page. For example, the number 12,305 would be read as page 123, the fifth title.

The purpose of the study was to determine the extent to which the library's (i.e., subject bibliographers') interpretation of the approval plan profile coincided with the interpretation of the vendor (i.e., the vendor's book selectors). That is, did the approval plan supply the titles that the subject bibliographers expected it to supply?

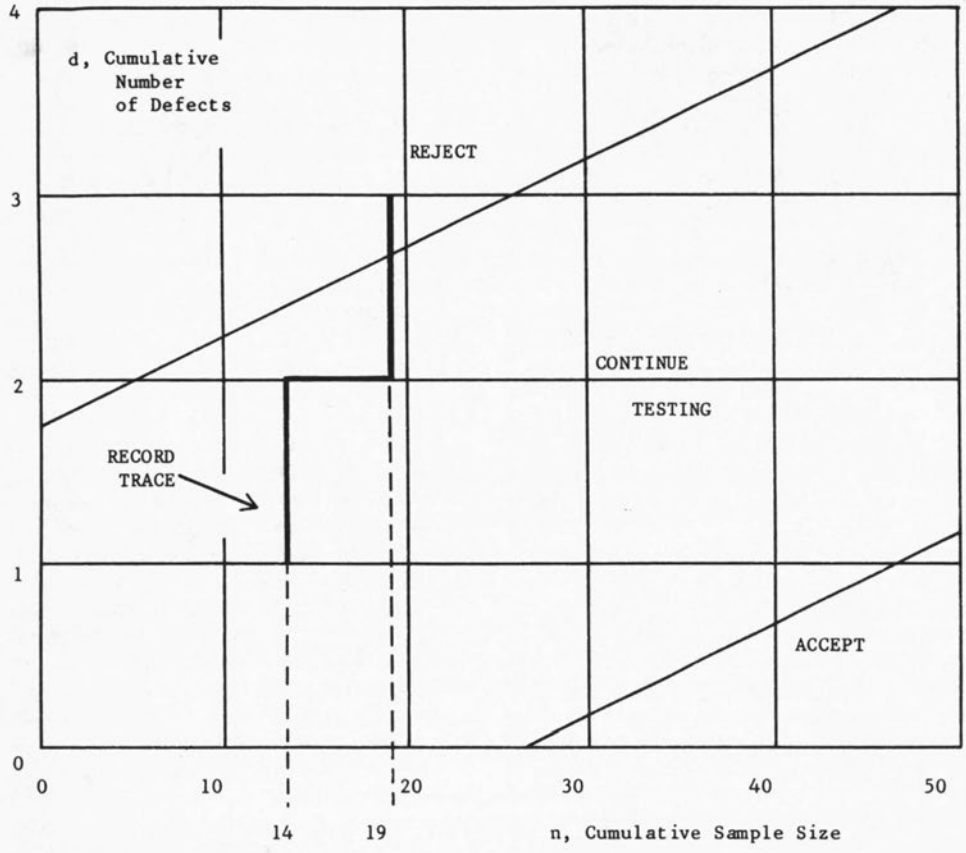
Consequently when a title was drawn by this method, it was included in the sample *only* if it was expected to arrive on the approval plan. Subject bibliographers reviewed each title drawn, in order to determine whether the books were expected to arrive on approval. If the book was not expected on approval, it was not included in the sample and a new random number was drawn. If the book was expected, it was included in the sample and the cumulative sample size n was increased by one.

A record trace was entered on the sequential sampling chart (figure 1) as sampling continued. Whenever the cumulative sample size n increased (because the title drawn was an expected book), the record trace was extended one unit to the right.

If an expected book was not received on approval, it was counted as a defect, the cumulative defect number d was increased by one, and the record trace was extended one unit up. If the book had been received on approval, the cumulative defect number d was not changed and the record trace was not moved upward, but held at the same height on the chart. The record trace for the KSU study (bold step trace in figure 1) shows by upward steps that defects were found at items 10, 14, and 19.

When the record trace entered the Reject region in figure 1, that is, when the third defect occurred at item 19, sampling was discontinued. Enough evidence had accumulated to support a statistical "Reject" conclusion indicating need for a clearer understanding between the library and the vendor regarding the approval plan. The staff time involved was minimal—only five or six hours after preliminary conferences on goals and methods.

It must be pointed out that questions concerning the status of individual books



Key:
For $\alpha = 5\%$, $\beta = 10\%$, $p_1 = 2\%$, $p_2 = 10\%$
Accept: $d = -1.3285 + 0.05025\,n$
Reject: $d = 1.7056 + 0.05025\,n$

Fig. 1
Sequential Sampling Chart

did arise during the monitoring program. In some cases communication with the vendor was necessary before it could be determined that a book was not expected and so should be dropped from the sample count n and the defect count d. In borderline cases the librarian, after gathering information from the vendor and elsewhere, should determine status according to the reflection on approval plan performance.

Results and Recommendations

The second component of the study was the detailed analysis of individual defects in order to identify generic problems (see table 1). The results verified and documented the impression of the librarians. The three defects identified resulted, as expected, from differing interpretation and understanding of the approval plan by the vendor and the KSU Libraries.

Librarians verified that titles published simultaneously in the United States by a United States publisher and in the United Kingdom by a United Kingdom publisher were automatically excluded from the domestic approval plan. Some excluded titles were supplied through a U.K. approval

TABLE 1

ANALYSIS OF DEFECTS

Classification	Example
Interface with foreign publications	Library expected to receive books published simultaneously in the U.S. by a U.S. publisher and in the U.K. by a U.K. publisher. However, such titles are automatically excluded from the domestic approval plan and supplied through a U.K. plan
Interface between subject areas	Instructions from the library to the vendor to exclude medical materials resulted in exclusion of materials on the politics and sociology of medicine that were expected
Previously published material	Instructions to exclude previously published material led to the exclusion of books containing some previously published articles, along with new material

plan; however, the U.K. plan was limited in coverage relative to the domestic plan, and as a result many titles were missed.

In a similar vein the library had excluded medical material from its approval profile, since KSU does not include a medical school. Unfortunately, the deletion of medical material also resulted in the exclusion of material concerned with the politics and sociology of medicine, topics of interest to the library.

Similarly, instructions to exclude previously published material from the profile also resulted in the exclusion of titles which included a mix of original and previously published articles. Clearly all these defects stemmed from inconsistencies in interpretation or understanding on the part of the library and vendor. With the inconsistencies identified and the necessary changes made, the defect rate can be expected to decrease, so that a second analysis in six to twelve months may well lead to an Accept conclusion.

The methodology explained here is adaptable to the needs of a wide range of libraries, since sequential plans for various Accept and Reject rates are readily available. The choice of the Accept rate p_1 is usually based on practical considerations, since more samples, on the average, are required if p_1 is decreased.

The choice of the Reject rate p_2 affects sample cost, but it can also be chosen by a given library to reflect the perceived role of the approval plan. If the approval plan is viewed primarily as an acquisitions device rather than as a collection development tool, then a defect rate of 15 percent may be reasonable. However, if the collection development role is emphasized, a reasonable defect rate may be 10 percent or less. The role of the approval plan, therefore, influences significantly the definition of what is and is not a reasonable defect rate.

The use of sequential analysis as a monitoring methodology has important implications for collection development. Sequential analysis involves only a small investment of staff time, may be repeated over a period of time, results in identification of specific problems and defects, and provides quantitative data of value in dealing with vendors and patrons.

In short, sequential analysis enables collection development librarians to "fine tune" their approval plan. Collection development librarians can, in other words, ensure that approval plans function correctly without investing so much staff time that the purpose of the approval plan is defeated.

Sequential analysis leads to an Accept conclusion or to a Reject conclusion. If an Accept conclusion is reached, librarians and patrons can be assured that receipt of material is generally consistent with the profile. A Reject conclusion indicates some inconsistency of interpretation between librarians and vendors, a situation that frequently results in collection gaps. Resolution of such inconsistencies through further analysis can lead to improved performance of the approval plan and of library service in general.

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