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# Urquhart's Law: Probability and the Management of Scientific and Technical Journal Collections Part 2. Probability in the Development and Management of a Central Document Delivery Collection

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**ABSTRACT.** Part 1 of this three-part paper discussed the genesis of the law formulated by Donald J. Urquhart on the use of scientific and technical (sci/tech) journals through interlibrary loan and central document delivery. It concentrated on the study of such use conducted by Urquhart in preparation for the establishment of the National Lending Library for Science and Technology (NLL), which became the central document delivery library of Britain. The focus of Part 1 was on the statistical and probabilistic bases of this law. In Part 2 the emphasis shifts to how Urquhart utilized probability to develop and manage the NLL's sci/tech journal collection. Urquhart based his collection development and management policies on a high-loan core of journals, causing the sta-

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bility of sci/tech journal use over time to become the main theoretical issue. Part 2 analyzes the controversy over this issue between Urquhart and his successor, Maurice B. Line. 

**KEYWORDS.** Donald J. Urquhart, scientific journals, document delivery, collection development and management, library use stability, probability

## *INTRODUCTION*

This second of a three-part analysis of Urquhart's Law of Supralibrary Use focuses on the logic deriving from this law for the development and management of a scientific and technical (sci/tech) journal collection of a central library, whose purpose is to provide document delivery support to sci/tech libraries at the local level. In Part 1 supralibrary use was defined as the use by a given library's patrons of materials supplied from outside the library through either interlibrary loan or central document delivery. It was contrasted to intralibrary use or the use of a library's own materials by its own patrons.

Part 1 first explained the Law of Scattering, which was formulated in the early 1930s by S. C. Bradford, head of the Science Museum Library (SML) in London. Bradford's Law describes the distribution of articles on a given topic over journal titles. It mandates that no special sci/tech library can possess all the titles necessary to its patrons and that such libraries require document delivery support from either other libraries at their level or a central comprehensive library. Bradford strove to convert the SML into such a central document delivery library.

The first part then related that the task of creating an official central comprehensive library for Britain was assigned to Donald J. Urquhart, who prepared for the establishment of the National Lending Library for Science and Technology (NLL) by analyzing the loans made by the SML to outside organizations in 1956. Urquhart found that these loans had two primary characteristics: (1) the vast bulk of the loans (80%) were satisfied by approximately 1,250 titles comprising less than 10% of the SML's journal collection; and (2) the number of SML loans satisfied by given titles was highly correlated with the number of libraries holding these titles. Due to these findings, Urquhart formulated a basic

tenet of his Law of Supralibrary Use, namely, that the supralibrary use of journals is indicative of their total use value and therefore also of their intralibrary use.

Part 1 then analyzed the statistical bases of Urquhart's Law. It demonstrated that library use is best represented by the Poisson process, i.e., the rare occurrence of events over time and space. Space was defined in library terms as either individual journals or the various subject classes to which these journals belong. The simple Poisson distribution was described as the model of total randomness, where the probability of occurrence is uniform, and the mean rate of occurrence as well as the variance around this mean is extremely small. Part 1 then utilized Urquhart's 1956 loan data to show that the highly skewed distributions characteristic of library use are a function of two stochastic processes. The first is "heterogeneity," which is that titles or subject groups of a library collection have differing probabilities of use. This results in compound Poisson distributions, where these titles or subject groups have different mean rates of use over time. The second stochastic process is "contagion," by which each use increases the probability of further use.

Part 1 explained that both these processes lead to the same type of distributions, thereby making their causal roles indistinguishable, and that the basic statistical model of such distributions is the negative binomial distribution (NBD). It was pointed out that the easiest way to distinguish a simple Poisson distribution from a compound Poisson/contagious one is to calculate the variance-to-mean ratio. If the ratio is 1, the distribution is the simple Poisson; if the ratio is significantly greater than 1, the distribution is of the NBD type. Part 1 elucidated the importance of the simple Poisson distribution for journal collection management through Borkiewicz's Law of Small Numbers, by which restricting a journal set to those elements manifesting extremely low or zero use, no matter what their different underlying probabilities, results in a usage distribution that fits the simple Poisson. Lexian statistics were employed to prove that the variance of such a set's usage is even lower than the variance that could be theoretically expected.

Part 2 details how Urquhart utilized probability to develop and manage the NLL journal collection, and the following points are made in it. Urquhart had only a limited knowledge of the Poisson distribution, knowing only its simple form, which he posited as the correct model of library use. Nevertheless, Urquhart utilized the simple Poisson in a manner compatible with the compound Poisson/contagious distribu-

tions that govern library use. The empirical findings of Urquhart's 1956 SML study were corroborated by a study of supralibrary use conducted in 1959 by the U.S. National Library of Medicine (NLM), which published a list of 300 of its most heavily used journals. However, around the same time Urquhart's hypothesis of the simple Poisson as the correct model of library use was disproved by a relegation study done at the University of Chicago by Fussler and Simon. This study found distributions of monograph use in two subject groups that manifested all the characteristics of compound Poisson/contagious distributions.

As a result of the findings of the 1956 SML study, Urquhart regarded the main problem of a national loan service as catering to the heavy demand for a relatively small number of journals and the small demand for a large number of journals. This conclusion caused him to center his collection development and management polices on a small core of approximately 1,500 journals identified as high-loan titles by the 1956 SML and 1959 NLM studies. These journals were given special treatment in terms of housing, binding, duplication, and purchase of backfiles. However, such a policy was based on the assumption of stability of journal use across time.

Part 2, therefore, analyzes the probabilistic bases and measurement of such stability. An explanation of the probabilistic bases is found in Bortkiewicz's Lexian theory of the relationship of homogeneity to stability. Developed in respect to the proper structure of insurance portfolios, this theory posits that the less homogeneous a set–i.e., the more heterogeneous it is in terms of component subsets with counterbalancing probabilities–the higher is the stability of the mean rate of occurrence across time. Sci/tech journal use is hypothesized to be inherently stable due to the multidisciplinary nature of sci/tech journal sets mandated by Bradford's Law of Scattering and its citation corollary, Garfield's Law of Concentration. Measurement of stability across time is discussed in terms of Poisson confidence intervals and how Urquhart utilized such intervals to manage the NLL journal collection.

Part 2 ends with an analysis of the controversy over stability engendered by Maurice B. Line, who succeeded Urquhart as director general shortly after the NLL became the British Library Lending Division (BLLD). On the basis of a series of studies of BLLD use, Line concluded that sci/tech journal use is not stable across time and that collection management cannot be based on a high-loan core. Part 2 resolves the controversy in favor of the Urquhart position.

## *URQUHART AND POISSON MODELS OF LIBRARY USE*

### *Urquhart and the Poisson Distribution*

Urquhart's historic importance in the development of library and information science as a discipline largely consists of his being the first librarian to apply probability to the solution of library problems. Specifically, by his own research and that sponsored by him, he was the first to introduce the Poisson process as a way of modeling the library use of scientific journals and showing how this process affected the use of these journals not only in individual libraries but also within a library system as a whole. Urquhart came to recognize the importance of probability at the very start of his work to set up the National Lending Library for Science and Technology (NLL). Thus, in a report on the early research for establishing this library, his chief assistant Bunn (1957, 284) stated, ". . . Dr. Urquhart is beginning to regard an understanding of the use of probability mathematics in a library as a more essential requirement than a knowledge of cataloguing and classification schemes." In his book, *The Principles of Librarianship*, Urquhart (1981, 76) emphasized the necessity of librarians being numerate as well as literate, and he defined numeracy as requiring knowledge of not only arithmetic but also statistics. In particular, Urquhart stressed the importance of having some understanding of the Poisson distribution. He was far in advance of his field in this matter, and in his autobiography Urquhart (1990, 61) reported that the librarians present at his first lecture on the NLL in 1957 were incapable of understanding his explanation of the Poisson formula, being totally baffled by what "e" signified.

In his *Principles* Urquhart (1981, 30) claimed that his application of the Poisson distribution to library collection management was the only occasion he could remember of using any of the specific knowledge he had learned in obtaining his undergraduate degree in physics. There is circumstantial evidence that Urquhart had little formal training in probability and statistics. One sign of this was his constant attribution of Bortkiewicz's analysis of the number of Prussian soldiers kicked to death by horses to Poisson himself despite every statistics textbook clearly stating that this study had been done by Bortkiewicz. Thus, Urquhart (1981, 76) wrote in his *Principles*: "Poisson was studying the number of grooms kicked to death by horses in the Prussian army." This mistake is almost a hallmark of Urquhart's writing, making it possible to identify his authorship even when it appears that he may have been

deliberately trying to conceal it. One source of his knowledge of the Poisson may have been his work during World War II at the Ministry of Supply, where Urquhart (1990, 13) had responsibility for certifying whether shipments met specifications. As the model of infrequent occurrences tightly grouped around a mean, the Poisson distribution is widely used in industrial quality control to determine whether a given consignment is meeting specifications. Much of Urquhart's work with the Poisson bears the mark of this industrial application being used to manage serials. Another sign of Urquhart's lack of formal training in probability is that he never went beyond the simple Poisson model despite working with compound Poisson distributions.

In their reports on the analysis of 1956 SML external loans in preparation for establishing the NLL, Urquhart (1959, 291) as well as Urquhart and Bunn (1959, 21) assumed that journal demand is random and therefore hypothesized the simple Poisson distribution as the appropriate model for these loans. However, they never tested this assumption but only presented hypothetical Poisson distributions of journals by external loans at given lambdas. In both cases they utilized lambdas–annual rates of loans per title of 0.5 in one case and 2 in the other–that were low enough to produce heavy concentrations of titles in the zero and other low-loan classes, thereby producing distributions that superficially resembled the actual distribution of 1956.

As has been demonstrated in Part 1 of this paper, the randomness assumption and the resulting Poisson hypothesis were both patently incorrect. Here it was shown that the observed distribution is better modeled by the compound Poisson model arising from the stochastic processes of heterogeneity and contagion. Nevertheless, as will be seen, despite being wrong in considering the simple Poisson as the correct model for the use of a sci/tech journal collection as a whole, Urquhart utilized this distribution for collection development and management in a way that is compatible with the compound Poisson model, achieving correct results with this simplified method. His main goal in utilizing the Poisson model was to identify high use serials to ensure their availability through duplication and special binding procedures as well as for their more cost-effective housing.

### *Validation and Rejection in the United States*

Shortly after Urquhart delivered his paper to the 1958 Washington conference on scientific information, the empirical findings of his analysis of the 1956 SML external loans on the nature of supralibrary use

were validated by one study in the United States. At the same time, his hypothesis of the simple Poisson distribution as the correct probabilistic model for this use was seriously called into question by another study in this country.

Empirical validation resulted from an analysis of the 77,698 interlibrary loan requests for serials made to the National Library of Medicine (NLM) by some 1,780 domestic and foreign libraries in 1959. This analysis was reported by Kurth (1962). The NLM study also found a high concentration of interlibrary loans on a relatively small proportion of the titles. This, too, was a function of a huge zero class of some 88%, since only 4,347 titles out of the approximately 37,000 in the NLM satisfied 100% of the requests. Moreover, of the 4,347 titles that were used, 1,235 or 28.4% were loaned only once. Kurth (1962, p. 21) divided the titles that were loaned into classes by level of use, and these were summarized as follows: heavy use–161 titles (3.70%), 30,203 loans (38.87%); moderate use–1,185 titles (27.26%), 38,512 loans (49.56%); and low use–3,001 titles (69.03%), 8,983 loans (11.56%). A list of the 300 titles most heavily borrowed from the NLM was published by Kurth (1962, pp. 32-38) in descending rank order of use, and here, too, there was evident a concentration of interlibrary loan use on prestigious titles. Thus, among the 15 top titles were such titles as *Lancet*, *British Medical Journal*, *Journal of the American Medical Association*, *New England Journal of Medicine*, *Science*, and *Nature*. In accordance with Urquhart's theory, four of the top 10 titles–*Lancet*, *British Medical Journal*, *Journal of the American Medical Association*, and *Journal of Clinical Investigation*–were also among those found highest in intralibrary use by studies done at Yale University, the Mayo Clinic, and the College of Physicians Library in Philadelphia. Kurth (p. 47) also reported that a great many interlibrary loan requests concerned relatively common titles. The NLM study occurred while Urquhart was in the midst of setting up the NLL, and he paid close attention. Urquhart (1963) described the NLM list of the 300 most heavily used titles as being helpful to special libraries in deciding which titles to collect.

Urquhart's hypothesis of the simple Poisson as the model for the use of scientific journal collections was called into question by a study led by a person attending the session of the 1958 Washington conference at which he delivered his paper. This person was Herman J. Fussler, who was soon to direct a relegation study at the University of Chicago. At the conference itself Fussler appeared to agree with Urquhart's assumption of randomness by stating during the discussion following the paper that studies thus far had not advanced a satisfactory explanation of the ap-

parent unsystematic use of available sources and services for scientific information (Urquhart 1959, 310). The University of Chicago study jointly authored by Herman J. Fussler and Julian L. Simon (1969) aimed to discover a statistical method that could predict with accuracy the frequencies with which groups of books with defined characteristics were likely to be used in a research library. The purpose of the study was to support relegation of low use materials to storage or a central document delivery library.

Fussler delineated the general problem analyzed by the project, while Simon was responsible for working out most of the procedures, devising several lines of investigation, and the initial interpretation of the data. Simon obtained his doctorate in 1961 from the University of Chicago Graduate School of Business on the basis of the project with a dissertation on the economics of book storage plans.

The University of Chicago study differed from Urquhart's SML analysis in a number of key respects. First, it was a study not of supralibrary use but of intralibrary use. Second, it analyzed not just journal use but both monograph and journal use. Third–and most important statistically–it did not approach the problem globally as did Urquhart but only on the basis of subject sets defined by conventional library classification systems. This has the tendency to reduce the Lexian causation of skewed distributions by making the sets more homogeneous in terms of possible subject subsets with wildly different underlying probabilities.

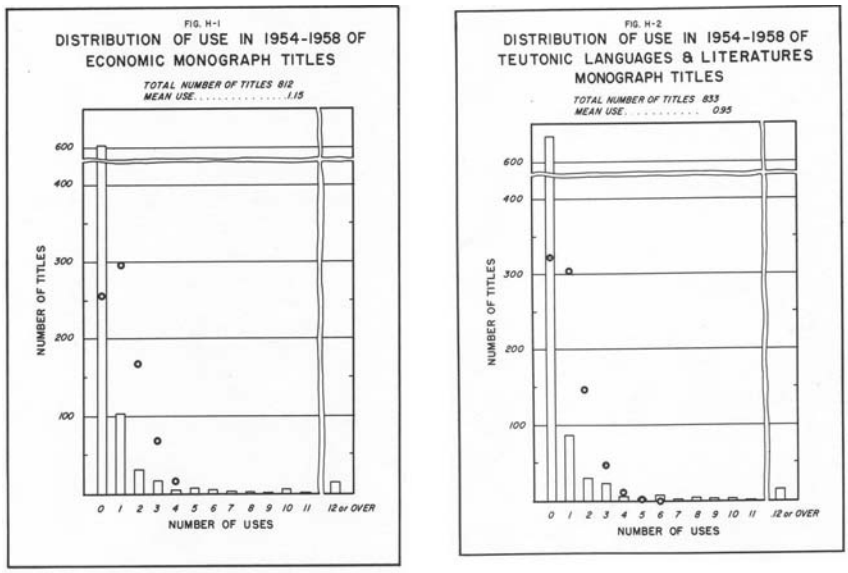
The project was based on a random model of book use, by which it was assumed that at any given moment each book in the library had a random probability of being used. This probability was estimated by grouping books together on the basis of common characteristics and then observing the use of this group. Use was hypothesized to be independent in that the use of a book depended only upon the underlying probability, which could change from year to year, and not upon whether it had been used in a previous period. The Chicago project specifically tested to see whether book use is contagious–i.e., whether the use of a book in one year raises its probability of being used in the next year–and found that the assumption of independence of use from one time period to another seemed to be supported by the data. However, it was admitted that the contagion test was imperfect due to the overall decrease in the use of books over time–or obsolescence–as well as by changes in the university population and book use. It will be seen below that such a conclusion may not have been tenable.

Monograph use in two subject sets–Economics and Teutonic Languages & Literatures–during the period 1954-1958 was used by the Chicago project (Fussler and Simon 1969, 14-34) to test the efficacy of a number of variables as predictors of library use. It was found that the best predictor of the future use of a title was its past use–a result that logically appears to have proven the operation of contagion. Such a conclusion appears even more justified by the fact that when the monograph use in both subject sets was fitted to the Poisson (pp. 187-189), the observed distributions did not resemble the Poisson by having a much higher variance caused by more observations than predicted at both the zero and the higher use points. The lack of fit of the Poisson to the distribution of monographic use was demonstrated with two graphs that are reproduced in Figure 6. [Editor's Note: The author has numbered his figures continuously in the three parts of his paper to allow unambiguous referencing.]

In these graphs the observed distributions are depicted as bars, and the theoretical Poisson distributions at the given lambdas are designated with points. Comparison of these graphs with the bar chart of the distribution of scientific journals by 1956 SML external loans in Figure 1 of Part 1 reveals that the observed distributions of Chicago intralibrary monographic use in Economics and Teutonic Languages & Literatures manifested the same signs of over-dispersion as had the SML supralibrary use of scientific journals. Here are the same high concentration below the mean, the same reduction below the uses predicted at the mean, and the same long tail to the right. These are the sure signs of the operation of a compound Poisson distribution of the negative binomial type resulting from heterogeneity and contagion. It can be theorized that the heterogeneity was more Pearsonian than Lexian due to the set definition by subject. The assumption of contagion seems even more justified by the finding of the Chicago project (pp. 68-92 and 145) that the decline in monograph use over time due to obsolescence was less than previously assumed and that this use continued to decrease indefinitely with the age of the title at a percentage rate that itself tended to decrease over time.

However, while undermining the hypothesis of the simple Poisson as the proper model of library use, the Chicago project conducted two analyses that had great relevance to Urquhart's theories of the nature of this use and the collection management principles that he derived from these theories. The first such analysis related to his concept of supralibrary use being a rough indicator of total use and therefore of intralibrary use. It was done by the Chicago project (pp. 53-67 and 146)

FIGURE 6. University of Chicago Study Graphic Demonstrations of Failure of Simple Poisson Model's Failure to Fit Monographic Use in Two Subject Classes




SOURCE: Herman H. Fussler and Julian L. Simon, *Patterns in the Use of Books in Large Research Libraries* (1969), pp. 188-189, Chicago: University of Chicago Press. Reprinted with permission.

through a comparison of book use at the University of Chicago to book use at Northwestern University, Yale University, and the University of California at Berkeley. An examination of the relative amount of use of the same books at the different libraries indicated that there is a considerable similarity in the reading interests of scholars at different institutions and that, for those titles held in common, predictions about future use at one institution would be quite accurate in predicting future use of the same books at other institutions. From this finding it is possible to hypothesize that supralibrary use and intralibrary use are both parts of aggregate library use and that libraries will tend to lend each other materials needed and therefore held by many libraries.

The second analysis specifically concerned journal use, and it tested the hypothesis that the past use of a serial is a predictor of its future use. Whether this hypothesis is true is of central importance for the manage-

ment of sci/tech journal collections. The Chicago project (pp. 93-106, and 147) concluded that the past use of a serial can be used to predict its future use. It found the most important characteristic of serials to be their nature as families of volumes whose use patterns are related to each other. This causes the use of volumes within the same serial to be closer to each other than to the amount of use of volumes chosen randomly from other serials, making it possible to employ the use of past volumes of a serial to predict the use of future volumes of the same serial. In this it is also possible to hypothesize the effect of contagion.

## *THE PROBABILISTIC BASES OF STABILITY*

### *Bortkiewicz and the Relationship of Homogeneity to Stability*

Posed in a different way, the question of whether the past use of a journal is a predictor of its future use is the question of whether journal use is stable across time. The issue of stability is a crucial one. Without such stability, the rational management of journal collections becomes much more difficult, and it is necessary to design a system capable of dealing with random events. In this section I will analyze the theoretical bases of the stability of journal use over time, defining hypotheses that other researchers may want to test.

In probabilistic terms the analysis of the stability of journal use over time involves the comparison of the Poisson lambdas–i.e., the mean rates of use–of individual journals or sets of journals from one observation period to another. Since the Poisson arises as a limit of the binomial, its lambda or mean is a function of its underlying p or probability. A major theoretical breakthrough on this question was made by Bortkiewicz (1941) in a paper that represented an English translation of research originally delivered in German before the Swedish Actuarial Society in 1917. Bortkiewicz (1931) produced a reduced, more simplified version of this paper, which was read before the American Statistical Association. In these papers Bortkiewicz set forth the theoretical bases of the need for portfolio diversification. His work attracted the attention of the famous economist John Maynard Keynes (1921, 391-405), who regarded the issue of the stability of relationships as crucial, perceived much of the value of Lexian statistics in its defining of this issue, and professed himself to be Bortkiewicz's admirer.

In his papers Bortkiewicz focused on the relationship between homogeneity and stability, applying Lexian analysis to the frequency of sui-

cides in Germany and its 40 constituent states in the decade 1902-1911. His argumentation was so mathematical and technical that even Keynes had difficulty in following his logic. However, its basic features are fairly easy to understand. As a result of his analysis, Bortkiewicz (1931, 18) came to the conclusion that "there exists between homogeneity and stability an antagonistic relation–small homogeneity goes hand in hand with great stability." Bortkiewicz's concept of homogeneity should be understood in terms of the binomial and Poisson requirement for equiprobabililty, i.e., that a given set or subset should be governed by a single probability and that therefore p remains constant from sample to sample. According to his argumentation, the more a given set or subset is governed by a single probability, the more prone it is to changes in this underlying probability and therefore the more unstable it is over time. His concept of heterogeneity must be understood from the Lexian perspective of a set comprised of subsets with different underlying probabilities. If this is the case, according to Bortkiewicz's reasoning, changes in the underlying probabilities of the subsets will tend to counterbalance each other, causing the aggregate probability of the entire set to remain fairly constant over time. Bortkiewicz argued that partitioning a large set into its component subsets according to some rational principle of classification tended to increase homogeneity and that therefore homogeneity and instability tended to increase with the narrowing of the field of observation.

In his paper to the Swedish Actuarial Society Bortkiewicz (1941, 55) pointed out that insurance experts had empirically come to the same conclusions on the relationship of homogeneity to stability. Here he stated, "Such men have recognized for a long time that it is in the interest of a balanced course of the insurance business and thus contributing to the stability of the statistics with which this business has to deal when the insurance cases are distributed according to space and other characteristics over a large area instead of being concentrated on very few localities and very few types of risks." In his later paper Bortkiewicz (1931, 21-22) took this analogy one step further, giving it a specifically Lexian twist. Taking as an example three fire insurance companies–A insuring only dwellings, B insuring only factories, and C insuring both–he pointed out that C would show relatively smaller fluctuations from fire damage from year to year than would be shown by the average of A and B. C's lower fluctuation than the average fluctuation of A and B together is consistent with Lexian theory of the Poisson that sets comprised of members drawn sequentially from urns with differing probabilities tend to have a variance below that of the binomial, which

requires that probability be constant during the drawings and not randomized in this fashion.

### *Stability and Confidence Intervals*

Bortkiewicz defined the probabilistic bases of stability relevant to journal use, but he did not advance a method for accurately measuring this stability. This was done with the development of the concept of the "confidence interval." Briefly defined, a confidence interval is a range of values within lower and upper limits calculated from the sample observations that are believed, with a particular probability, to contain the true parameter value. For example, a 95% confidence interval implies that if the estimation process were frequently repeated, 95% of the calculated intervals would be expected to contain the true parameter value. The higher the confidence level, the broader must be the required confidence interval. Therefore, a 99% confidence interval for a given parameter is wider than its equivalent 95% confidence interval.

The standard method for estimating the confidence intervals of Poisson lambdas is given in E. S. Pearson and Hartley (1966, 80-83; 136-137, Table 8; 227, Table 40). This method is based upon the close mathematical relationship of the Poisson to Pearson's chi-squared distribution, which in turn is replaced by the normal distribution as a measure of probability as frequencies become higher. Therefore, with the Pearson and Hartley method, the probability of the confidence intervals for Poisson lambdas from 0 to 50 is derived off the chi-squared distribution, and these results are presented in Table 40 (p. 227) entitled "Confidence limits for the expectation of a Poisson variable." For lambdas above 50, Pearson and Hartley (p. 83) present a method of calculating confidence levels off the standardized normal deviate.

Table 9 presents the 95% confidence intervals for Poisson lambdas that have been selected, because they delimit the external loan classes within which Urquhart presented his 1956 Science Museum Library use data. This table is read in the following manner. If a serial had, for example, an observed loan rate of 3 in 1956, then there was a 95% probability that its true loan rate was somewhere between 0.62 (or 1) and 8.77 (or 9).

Comparing Table 9 with Table 2 of Part 1 gives some idea of the stability of the external loan classes over time. If, as in the first part of Table 2, the collection is segmented into two classes–Low from 0 to 9, High from 10 to 382–then there is a 95% chance that a title with four loans in 1956 could shift from the Low Loan Class to the High Loan

TABLE 9. Ninety-Five Percent Confidence Intervals for Poisson Lambdas Delimiting 1956 Science Museum Library (SML) External Loan Classes

| Observed Lambda | True Lambda Likely to Be Within | | Range from Lower to Upper Limit |
|---|---|---|---|
| | Lower Limit | Upper Limit | |
| 0 | 0.00 | 3.69 | 3.69 |
| 1 | 0.03 | 5.57 | 5.54 |
| 2 | 0.24 | 7.22 | 6.98 |
| 3 | 0.62 | 8.77 | 8.15 |
| 4 | 1.09 | 10.24 | 9.15 |
| 5 | 1.62 | 11.67 | 10.05 |
| 10 | 4.80 | 18.39 | 13.59 |
| 20 | 12.22 | 30.89 | 18.67 |
| 30 | 20.24 | 42.83 | 22.59 |
| 40 | 28.58 | 54.47 | 25.89 |
| 50 | 37.11 | 65.92 | 28.81 |
| 100 | 81.13 | 121.38 | 40.25 |
| 382 | 344.42 | 422.06 | 77.64 |

Adapted from Pearson and Hartley 1966, 80-83; 136-137, Table 8; 227, Table 40.

Class in the next observation period. Moving up the frequency scale, if, as in the second part of Table 2, one further segments the High Loan Class by separating out a Super High Loan Class of those titles with 40 loans or more, then there is a 95% probability that a title with 50 loans in 1956 could shift from the Super High Loan Class to the High Loan Class in the next observation period. It is to be noted that the further away the number of loans is in either direction from the segmentation boundaries, the less likely titles are to shift from one loan class to another. Of great interest is the last column of Table 9, which shows how the confidence intervals progressively narrow from 77.64 at 382 loans to 3.69 at zero loans. The logical result of this is that in absolute terms stability is the highest at the lower frequency levels, where Bortkiewicz's Law of Small Numbers holds sway.

Putting all the preceding together, it is now possible to formulate the following hypotheses in respect to the stability of sci/tech journal use over time. First, due to Bradford's Law of Scattering, all sci/tech journal titles and sets are heterogeneous in terms of subject matter. Therefore they are comprised of subject subsets with different underlying probabilities, enhancing the stability of their use over time. Second, the

broader the subject coverage of sci/tech journals, the more stable should be their use over time. Third, the more heterogeneous the patron population in terms of scientific specialties, the more stable should be the use of sci/tech journals over time. And, finally, stability should be highest at the lower frequency levels, where in absolute terms the probability of major shifts in use is the lowest.

## *PROBABILITY AND THE NATIONAL LENDING LIBRARY FOR SCIENCE AND TECHNOLOGY (NLL) JOURNAL COLLECTION*

### *The Assumption of Stability in NLL Collection Development and Management*

In his development and management of the National Lending Library for Science and Technology (NLL) journal collection, Urquhart based his work on the assumption that the underlying probability of a given journal being loaned remains stable over time. Therefore, he thought that the observed use of a journal is a predictor of its future use with an accuracy probabilistically determined by the appropriate confidence interval. This led him to apply the simple Poisson model to collection analysis in a manner that is compatible with the compound Poisson model.

The assumption of the ability to predict the future use of serials from past use was implicit in the planning for the NLL from the very start. Urquhart (1957, 23) noted that serial publications would form the main part of the collections of the intended NLL, stating, "For serials it is possible to predict roughly the demand for future issues from the demand for existing issues . . . " Bunn (1962) reported that this assumption was one of five factors that were explicitly taken into consideration in developing a periodical binding policy during the planning of the NLL. She stated this assumption thus (p. 20): "It is possible to predict the future demand on a periodical title if the previous demand is known." Urquhart combined the assumption of stability of journal use over time with the finding of the highly skewed nature of supralibrary use by his study of 1956 SML external loans. The result was a collection development and management policy based upon a stable core of high-loan journals.

In his *Principles* Urquhart (1981, pp. 76-78) gives a clear explication of his methods of collection analysis in Appendix A entitled "A Note on

Statistics for Librarians." Explained in probabilistic terms, he first partitioned the journal collection–best represented by the compound Poisson distribution–into its individual components or titles, which then could be modeled by the simple Poisson distribution. For this purpose, each title could be assumed to be a set of volumes with their own lambda or mean rate of use over some period of time. To demonstrate the randomness of journal use over time, Urquhart replicated and explained a part of the Pearson and Hartley table on Poisson confidence limits, giving the 95% confidence intervals for a number of Poisson lambdas.

In his autobiography Urquhart (1990, 222-223) employed a technique for estimating the confidence limits around the Poisson lambda that can be done without resorting to the Pearson and Hartley table. This technique is based on the property of the Poisson distribution that lambda equals both the mean and the variance. Therefore, the standard deviation can be easily calculated by taking the square root of the lambda or mean. In his autobiography Urquhart postulates a given periodical as a group of volumes having a lambda or mean rate of use over some period of time, and he calculates the confidence interval of this lambda with a formula that makes its range from two standard deviations below the mean to two standard deviations above the mean. I have tested this method for lambdas of 5, 10, 50, and 382, obtaining the following results: confidence interval for 5–0.53-9.47; confidence interval for 10–3.68-16.32; confidence interval for 50–35.86-64.14; and confidence interval for 382–342.91-421.09. Although technically the standard deviation describes the dispersion around the mean and not the dispersion of the mean, comparison of these results with Table 9 reveals that this method yields estimates of the equivalent 95% confidence intervals that are close enough for practical library purposes.

Urquhart was acutely aware of the significance of the tendency of Poisson lambdas to shift within confidence intervals from one observation period to another for the evaluation and management of library collections. He manifested evidence of this in his report on the analysis of 1956 Science Museum Library (SML) external loans to the 1958 scientific information conference in Washington. Thus, Urquhart (1959, 291) stated in this report, the fact that of the 9,120 current serial titles held by the SML 4,821 were not used during 1956 indicated not that SML was holding 4,821 titles which would never be loaned but only that the demand for these titles was very low. Table 9 indicates that in another year there would be a good probability that the number of their external loans use could be as high as four.

In his *Principles* Urquhart (1981, 77) pointed out the difficulties that Poisson confidence intervals posed for libraries in weeding collections. According to him, in many academic libraries a publication used on the average three times per year would be regarded as one of the more appreciably used items. However, he noted, since the observed use of such a publication might vary between one and nine times, there is considerable difficulty in employing observations of the use of individual publications as a basis for making decisions about removing so-called "low use" items from a collection. According to Urquhart, this difficulty can be overcome, if a group of publications can be considered in the same use category such as the parts of last year's volume of a monthly periodical or–as in the Chicago project–monographs classed in the same subject group. Then, he stated, it is possible to obtain more reliable data both about discarding and duplicating items.

In a progress report to the international library community on setting up the NLL Urquhart (1959a) summed up the 1956 SML analysis as revealing that the main problem of a national loan service was to cater to the heavy demand for a relatively small number of serials and the small demand for a large number of serials. Bunn (1958, 256) supplied the numbers by reporting that the SML study had found that 80% of the demand was for serials and that 80% of this demand was for about 1,000 particular serials. She dismissed the rest of the serials by stating that one copy held in the NLL would be sufficient not only to meet total UK demand but also the international demand from all of Western Europe. Urquhart (1957, 26-27) reported that a 1951 analysis of SML loan service had revealed that three major causes of failures to satisfy loans–"on loan," "not loanable," and "at binders"–arose mainly because the SML had as a rule only one copy of any item. To reduce the number of such failures at the new NLL, he proposed two remedies: (1) the acquisition of additional copies of items in frequent demand; and (2) altering the traditional way libraries bound periodicals.

Concerning the first remedy, Urquhart (1981, 77-78) explained in his *Principles* his method for deciding which journals required multiple copies. He based this decision on what he termed the concept of "shelf availability." For example, if in a time interval equal to 10 loan periods, a part was used on average four times, the shelf availability would be 0.6–6/10–with one copy. Adding an extra copy would increase the shelf availability to 0.8 by reducing the average number of loans per copy to two. In probabilistic terms the problem could then be treated as two sets with a non-availability of 0.2, so that the likelihood of no copy being available was 0.2*0.2 or 0.04. To reduce unnecessary duplication,

Urquhart minimized the average number of uses by employing the lower confidence limit of the observed use as the true lambda. Thus, if the observed use of 12 parts of a serial was 50, Urquhart assumed that the true use of the 12 parts was 37.1 in accordance with Table 9 and that therefore the true average use per part was 37.1/12 or 3.1. To show the low use of the majority of scientific journals and the high skew in the distribution of their use, Urquhart (1959a, 175) reported that it had been necessary to duplicate less than 100 serials even on the assumption of a doubling of SML use.

However, it was in the second remedy for the failures to satisfy loan demand–altering the traditional way of binding periodicals–that there was most explicitly implemented the principle of being able to predict the future use of serials from their past use and therefore the relative stability of this use across time.

The new policy and its rationale were set forth by Bunn (1962). Instead of combining the separate issues of highly used serials into volumes as had been traditionally done, it was decided to bind them individually. Together with the postal advantages of such a policy, Bunn pointed out that it would increase the shelf availability of articles in highly used journals, since only an individual issue would have to be sent to a given borrower, leaving the other issues of the volume on the shelf for other borrowers. Bunn reported that just over 1,500 current periodicals were being bound in such a fashion and that these periodicals included not only the 1,200 serials found most heavily used in the 1956 SML analysis but also the 300 titles most heavily borrowed from the U.S. National Library of Medicine (NLM) in 1959. Bunn noted that about one half of the loans made from the NLL were being satisfied by periodicals with individually bound issues even though they comprised only a small percentage of the periodical stock.

These same serials also received different treatment in another way. Urquhart (1962, 321; 1963) reported that extensive purchases of backfiles were being made only for these same serials. Moreover, Houghton (1972, 71) stated that the NLL held complete runs of the 1,200 most heavily used serials in a separate storage area that also housed the receipts and dispatch bay–an arrangement that facilitated the movement of the most heavily used material.

Thus, Urquhart's development and management of the NLL serials collection were based upon a high-use core capable of satisfying the bulk of supralibrary demand. The assumption of stability is implicit in the fact that the individual titles of this core were the approximately 1,500 titles ranked highest in supralibrary use by the analyses of SML

external loans in 1956 and NLM interlibrary borrowings in 1959. Therefore, the best representation of this policy is the first section of Table 2 in Part 1, where the SML serials holdings were partitioned into a low-loan class of zero to nine external loans and a high-loan class of ten external loans or more. Theoretical analysis of the operation of Poisson lambdas over time has demonstrated that, while there may be considerable shifting between these two classes among those titles with observed loans close to the class boundary, the further the observed number of loans moves away from this boundary, the less likely this is to happen. In absolute terms the greatest stability over time should be manifested by those titles in the lowest loan classes, where Bortkiewicz's Law of Small Number is operative and the distribution should always fit the simple Poisson no matter what the subject coverage of the titles there.

## *THE CONTROVERSY OVER THE STABILITY OF SUPRALIBRARY USE*

### *Studies of Supralibrary Use Under Urquhart's Successor as Director General*

The concept of basing collection development and management on a stable core of high-use journals was challenged by Maurice B. Line, who succeeded Urquhart as Director General in 1974 after the NLL became the British Library Lending Division (BLLD). In their classic study of obsolescence Line and Sandison (1974) also postulated the simple Poisson distribution as the proper model for library use, stating (p. 293) that "we can consider its properties a relevant guide to what might be expected." However, like Urquhart, they never tested their postulate against reality but only presented some hypothetical use figures that would result if such were the case. They then emphasized (p. 295) that in respect to serials "no existing studies can be used to predict future usage." This conclusion is a logical one in the light of their postulate of the simple Poisson as the proper model for library use, for this distribution is the model of total randomness.

Empirical proof for such a conclusion appeared to be provided by a series of three analyses of BLLD use that were conducted under Line's directorship in 1975, 1980, and 1983. The first of these analyses was reported by Bower (1976). It consisted of an examination of a sample of 61,333 serial requests received by the BLLD during a three-month period in 1975. The distributional findings were similar to those of Urquhart in

his analysis of 1956 SML external loans in that 1,300 serials representing 5% of the titles held by the BLLD accounted for 80% of the demand. Clarke (1981) reported the 1980 study of BLLD serials use. This study consisted of an analysis of a sample of 66,430 serial requests received during ten working days over a two-week period in May. Once again the distribution was highly skewed with only 10% of the requested titles satisfying 50% of the demand. The 1983 analysis of BLLD use was reported by Merry and Palmer (1984). It had the same sampling period as the 1980 study–10 consecutive working days in May–and analyzed in detail 61,946 requests received during this period for 18,465 titles held by the BLLD. The 1983 analysis found the same distributional pattern–2,158 titles satisfying 50% of the serial demand–that had previously been found at the SML and BLLD.

Throughout the three BLLD analyses, one of the main focuses was on the stability of high-use core of serials over time. Line (1984) summarized the findings of these analyses on this matter and compared the stability of BLLD use of journals to the stability of citations to journals as reported in the Science Citation Index (SCI) and Social Science Citation Index (SSCI) Journal Citation Reports published by the Institute for Scientific Information (ISI). In doing so, he produced a table, which is replicated by Table 10. This table gives the percentage overlap of the top strata of journals ranked in descending order by BLLD use, SCI citations, and SSCI citations for two years separated by time intervals of three and five years.

The most outstanding feature of the data in Table 10 is the extraordinarily high stability of the citation rank order of journals over time in respect to the more moderate stability in the rank order of journals by BLLD use. Thus, in terms of SCI citations for the top strata of 100 to 500 journals, the five-year (1975-1980) overlap ranged between 83% and 88%, whereas the three-year (1979-82) overlap ranged between 91% and 95%. Using SSCI citations as the measure of these same top strata, the five-year (1977-82) overlap ranged between 78% and 83%, whereas the three-year overlap ranged between 84% and 88%. In contrast, with BLLD use, the five-year (1975-80) overlap ranged between 54% and 56%, whereas the three-year (1980-83) overlap ranged between 57% and 62%.

In his analysis of the data, Line (1984) stated that the "low" overlap in the top titles requested from the BLLD in different years had been totally unexpected, suggesting that it might be dangerous to rely unduly on a rank list of journals relating to one year for collection development and management purposes. This conclusion had been first advanced by

TABLE 10. Similarity of Rank Lists Serials at Three-Year and Five-Year Intervals: British Library Lending Division (BLLD) Data vs. Citation Data

| | % Titles Common to Both Lists | | | | | |
|---|---|---|---|---|---|---|
| | BLLD Data | | Citation Data | | | |
| | Serials Requested from BLLD | | *Science Citation Index* | | *Social Science Citation Index* | |
| Top X Titles on Lists | 1975-80 (5 Years) | 1980-83 (3 Years) | 1975-80 (5 Years) | 1979-82 (3Years) | 1977-82 (5 Years) | 1979-82 (3 Years) |
| 100 | 60% | 57% | 88% | 95% | 83% | 88% |
| 200 | 56% | 62% | 83% | 93% | 78% | 84% |
| 300 | 54% | 61% | 86% | 93% | 81% | 87% |
| 400 | 56% | 62% | 88% | 91% | 79% | 88% |
| 500 | 56% | 61% | 87% | 92% | 80% | 87% |
| 1,000 | 56% | 60% | 83% | - | - | - |

To be read as follows: Of the top 100 titles in the 1975 and 1980 BLLD rank lists, 60% were common to both; of the top 300 titles in the 1979 and 1982 *Science Citation Index* rank lists, 93% were common to both. Adapted from Line 1984, 186.

Clarke (1981) in her report, where this question had first been analyzed in detail. Noting that of the top 5,000 titles on both the 1975 and 1980 lists only 2,591 (52%) were common to both lists, she wrote (p. 111): "This inconsistency of rank lists over time sheds doubt on the continuing value of core lists of serials, which might decrease substantially in validity over a relatively short period." Such conclusions undermined the entire theoretical basis of Urquhart's collection development and management policies.

### *The Urquhart Response to the Studies' Inference of Supralibrary Use Instability*

The response to the studies and their inference of supralibrary use instability came in the form of an article entitled "Has Poisson Been Kicked to Death?–A Rebuttal of the British Library Lending Division's Views on the Inconsistency of Rank Lists of Serials" ostensibly written by Urquhart's son, John A. Urquhart (1982). This stinging riposte was an answer to the initial conclusion of instability derived from the comparison of 1980 BLLD use to 1975 BLLD use that appeared in the article by Clarke (1981). It featured the Library Statistical Fraud Squad headed by Sherlock Holmes rushing off to the BLLD to investigate the murder of one Poisson, "whose name is inextricably linked to the num-

ber of horse grooms kicked to death in the Prussian army." This conflation of Poisson's name with Bortkiewicz's work is suggestive of the historical error always made by Donald, and it makes one suspect that Donald was the real author of the piece. The issue at stake was succinctly captured in the following exchange between Holmes and Watson (p. 97):

> 'Elementary, my dear Watson. Either they would have reported near perfect overlap between the use of titles from one survey to the next, which would have meant the end of Poisson . . .' 'But they didn't, Holmes, they said there was only some overlap, and I quote: "It certainly seems that the consistency of rank lists over time is not very high."' 'Precisely, my dear Watson, and so they concluded that use in one survey was not a good predictor. It amounts to the same thing. In either case Poisson would have been finished off.' 'Good lord, Holmes, this is serious. If they get away with the demise of Poisson there's no knowing what intellectual crimes they may go on to commit . . .'

The article demonstrated the effect on the percentage overlap between the top 5,000 journals ranked in descending order by BLLD use in 1975 and 1980 from the natural variation of the Poisson lambda with an interesting model comprised of a matrix of simple Poisson distributions. From this model it was possible to draw the following conclusions. If one restricts oneself to a set of 3,847 titles used from three to ten times in one survey, assuming that their observed use is their true lambda, then, with no change in behavior, 823 or 21.4% could drop at random below three uses on the next survey. Moreover, with the same assumptions, the number of these titles used three times could change–also at random–from 1,253 titles in the first survey to 571 in the next. Besides this demonstration of the effects of Poisson confidence intervals, the paper focused on the methodological errors of the BLLD study, of which the following can be considered major ones: (1) births, deaths, marriages, and divorces of titles were not taken into account; (2) sampling methods and sizes were different in 1975 and 1980; and (3) the two-week sampling period of 1980 was much shorter than the three-month sampling of 1975. On the issue of stability over time specifically, the main charge leveled by the paper against the BLLD study is that it failed to understand that natural variation–sometimes surprisingly pronounced for individual titles–can be expected from one survey period to another and that this variation may be greater due to peaking of demand

over short periods. Taking everything into account, the paper declared (p. 99), "The statement that 'This [survey] sheds doubt on the value of core lists since they change significantly over a period of only a few years' is therefore wrong."

In his autobiography Donald Urquhart (1990) reiterated the main point of the paper by stating that those who compare rank lists often overlook the effect of the confidence limits within which Poisson lambdas move, and therefore (p. 223) "have come to fallacious conclusions from the changes in rank observed in different periods."

### *A Resolution of the Controversy*

In his analysis of the relative stability of BLLD and ISI rank lists over time Line (1984) conceded that the instability of the BLLD rank lists may have been a little "unreal" (p. 146) in that a longer survey period or a much larger sample would have reduced the fluctuation. However, he argued that the samples were very large and sampling error alone was very unlikely to have caused the much smaller overlap of the BLLD lists in comparison to the ISI lists, which were based on the entire population of citations and therefore were not subject to sampling error. According to Line, the likely reason for the discrepancy was that BLLD supralibrary use was inherently more unstable than citations. He described the high overlap of the ISI lists as "remarkable" (p. 145), given that Urquhart had demonstrated that there were good statistical reasons for expecting substantial fluctuations also in the ISI lists. Seeking the underlying causation for the discrepancy, Line noted supralibrary use was affected by local finances, since budgetary circumstances influence libraries in their reliance on external borrowing versus acquisitions. However, Line found the main causation in the different sources of the data. He pointed out that the BLLD served both academic and industrial libraries, whereas citations were made primarily by authors at academic institutions. He pointed out that the BLLD use may have fluctuated more due to the dual nature of its patron base, and he hypothesized that users of industrial libraries may be more responsive to technological change than academics. However, here it should be noted that according to Bortkiewicz's Lexian theory of the inverse relationship of homogeneity and stability, the dual nature of the BLLD patron base should have been a cause of stability due to the counterbalancing probabilities of academic and industrial use. This theory is explanatory in the high stability of citation rates over time.

Line missed the main theoretical reason for the high stability of citation rankings of journals over time. This reason stems from the interplay of the principles on which the ISI citation indexes are based with Bortkiewicz's findings on the inverse relationship of homogeneity to stability. The principles underlying these citation indexes were derived off Bradford's Law of Scattering by the founder of ISI, Eugene Garfield, as a result of a 1971 study of citation patterns to journals indexed by the SCI. Garfield (1972) reported the results of this ISI study in a seminal article published in the journal *Science*. The sample, on which the study was based, was all the references published during the last quarter of 1969 in the 2,200 journals then covered by the SCI. This amounted to approximately one million citations to journals, books, reports, theses, etc. The ISI study found that citations have the same type of distribution discovered by Urquhart in his analysis of 1956 SML external loans. No matter how the data were analyzed, it was found that a small core of journals dominated the frequencies being counted. For example, of the 2,200 journals covered by the SCI, only 152 titles were cited in 50% of all the references; about 500 journals published approximately 70% of all the articles; and a small group of 250 journals provided almost half of the references processed for the SCI. Garfield (1972) noted that the predominance of cores of journals was ubiquitous in individual disciplines like chemistry, but he stated that the ISI study demonstrated the predominance of a small group of journals in the entire citation network. As a result of this study, Garfield came to the following conclusion with respect to Bradford's law (1972, 476):

> . . . I can with confidence generalize Bradford's bibliographical law concerning the concentration and dispersion of the literature of individual disciplines and specialties. Going beyond Bradford's studies, I can say that a combination of the literature of individual disciplines and specialties produces a multidisciplinary core for all of science comprising no more than 1000 journals. The essential multidisciplinary core could, indeed, be made up of as few as 500 journals . . .

Garfield (1983, 21 and 160) used the analogy of a comet to explain his Law of Concentration. By this analogy Bradford's law can be conceptualized as a comet, with the nucleus representing the core journals of a literature and the debris and gas molecules of the tail representing the additional journals that sometimes publish materials relevant to the subject. This tail becomes wider in proportion to the distance from the

nucleus, but Garfield's Law of Concentration solves this problem from the viewpoint of abstracting and indexing coverage by positing that the tail of the literature of any one discipline consists, in large part, of the cores of the literatures of all other disciplines, producing a small multidisciplinary core for all of science.

Garfield's Law of Concentration guarantees that sets of citations to scholarly journals or subject classes of such journals must be extraordinarily heterogeneous and comprised of subject subsets with different underlying probabilities. In terms of Lexian statistics and Bortkiewicz's theories on the inverse relationship of homogeneity to stability, its implications are that the citation frequencies of scholarly journals should manifest an extremely high variance and stability over time resulting from the heterogeneities and complex interactions of the subject subsets with different underlying probabilities. This stability should be enhanced by the principle of contagion, by which a citation to a journal increases the probability of its being cited again and vice versa. Line substantiated this stability with his overlap analyses of lists of journals ranked in descending order by SCI and SSCI citations. The high stability of citations, which he discovered, also has implications for the stability of BLLD use. Bensman (2001) demonstrated that there was a strong positive relationship of SCI citations to NLL use. A logical conclusion from this is that the stability of BLLD use was actually higher than that found by Line, whose results were probably distorted by the shortness of the 1980 and 1983 sampling periods.

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