

Urquhart's Law:
Probability and the Management
of Scientific and Technical
Journal Collections
Part 3.
The Law's Final Formulation
and Implications for Library Systems

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ABSTRACT. This is the last part of an analysis of the law formulated by Donald J. Urquhart in respect to the use of scientific and technical (sci/tech) journals through either interlibrary loan or central document delivery. The first part discussed the genesis of this law as well as its statistical bases; the second dealt with the implications of the law for the development and management of the sci/tech journal collection of a central document delivery library. Part 3 concentrates on its consequences for all the libraries of a given library system. There is analyzed in this part the controversy over the validity of this law that caused Urquhart to formulate it in an explicit manner. Part 3 discusses studies at various libraries that have corroborated this law, postulating that this law forces a probabilistic re-conceptualization of the functioning of the sci/tech journal system. Throughout this part, there are noted the consequences

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of the law for such matters as sci/tech journal sales, resource sharing, document delivery, interlibrary loan, and the transition from individually held paper copies of journals to shared electronic databases. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <<http://www.HaworthPress.com>> © 2005 by The Haworth Press, Inc. All rights reserved.]*

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INTRODUCTION

Part 3 represents the final installment of an analysis of the law formulated by Donald J. Urquhart in respect to supralibrary use. Throughout this analysis, supralibrary use has been defined as the use of materials supplied to the patrons of a given library either through interlibrary loan from other libraries at the same hierarchical level or through document delivery from a central, back-up library. Such use has been contrasted to intralibrary use or use of a library's materials by its own patrons.

The focus in Part 1 was on the statistical and probabilistic bases of Urquhart's Law of Supralibrary Use. This part set forth how this law was a natural consequence of the Law of Scattering conceived in the 1930s by S. C. Bradford, director of the Science Museum Library (SML) in London. Bradford's Law posited that the articles on a given scientific and technical (sci/tech) subject concentrate in a small core of journals and then distribute themselves over journal zones that have to increase exponentially in number of titles to contain the same number of articles as the core journals. Due to such a distribution, sci/tech libraries cannot hold all the titles necessary to their patrons and must have document delivery support from either other sci/tech libraries or a central, comprehensive sci/tech library. Bradford strove to make the SML into the national sci/tech support library of Britain, but this goal was achieved by Urquhart, who founded the National Lending Library of Science and Technology (NLL). The NLL later was merged into the British Library Lending Division (BLLD), now called the British Library Document Supply Centre (BLDSC).

Part 1 related how Urquhart prepared for the establishment of the NLL by conducting the first scientific study of sci/tech journal use by analyzing the loans made by the SML to outside organizations in 1956.

This analysis made two key findings: (1) the distribution of these loans was highly skewed with less than 10% of the SML's journal collection accounting for about 80% of the loans; and (2) the number of SML loans of given journals was highly correlated with the number of United Kingdom (UK) libraries holding these journals. Such findings caused Urquhart to conclude that the supralibrary use of sci/tech journals was indicative of their total use value and therefore of their intralibrary use.

Urquhart's 1956 SML loan data were then utilized in Part 1 to demonstrate the probability distributions governing library use. It was shown that library use is best modeled by the Poisson process, which is the rare occurrence of events over time and space. Space was defined in library terms as individual titles or subject groups of titles. Two types of Poisson distributions were discussed. The first was the simple Poisson distribution, which arises under the following conditions: (1) the probability of occurrence is extremely low and uniform; (2) occurrences are independent in that an occurrence does not affect the probability of further occurrences. This distribution has one parameter, which is λ (lambda) or mean rate occurrence, and it is characterized by a low mean and variance with the two being equal to each other. The simple Poisson was presented as the model of total randomness.

The type of probability distribution governing 1956 SML loans was demonstrated in Part 1 to be a form of compound Poisson distribution. Such a distribution is characterized by a variance much greater than mean. Compound distributions were pioneered by Lexis, who developed the prototype of such distributions. He proved that distributions characterized by excess variance arise in sets comprised of subsets with different underlying probabilities. Sci/tech journal distributions tend to be Lexis distributions due to Bradford's Law of Scattering, which mandates that sci/tech journal subject sets are composites of various subject subsets with differing probabilities. Part 1 analyzed the two stochastic processes causing library use distributions to be highly skewed. The first is "heterogeneity," which was described as having two forms. One is Lexian in that it consists of the probabilistic differences of the various subject subsets comprising sci/tech journal sets; the other arises from the probabilistic differences of the titles of homogeneous sci/tech journal subject sets due to such factors as importance, size, age, language, etc. The other stochastic process is "contagion," according to which each use of a sci/tech journal increases the probability of its further use and decreases the probability of other journals being used. In discussing the Poisson process, Part 1 stressed the importance of Bortkiewicz's

Law of Small Numbers for library collection management. According to this law, if the field of observation is restricted to a set of elements manifesting a low number of occurrences, no matter what the differing probabilities of the subsets, the resulting distribution is always the simple Poisson. Lexian statistics were utilized to prove that the variance of such a distribution is always lower than the variance that could be theoretically expected.

Part 2 focused on Urquhart's utilization of probability to develop and manage the sci/tech journal collection of the NLL. Its main points can be summarized as follows. Urquhart had only a limited grasp of the Poisson distribution, knowing only its simple form, which he posited as the correct model of library use. The empirical findings of his study of 1956 SML external loans were corroborated by a study of supralibrary use conducted at the U.S. National Library of Medicine in 1959, but his hypothesis of the simple Poisson as the correct model of library use was undermined by a relegation study done contemporaneously at the University of Chicago by Fussler and Simon. The latter study found distributions of monograph use in two subject groups that manifested all the characteristics of compound Poisson/contagious distributions. Nevertheless, the Chicago study made two findings that buttressed not only Urquhart's concept of supralibrary use as an indicator of total library use but also his method of managing sci/tech serials. In respect to the first, it demonstrated that the reading interests of scholars at different universities are similar and that monograph use at one university library can be utilized to predict monograph use at another university library. Concerning the second, the Chicago study proved that the volumes of a given serial act as a family with a similar use and that, therefore, the use of past volumes is indicative of the use of future volumes.

Due to the findings of the study of 1956 SML external loans, Urquhart came to regard 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 caused him to base his development and management of the NLL sci/tech journal collection on a high-use core of titles, which received special treatment in terms of backfile purchases, duplication, binding, and housing. Like the Chicago study, Urquhart regarded a serial as a family of volumes, but he took this concept one step further. Basing himself on the fact that volumes of a given serial have a mean rate of use, Urquhart posited that the use of a single serial can be modeled by the simple Poisson. Such a conceptualization of the NLL sci/tech journal collection as a composite of

simple Poisson distributions is fully compatible with the compound Poisson distribution that actually governed this collection as a whole.

In line with the finding of the Chicago study, Urquhart assumed in his collection development and management policies that the past use of a journal's volumes is predictive of their future use and that journal use is stable across time. His centering of these policies on a high-use core made such stability a major concern. Therefore, Part 2 analyzed the probabilistic bases and measurement of such stability. It explained the probabilistic bases in terms of 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. Part 2 hypothesized that sci/tech journal use is inherently stable due to the multidisciplinary character of sci/tech journal titles and sets mandated by Bradford's Law of Scattering and its citation corollary, Garfield's Law of Concentration. Stability was also considered a natural consequence of contagion, where each use of a journal increases the probability of its further use and decreases the probability of other journals' use. Measurement of stability across time was demonstrated through means of Poisson confidence intervals and how Urquhart utilized such intervals to manage the NLL journal collection. It was noted that theoretically in absolute terms journal use across time has to be most stable in the low- and zero-use classes, where Bortkiewicz's Law of Small Numbers is operative. Part 2 finished 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 resolved the controversy in favor of the Urquhart position.

The emphasis of Part 3 is on the implications of Urquhart's Law of Supralibrary Use for library systems. This part begins by discussing a study of intralibrary use in the early 1970s at University of Newcastle upon Tyne for purposes of relegating part of the collection to remote storage. The Newcastle study was conducted by Urquhart's son and daughter-in-law, John A. Urquhart and Norma C. Urquhart, and it tested hypotheses formulated by Donald with NLL use data supplied by him. This study made two major breakthroughs. One was that it

marked the first time that the compound Poisson distribution—specifically, the negative binomial distribution (NBD)—was put forward as the proper probabilistic model of library use. Relegation methods utilizing both the simple Poisson and NBD were analyzed, and these methods included a practical implementation of Bortkiewicz's Law of Small Numbers. The other breakthrough of the Newcastle project was to demonstrate that supralibrary use of sci/tech journals is generally predictive of their intralibrary use but most accurate in these predictions in respect to the zero-use class that is governed by Bortkiewicz's Law of Small Numbers. Thus, the Newcastle project corroborated Urquhart's theories of supralibrary use.

Part 3 then discusses the circumstances that led Urquhart to formulate his Law of Supralibrary Use in an explicit manner. Here it is noted that librarians did not understand Urquhart's Law, because they were not only unaware that the distribution of library use is highly skewed but thought that the supralibrary use and intralibrary use are inherently different. The occasion for Urquhart's explicit formulation of his law were studies conducted at the BLLD by his successor, Maurice B. Line, and others that supposedly found low correlations of NLL/BLLD use with citations and intralibrary use at another British library. These findings caused Line to question whether either citations or supralibrary use could be used as guides by libraries in the management of their sci/tech journal collections. The studies raised a storm of controversy, during which the charge was made that Line's conclusions were invalid in respect to citations, because the supralibrary use of sci/tech journals is of a different nature than their intralibrary use. This charge motivated Urquhart to formulate explicitly his law and its theoretical bases. The controversy is resolved in Part 3, which proves that Line's findings resulted from faulty statistical techniques and that proper statistical techniques reveal a strong association of citations with both supralibrary and intralibrary use. Part 3 concludes by reviewing various studies done in France, Turkey, and the United States that validate Urquhart's Law of Supralibrary Use.

Throughout its analysis of these matters, Part 3 discusses the implications of Urquhart's Law for libraries and library systems. It notes that this law forces the probabilistic re-conceptualization of the functioning of the sci/tech journal system. According to this re-conceptualization, each journal must be conceived as having a probability of aggregate use that includes both supralibrary and intralibrary use. This probability of aggregate use can be estimated from supralibrary use, library holdings,

citations, expert ratings, etc. The probability of use at individual libraries will vary around this aggregate probability due to different patron bases, but use of journals tends to be comparable at comparable libraries. Bortkiewicz's Law of Small Numbers holds for the library system as a whole, and sci/tech journal use at different libraries is most similar in the low-and zero-use classes. Part 3 notes the implications of such a system for sci/tech journal sales, resource sharing, document delivery, interlibrary loan, and the transition from individually held paper copies of journals to shared electronic databases.

THE UNIVERSITY OF NEWCASTLE UPON TYNE STUDY OF INTRALIBRARY USE

Nature and Importance of the Study

The final bases for the formulation by Urquhart of his law of supralibrary use were established by a research project he sponsored at the University of Newcastle upon Tyne. This project made a theoretical breakthrough in the probabilistic modeling of library use, and, in doing so, it provided the proper perspective from which to approach the question of the stability of journal use across time. The research project, which lasted from 1973 to 1975, was an analysis of the use of materials at the University of Newcastle upon Tyne library. This project was implemented by Urquhart's son and daughter-in-law, John A. Urquhart and Norma C. Urquhart (1976), under whose names the project reports were published. John assumed responsibility for the project, whereas Norma did the evaluation and analysis of the data that had been collected. Like the Chicago project, the Newcastle project was done for the purpose of relegation and stock control. Despite their age, these analyses still remain among the best relegation studies ever done. The goals of the Newcastle project were established at a meeting at the National Lending Library for Science and Technology (NLL) under the chairmanship of Donald Urquhart in January 1972. At this meeting papers by Donald and his successor Maurice B. Line outlined two major areas for stock control investigations within libraries: (a) acquisitions policies in relationship to what not to acquire but to obtain through interlibrary loan; and (b) retention policy in respect to what to discard or relegate from existing stock due to lack of space or other considerations.

The Probabilistic Breakthrough

The Newcastle project is notable for two things. One is that it was the first study to suggest the negative binomial as the correct model for overall library use. This was done by the Urquharts during their consideration of the proper methods that should be employed in the relegation of monographs. In their consideration of this problem they started from the work of Richard W. Trueswell. During the 1960s, Trueswell, a professor of industrial engineering, replicated in studies of intralibrary use at a number of libraries in the U.S. what Donald Urquhart had first found in his 1956 Science Museum Library (SML) study of supralibrary use—that the distribution of library use is highly skewed with the use concentrating on a relatively few of the items held by a library. On this basis Trueswell formulated his famous 80/20 Rule, by which 80% of the use is satisfied by 20% of the collection. In his writings Trueswell generally modeled his rule with mathematical curves. Trueswell's 80/20 Rule is an empirical law derived off observations of a single phenomenon without any general applicability for scientific inference. Urquhart and Urquhart (1976, 22) noted this aspect of Trueswell's law, writing:

It is regrettable that hitherto no explanation has been offered for the nature of the curves produced by Trueswell. Indeed, the descriptive curves have been presented as self-explanatory. The curve is the proof.

Urquhart and Urquhart (1976, 22-24, 39-45) then proceeded to rectify this situation. To do this, they first constructed a use curve of the type plotted by Trueswell on the basis of the simple Poisson model of overall library use. This is the model that was advanced by Donald, utilized, tested, and rejected by the Chicago project, as well as postulated by Line and Sandison. Urquhart and Urquhart based their model on a hypothetical library, where each book has an equal probability of 0.01 of being borrowed in any one fortnight, pointing out that with such a model 40% of the stock sample would account for 40% of total circulation. They compared the results of this model to Trueswell's 80/20 Rule and actual stock sample curves, where 40% of the stock accounted for 80% of the use, finding Trueswell's rule a closer fit to reality.

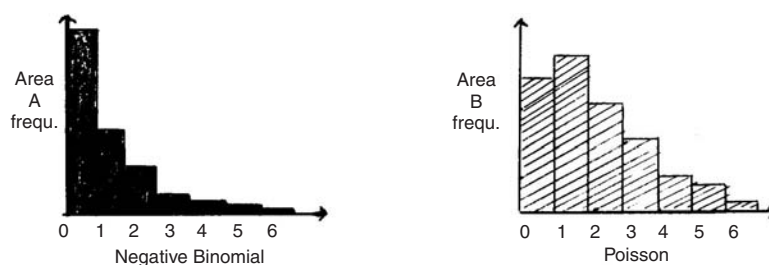
Urquhart and Urquhart then plotted use curves on the basis of a rudimentary compound Poisson model of a library, where 10% of the books have a 0.1 probability of being borrowed in a fortnight and 90% of the books have a 0.01 probability of being borrowed in a fortnight. They found these curves remarkably similar to some of Trueswell's curves but with 90% of the stock still exhibiting low random use. As a result of this experiment, Urquhart and Urquhart concluded that there are different levels of use within a library collection, and they therefore recommended the negative binomial distribution as the model for overall library use, since it plotted the Poisson curve associated with each level of use.

Urquhart and Urquhart noted that negative binomial distributions are common throughout nature, modeling such diverse phenomena as the aggregation of algae cells on cultured media, the distribution of herring shoals in the North Sea, or the spatial distribution of a field of cows. Urquhart and Urquhart (1976) took a random sample of monograph titles from the different subject areas and found that the use patterns of the sample followed the negative binomial distribution. Noting the Lexian bases of this distribution, they stated (p. 94) that these use patterns indicated "a somewhat heterogeneous collection of books made up of subcollections with different average levels of use."

Of greatest interest are the practical conclusions, which Urquhart and Urquhart (1976, 95-96) drew for the relegation of monographs in respect to the nature of the probability distributions underlying their use. Here is most clearly seen the difference between an empirical law and a probability model. In line with the above discussion, the options for relegation were considered in terms of whether the distribution of the monograph use in a given subject area had been the negative binomial or the Poisson. To illustrate these options, Urquhart and Urquhart provided two graphic models—one of subject area A with the negative binomial pattern of monographic use, the other of subject area B, where monographic use followed the Poisson distribution. These graphic models are reproduced in Figure 7.

According to Urquhart and Urquhart, if the use distribution had been the negative binomial, certain books would be consistently in minimal or zero demand, so that a cut-off point based on past use would be feasible. In terms of the negative binomial model of monographic use in subject area A, such a point could be set at two uses and below, thereby encompassing the majority of the monographs in this area. However,

FIGURE 7. Newcastle Project's Comparative Graphic Models of Negative Binomial and Simple Poisson Distributions of Monographic Use



SOURCE: Urquhart and Urquhart 1976, 95.

NOTE: The horizontal x-axis designates the number of uses for a given monograph; the vertical y-axis indicates the number of monographs at that level of use.

Urquhart and Urquhart state, if prior monographic use had fitted the Poisson distribution such as in subject area B, then no group of low-use monographs could be isolated, and the use of monographs would have been entirely random, so that relegation on the basis of past use would be no more efficient than relegation at random.

In discussing the various options arising from this situation, Urquhart and Urquhart proposed not only relegating at random from Poisson areas like B, if the use here were very low, but also isolating the low-use monographs in negative binomial areas such as A and relegating at random from among them. The combination of restricting the relegation process to those subject areas manifesting low Poisson use and the lower frequency classes of those subject areas governed by the negative binomial would be restricting the field of observation to low frequency classes no matter what the subject area and a practical implementation of Bortkiewicz's Law of Small Numbers. Although done in respect to monograph relegation, the justification and utilization of the compound Poisson by Urquhart and Urquhart to model library use provided a theoretical basis for Donald's centering his management of the NLL scientific journal collection around a high-use core. This is because it provided a theoretical framework for segmenting a library's holdings into low-use and high-use subsets, whose composition should be stable over time at both extremes but particularly at the lower frequencies, where shifts of the means are small in absolute terms.

Relationship of Supralibrary Use to Intralibrary Use

The other notable feature of the Newcastle project was its analysis of the relationship of the intralibrary use of scientific journals to their supralibrary use. At the meeting at the NLL in January 1972 under the chairmanship of Donald, it was suggested that there be examined the question of whether an item was worth holding locally if little or no demand had been revealed for it in the records of the NLL. As reported in Urquhart and Urquhart (1976, p. 56), it appeared particularly valuable to test the hypothesis that if a title has not been requested from the NLL for a given number of years, there would be no need to hold it locally. It also seemed desirable to identify the exceptions to any such rule. This in effect was an empirical test of one of the main conclusions drawn by Donald Urquhart (1959, 290) from his analysis of the 1956 external loans by the Science Museum Library that "the use of the copies of a serial in the library [SML] is a rough indication of its total use value in the United Kingdom." Not surprisingly, Urquhart and Urquhart (1976, 20-21 and 65) made testing this hypothesis a priority of the Newcastle project. To assist them, Donald made available a survey of NLL use that was four years old at the time of the Newcastle project.

In approaching the problem of relegation, Urquhart and Urquhart (1976, 93-94) pointed out one major advantage of serials over monographs in this matter. This was that the use of periodical material is generally consistent within a given run, making it possible for predictions of future usefulness to the reader to be more precise. This premise had been validated by the Chicago study and was the same one on which Donald had based his work. However, they then combined this advantage with the fact that their analysis of periodical use in several subject areas had shown that the number of periodical titles used over time tends to rise and then level off at a certain ceiling, leaving a substantial zero-use class of periodical titles. They noted that humanities journals tended to take longer to reach this saturation point than science journals due to the greater scattering of the use of humanities materials. The Newcastle project made what was probably its most significant finding in its analysis of NLL use as a predictor of the zero-use class of sci/tech journals at the local level.

It is difficult to summarize the findings of the Newcastle project on the relationship of the use of sci/tech journals at the NLL to such use at the University of Newcastle upon Tyne library from the material published under the name of Urquhart and Urquhart (1976). The reason for this is that this volume is a rough compendium of interim and final re-

ports as well as other items written by various authors. Moreover, there is evidence of hasty writing and inadequate proofreading resulting in numerous errors and ambiguities. However, John A. Urquhart (1976; 1977; 1978) published three rather cogent summaries of these findings, and these summaries are what will be utilized to present the results of the Newcastle analysis of the relationship of the supralibrary use of sci/tech journals to their intralibrary use.

In general, the Newcastle project found a strong positive association between the NLL supralibrary use of sci/tech journals and the Newcastle intralibrary use of such journals. John Urquhart (1978, 121) noted that the positive association was all the more remarkable since the NLL data was four years older than the Newcastle data. This indicates a certain stability of use across time. However, John (1977, 34) pointed out that the predictive ability of the NLL data was less in a subject area like medicine, where the University of Newcastle upon Tyne had a strong program. To quote one set of figures given by John (1978, 121), in the science category, of the 26 titles with low NLL use, 17 had no current use and 9 had current use at Newcastle, whereas of the 45 titles with high NLL use 14 had no current use and 31 had current use at Newcastle. This same pattern was found in medicine. Here, of the 63 titles with low NLL use 43 titles had no current use and 20 had current use at Newcastle, and of the 70 titles with high NLL use 19 had no current use and 51 had current use at Newcastle.

The NLL data performed extremely well in predicting the low- and zero-use classes of sci/tech journals at Newcastle. As stated by John (1976, 418), the NLL data was "effective in predicting low or zero use not only for dated stock but also for current titles." According to John (1977, 33), it was better to relegate serials than monographs for the following reason: "We could . . . be more confident in predicting use, or rather non-use, since we were dealing with groups of books [sic] which had relatively constant use patterns." He presented data showing that, with the exclusion of annual, specialist, and new journals, the NLL data had a 3% error rate in predicting titles with zero use at the University of Newcastle upon Tyne library in the science category. However, in medicine the error rate was 19%. John (1977, 34) also reported that in most cases titles not held at the NLL had zero use at Newcastle. As crude as these measurements were, they did indicate that, in respect to sci/tech journals, there is a strong relationship of supralibrary use to intralibrary use, that libraries act not as individual units but as a system, and that Bortkiewicz's Law of Small Numbers holds not only for individual libraries but also for the library system as a whole.

URQUHART'S LAW

Controversy Over the Nature of Supralibrary Use

In a festschrift dedicated to Urquhart in honor of his retirement as Director General, Gordon Williams (1975), Director of the Center for Research Libraries in Chicago, discussed the revolutionary nature of Urquhart's findings in respect to supralibrary use. According to Williams, a constant assumption underlying interlibrary loan operations in the U.S. had been embodied in the 1968 revision of the ALA interlibrary loan code with the statement, "It is assumed that each library will provide the resources to meet the study, instructional, informational, and normal research needs of its users, and that requests for materials from another library will be limited to unusual items which the borrowing library does not own and cannot readily obtain at moderate cost (American Library Association, Reference Services Division 1968, 43)." In other words, supralibrary use is the use of marginal items. Williams furthermore pointed out that most librarians were not fully aware that, even at the local level, use concentrated on a small portion of a library's collection. It was this assumption combined with this lack of awareness that made Urquhart's findings so surprising, and Williams summed up the situation thus (pp. 202-203):

What surprised even more than the concentration of use on a small number of journal titles was that the titles found to be most requested on interlibrary loan corresponded so closely to the titles most used in local libraries. Not only that, but the titles are the same ones that are usually characterized as the 'most important,' or 'fundamental' journals in their fields, and that librarians believe are 'widely held,' meaning that they are subscribed to by most libraries with even moderate interest in the fields covered. It would therefore seem reasonable to expect that whatever else might be borrowed on interlibrary loan, these journals would not be borrowed at all, or at most only rarely.

Urquhart did not explicitly formulate his findings on the nature of supralibrary use as a law until after his retirement as Director General. The occasion for this formulation was a controversy that erupted as a result of efforts by his successor, Line, to investigate the validity, utility, and ramifications of these findings. Among the first of these efforts was a study by Line and Wood (1975) on the effect of the BLLD photocopy-

ing service on journal sales. This study was based on data from the 1975 survey of BLLD use and entailed an analysis of 81 journals, which by extrapolation from this survey would have had 300 or more copies made annually of articles published in the three most recent years. Line and Wood found these journals to be well-established titles, widely held by libraries and with large circulations, concluding that the BLLD service had little effect on journal sales. The nature of these titles convinced Line and Wood that most of them had to be held by most academic libraries. Seeking a reason for the concentration of BLLD use on such journals, Line and Wood focused on the fact that a large component of the demand on the BLLD resources came from industrial libraries. According to their reasoning, what is a standard journal to an academic community is a marginal item to a specialized industrial library. Such a conclusion derived from the accepted concept of supralibrary use as marginal use.

A different interpretation of this phenomenon was provided by another study of the relationship of document delivery to journal sales that was done two decades later by the British Library Document Supply Centre and the Canada Institute for Scientific and Technical Information (1996). The British Library Document Supply Centre is the successor organization to the BLLD, and, unlike Line and Wood, the later study investigated precisely which organizations were utilizing document delivery services. Its findings fortified the conclusion of Line and Wood that central document delivery has little effect on journal sales. The Anglo-Canadian study found that organizations subscribing to journals also make use of document supply services with sometimes as much as 62% of document supply demand for a particular journal emanating from organizations subscribing to it and that subscribing organizations are frequently among the heaviest users of document supply to titles, for which they have subscriptions, with one subscriber to a given journal accounting for 20% of the total document supply demand for it. Such a finding indicates that supralibrary use is not merely marginal use.

The defining moment in Urquhart's formulation of his law came with a study done at the British Library Lending Division (BLLD) by Scales (1976) on the relationship of citations to supralibrary use. In this study Scales utilized the same 1969 *Science Citation Index* (SCI) data, which Garfield had analyzed in developing his Law of Concentration. She compared these 1969 citations of journals to a National Lending Library for Science and Technology (NLL) use survey conducted in 1969 of journal issues published in the 1967-1969 period. To make the citation

and use data comparable, Scales excluded any NLL titles that did not also appear among the SCI source journals and considered citations only to the 1967-1969 issues.

Scales' final lists consisted of 1,571 journals ranked in descending order by NLL use and 880 journals ranked in descending order by SCI citations. To test the hypothesis that NLL use was typical of that in the UK generally, Scales utilized Urquhart's method of comparing this use to the mean number of journal holdings in the *British Union Catalogue of Periodicals* (BUCOP), using the 10 most frequently loaned titles and then random samples of 10 titles loaned 10, 2, and 0 times. Her results mirrored Urquhart's 1956 findings: top 10 titles in loans (mean of 157.7 loans)—34.3 holdings; 10 titles loaned 10 times—24.3 holdings; 10 titles loaned 2 times—16.4 holdings; and titles loaned 0 times—4.9 holdings. Scales (p. 21) pointed out that "there is a definite tendency for those journals used less frequently to be those held by the least number of libraries and vice versa," suggesting that the hypothesis of NLL use being typical of UK use generally was a "reasonable one."

Scales found what she considered to be a tenuous relationship between NLL supralibrary use and SCI citations. Her measure of this relationship was the Spearman rank correlation coefficient. For the 50 most used journals the correlation between NLL use and SCI citations was 0.42, whereas for the 50 most cited journals this correlation was only 0.26. Only the first correlation was statistically significant. Trying a different tack, she compared the number of journal titles common to both the NLL use and SCI citation lists at different levels from the top 5 to the top 480 on both lists. For the top 50 the overlap was 16 journals, and the correlation between use and citations for these titles was only 0.067. Scales found it necessary to consider more than 250 journals before 50% occurred on both lists. Concentrating on citations as a predictor of library use, she hypothesized that the highest correlations would be at the upper levels, and she tested this hypothesis by calculating Spearman correlation between use and citation for the journals ranked 51 to 100 by citations. The correlation of 0.002 here proved to be far less than the correlation the 0.26 for the top 50 citation journals.

An experiment ranking these top 50 citation journals by citation impact factor demonstrated that this citation measure was even less predictive of library use, reducing the correlation for these journals from 0.26 to 0.16. Scales further tested the validity of citations as predictors of library use by correlating the rankings of the 50 physics journals most highly used at the MIT Science Library with their NLL use ranking and their citation ranking. She found that MIT use had a low correlation

with NLL use and correlated better with citations than did NLL use, causing her to conclude tentatively that SCI citations were of more use to American libraries than to British libraries. As a result of these findings, Scales concluded that journal citation rankings are not good indicators of actual library use and do not constitute valid guides for journal selection by libraries.

The publication of the Scales study ignited a controversy that was conducted primarily through letters to the editor published in the *Journal of Documentation*. This controversy revealed ignorance about Urquhart's work and a deep misunderstanding of the nature of supralibrary use. Scales had attacked citations from the perspective of Urquhart's theory that supralibrary use is indicative of all library use—supralibrary and intralibrary—and therefore the low correlations were the result of SCI citations not being valid indicators of library use. However, such a viewpoint was contrary to the standard view of supralibrary use. Thus, Morgan (1976) questioned whether NLL use figures were typical of use throughout the country, and he posited that the low correlation of MIT use with NLL use in physics had more to do with the different nature of the libraries than with any national differences.

Morgan noted that the mean BUCOP holdings of the ten most cited journals were much higher than those of the ten titles most used at the NLL—70 vs. 34—arguing that it was the wide availability of these titles that was at the root of the low correlation of NLL use with SCI citations. The most forceful assertion of the accepted view of supralibrary use against the Scales' argumentation was made by a lecturer at the City of Birmingham Polytechnic library school named Rowley (1976), who wrote (p. 319):

This leads us to my major criticism in Pauline Scales' work . . . Every practicing librarian knows that the requests forwarded to the NLL are unique in some way e.g. fringe, obscure, or foreign items. The core demand on most libraries is met from their own stock without recourse to the NLL. Demands on the NLL's services may reflect certain individual user's core demands, but this can only be a small group. Journals which are core journals in a subject field, in the sense that many libraries purchase them, and many readers consult them, are not normally those which will be obtained from the NLL (despite the demand from special libraries for some 'popular' journals which to them represent peripheral interests). I cannot accept the thesis that the demand on NLL stock is in any way

typical of the demand in any other type of library, or of demand and use of periodicals generally.

Rowley criticized BUCOP as an unrepresentative list of UK library holdings, and she asserted that a low number of holdings does not necessarily imply low usage. In respect to the low correlation of MIT use of physics journals with their NLL use and MIT's better correlation with citations, Rowley interpreted this not as a result of national differences but as indicating that NLL use is not typical of library use in general, suggesting that NLL use is more likely to be more equally distributed over periodicals, i.e., conform to the Poisson distribution.

In their letter responding to Rowley's criticism Line and Scales (1976) affirmed the validity of Urquhart's findings on supralibrary use and—using the new name for the NLL—rejected her assertion that requests forwarded to the British Library Lending Division (BLLD) were “unique in some way e.g. fringe, obscure, or foreign items.” On the contrary, they pointed out, journals most heavily requested were generally very common ones such as *Science* and *Nature*. To buttress their case on the nature of supralibrary use, Line and Scales reported that subsequent work at the BLLD had revealed good correlations between the BLLD rank list and rank lists of journals used at three university libraries. They also noted that BLLD rankings had proven effective in identifying low use titles at the University of Newcastle upon Tyne library.

Line and Scales reinforced the basic conclusions of the Scales study by summarizing some of the key arguments Line (1977) had made in a paper he had presented to a 1976 conference in Amsterdam with the provocative title, “On the Irrelevance of Citation Analyses to Practical Librarianship.” In this paper Line repeated the argumentation of Line and Wood (1975) that interlibrary loan requests to the BLLD were indicative of use in a general academic library, because most of the libraries using BLLD were special industrial libraries and journals marginal to such libraries are central to a university library. In seeking reasons for the poor relationship found by Scales between BLLD use and SCI citations Line listed the following possibilities: (1) some users, especially in industrial research, read but publish little, so that their uses would be little reflected in citations; (2) the SCI citations were derived entirely from journal sources, and the lack of monograph coverage may have introduced serious distortions; and (3) a high proportion of the SCI source journals were American and may have reflected American use rather than British use, of which BLLD use was a reflection.

All this caused Line to wonder not only whether citation studies were valid indicators of library use but even whether they were reliable indicators of citations. To test this hypothesis, he conducted a simple experiment by performing rank-order correlations among lists ranked by number of citations derived from different cores of source journals, finding widely ranging overlaps (35-80%) and correlation coefficients (0.28-0.86) among the various lists. The conclusion, which Line drew from this finding, was that the rank order of journals is dependent upon how the set containing them is defined, and he stated that this is also the reason why use data differs from library to library. Therefore he admonished librarians to study the uses and interlibrary loan requests of their own patrons. It was this finding that was emphasized by Line and Scales (1976, 322), who stated, "Since citation rank lists based on different source journals show striking differences, the statistical probability that any one of them, based on however large a number of source journals, will fit any one library must be very small."

Needless to say, this entire line of argumentation was rejected by Cawkell (1977; 1978, 45), UK representative of the Institute for Scientific Information, who focused on the nature of supralibrary use. Cawkell asserted that libraries borrow from the outside those journals to which they do not subscribe due to insufficient use but conceded that BLLD use may be dominated by prime journals of science due to their being borrowed by the large component in the BLLD patron base of special libraries, for which such journals are marginal. However, in his opinion, if such were the case, then a "fringe corpus" derived in such a way was "fortuitous" and not acceptable as "a definitive list of the most important journals."

In a follow-up letter to the *Journal of Documentation* Line and Steemson (1977) reported on further research at the BLLD on the relationship of supralibrary use to citations. This research rectified some of the errors in method of the preceding research. First, Line and Steemson identified a major fault in the Scales paper, clarifying the reasoning behind its method. According to them, what librarians need to know is not the core journals in a given subject, which are well enough known anyway, but what journals outside this core they should acquire. To find this out, Scales had first calculated the Spearman rank-order correlation of the 50 most cited journals with NLL use, obtaining 0.26, and then the second most cited journals, whose correlation was 0.002. Line and Steemson combined the two samples into the top 100 cited journals and found a Spearman rank-order correlation of 0.28 significant at the 0.01 level. When Line and Steemson calculated the Spearman correlation co-

efficient for all 880 journals common to the NLL and SCI lists, the result was a respectable 0.6. Second, Line and Steemson corrected the assertion made in Line and Scales that good correlations had been found between the BLLD ranked list and the rank lists of three academic libraries. They stated that two of the academic lists were too short (100 and 68 titles) for drawing any valid conclusions but reported that the third list of 565 titles had produced a very significant correlation of 0.42 when ranked by BLLD use. However, they noted that only 15 titles were ranked above 50 on both lists and 34 above 100 on both.

Replicating Scales' method of correlating the top 50 titles for the BLLD and academic list, Line and Steemson obtained correlations of 0.23 and 0.45 respectively. They noted that these results were remarkably similar to the correlations of 0.42 and 0.26 Scales had obtained for the top 50 of the BLLD and ISI lists, stating that this further illustrated the danger of comparing short or truncated lists. Line and Steemson regarded such correlations as too low for the needs of librarians. In their opinion, the main conclusion of the Scales article—that citation rank lists are poor indicators of library use and of little practical value to librarians—still held good.

More significantly, Line and Steemson felt compelled to correct the Scales article as well as the Line and Scales letter in the sense that the BLLD rank list suffered from the same faults, thereby rejecting both citations and supralibrary use as universally valid indicators of library use. While conceding the possible validity of these measures as general indicators of journal importance, they rejected their utilization by libraries for the purpose of selecting individual titles. However, Line and Steemson suggested that long ranked lists based on either citations or supralibrary use may have a negative utility in that librarians could see whether they were acquiring journals with a low rank and carefully examine the local use of these journals. This suggestion was in conformance with the finding of the Newcastle project that NLL supralibrary use had been most predictive in respect to titles in the low and zero classes of Newcastle intralibrary use.

Urquhart's Formulation of His Law

The controversy, which was engendered by the Scales study, caused Urquhart to clarify and codify his thinking on supralibrary use. This he did in a letter to the *Journal of Documentation*, which was largely a response to Rowley's letter criticizing the Scales study. This letter marked the first time he used the term "Urquhart's Law." Urquhart (1977)

opened this letter by declaring, "It is a serious matter when a lecturer in a library school contradicts without producing any evidence one of the most useful laws of library science." He then stated the law thus:

In its more pedantic form the law states that the inter-library loan demand for a periodical is as a rule a measure of its total use. As far as I am aware the existence of such a law was first indicated in my report of a survey of the use of journals in the Science Museum Library in 1956. For this reason perhaps the law should be called Urquhart's Law . . . The apparent exceptions to the law are few in number and may be statistical curiosities. The 'measure' is probably 'roughly proportional,' but this has not been confirmed. A deduction from the law that if a periodical is rarely used at Boston Spa [location of the NLL and BLLD-SJB] it would be rarely used in a university library has been confirmed at Newcastle.

From this definition it is obvious that Urquhart thought that supra-library use was not a precise predictor of intralibrary use except at the lower frequencies governed by Bortkiewicz's Law of Small Numbers, and in this respect he was in agreement with the position being advanced by Line. Urquhart then connected his law with the logic of Bradford's Law of Scattering in the following manner:

I appreciate that if you think all organizations have their core journals and have to rely on borrowing peripheral journals Urquhart's law seems to be unreasonable. However, this line of reasoning leads to the conclusion that the most heavily used journals at Boston Spa would be the very uncommon journals of which Boston Spa has possibly the only holding. This is clearly not the case so the line of reasoning is wrong. The trouble is that it focuses attention on what an organization does about periodicals and not on what happens to particular periodicals. If you think in terms of individual periodicals you would have a 'core' of users: that is those organizations holding a periodical and some peripheral users, that is those who have to borrow it. It is reasonable to suggest the larger the core the larger the periphery. Indeed this line of reasoning leads to the conclusion that the law would also apply to monographs.

Urquhart then spelled out the implications of his law for cooperation among libraries thus:

. . . A deduction from the law is that the heaviest inter-library loan demand is for the commonest items and these are the ones that the holding libraries have no wish to lend as they are heavily used locally. A failure to appreciate this . . . has hindered the development of satisfactory inter-library lending services in a number of countries including the USA and India.

Urquhart concluded his letter by urging that his law be taught to all library school students so that libraries not make mistakes about inter-library loan policies in the future. In his *Principles*, Urquhart (1981, 85) gave his law the following formulation:

The fact that the heaviest inter-library demand is for periodicals which are held by a number of libraries is of major importance in designing inter-library services. To draw attention to this relationship I have called it 'Urquhart's law.' It means, for instance, that the periodicals in the Boston Spa collection which are rarely used are unlikely to be used to any appreciable extent in a British university. There may be some exceptions to this deduction and there is no precise relationship between the number of copies held by libraries, and the inter-library demand for a periodical. Nevertheless, the law is very important in considering the need for a central library collection.

The main tenets of Urquhart's Law can be summed up under the following three points: (1) the supralibrary use of a scientific journal is positively associated with the number of libraries holding this journal in a given library system; (2) the supralibrary use of a scientific journal is indicative of its total use value in a given library system and therefore is a predictor of its intralibrary use at the libraries within this system; and (3) the libraries of a given library system have common zero- and low-use classes.

VALIDATION AND IMPLICATIONS OF URQUHART'S LAW

A Resolution of the Controversy Over the Nature of Supralibrary Use

Much of the confusion and disagreement resulting from the Scales paper on the relationship of citations to supralibrary use stemmed from

the faults of her primary analytical tool—the Spearman rank correlation. In his letter Brookes (1976) focused on the inappropriateness of this technique to the problem at hand. Brookes noted that Spearman was an experimental psychologist, who devised his correlation for comparing ranks of a different kind—ordinal ranks derived from personal judgment rather than interval or ratio ranks constructed from frequencies. According to him, Spearman took the dubious step of equating the ordinal first with the cardinal number 1, the ordinal second with the cardinal number 2, etc. Brookes pointed out that this has the effect of making all shifts in rank equivalent to each other. In his opinion, given the nature of the data, a technique, which correlates ranks on this basis, is “wholly unrealistic.”

In his criticism of Scales’ use of the Spearman, Brookes concentrated on the lower end of the distribution, where frequencies are small. He noted that the lowest citation rank of her top 50 journals by either NLL use or SCI citations was 881, whose citation frequency was down to four, hypothesizing that the citation frequency of the next lower rank—882—was only 3. Brookes then declared that frequencies as small as 4 or 3 are much too low to be considered as a basis for calculations on ranks. Stated in its simplest form, his argumentation began by considering citation counts to a given journal as random events whose frequency is governed by an underlying probability. This frequency can be considered as the journal’s Poisson lambda or mean. Starting from this concept of citations, Brookes then employed the reasoning of the laws of large numbers that the larger the sample, the more accurate the estimate of the true mean. In his view, an astronomical number of citations would be required, before it could be safely established that the citation rank of one journal was higher than that of another journal particularly at the lower citation frequencies. By his estimate 881 journals would need approximately 1.5×10^{11} citations overall to establish their rank stability with 95% confidence—a large number even by ISI’s standard of activity. According to Brookes, ISI citation lists should be considered samples of the current scene, and the effect of using ranked samples based on low frequencies was to introduce sample variance unrelated to the question under consideration into the correlation. Brookes (1976, 321) concluded his criticism of the Scales paper with the judgment, “The hypothesis that citation counts of serials are of little use as indicators of usage therefore remains unproven by the techniques described in her paper.”

Brookes’ criticism of Scales’ use of the Spearman rank correlation becomes much more cogent, when it is combined with Urquhart’s

warning set forth in Part 2 of this paper about coming to fallacious conclusions in comparing rank lists by ignoring the effect of the confidence limits within which Poisson lambdas move from one sampling period to another. This danger can be demonstrated with Urquhart's data on the distribution of the external loans made by the Science Museum Library (SML) in 1956 across journals. These data were analyzed in this paper's Part 1. The loans were exponentially distributed over the titles, creating the type of distribution most common in library and information science. Ranking the journals downward by number of loans results in the two-class segmentation of Table 2 of Part 1: high (10-382 loans)–1,251 titles (6.95%), 42,101 loans (79.11%); low–16,749 titles (93.05%), 11,115 loans (20.89%).

This type of distribution has two major consequences for ordinal rankings on which the Spearman is based. First, the interval distances between the ordinal ranks becomes less and less as one moves down from the high-frequency ranks to the low-frequency ranks, so that the low-frequency ranks—where the bulk of the titles are concentrated—are separated by only one loan. This means that equal changes in frequency result in much larger changes in rank at the lower level than at the higher level. The second major consequence relates specifically to Poisson confidence limits, whose characteristics and impact have been demonstrated and discussed in Part 2 in conjunction with Table 9 there. Here it was shown that the confidence intervals of the frequencies, on which the ordinal ranks are based, become smaller and smaller as one moves down from the high-frequency ranks to the low-frequency ranks. Due to this, it was noted, the further one moves in either direction from the border demarcating the dividing line of the high class from the low class—10 loans, in this case—the smaller the chance a title could shift classes from one observation period to another.

Inspection of Table 9 reveals that this narrowing of confidence intervals is not enough to prevent a large amount of churning of ordinal ranks from one observation period to another due to the close interval distances between these ranks at the lower levels. Thus, there is a 95% chance that the true lambda of a title with three observed loans is between one and nine loans, covering practically the full gamut of possible ranks in the low class, where the interval distances between ranks are only one loan and the bulk of the titles are located. This suggests that the Spearman rank correlation, which works by comparing individual ranks, may be biased downward by a large amount of churning among the lower ranks. Much of this lower-rank churning may be considered irrelevant from the practical viewpoint, and a more meaningful picture

of the relationship of citations to library use may be obtained by a technique operating within broadly defined accuracy limits that are more suitable to the purpose of the analysis, control for the lower-rank churning, and capture the overall stability of the use classes.

An interesting insight into this question was provided by Pan (1978), whose research was contemporaneous to that of Scales. Pan studied the relationship of citations and expert librarian ratings of journals to their use in a number of biomedical libraries, which included those of Columbia, Harvard, and Yale. Her sample consisted of 169 titles, of which 97 were most frequently cited in the *Science Citation Index*, 41 were nominated by personnel in the participating libraries, and 31 were randomly selected. The use counts were collected for one semester and included circulation, interlibrary loan, as well as in-house use such as photocopying. Pan employed two methods to test the relationship of citations to library use: the Spearman rank correlation and chi-squared tests of the journal distribution across four categories: high citation/high use journals, high citation/low use journals, low citation/high use journals, and low citation/low use journals. Pan set the median values of the counts as the dividing line between high and low categories. She found a significant correlation of 0.47 between the rankings of the journals by their citation and use counts. It should be noted that this correlation was lower than the 0.6 reported by Line and Steemson (1977) between all 880 journals common to the NLL and SCI lists used by Scales.

A different picture emerged from the analysis of the distribution of the journals across the four chi-squared categories. Here Pan reported that, in 72% of the test journals, high citation indicated high use, while low citation indicated low use. Testing other variables, she found other indicators of high library use to be: total number of articles published during a specified period, expert librarian ratings, and number of subscriptions to a journal. This last finding can be regarded as an empirical validation of Urquhart's Law, and it surprised Pan, who had expected that journals with large circulations would not be in great demand at libraries, since users would be more likely to have their own copies. Instead, she reported (p. 32) that the opposite had been found and that "journals which were highly subscribed to were more likely to be the ones most frequently used in libraries." As a result of her research, Pan (p. 33) came to the conclusion that her findings indicated that "the frequency with which journals are cited is at least as reliable in predicting the potential use of journals in libraries as the judgment of experienced librarians familiar with the journals and with their users." Seeking the

reason why her results contradicted the findings of Scales, Pan located it in the nature of the libraries under analysis, writing (pp. 33-34):

. . . The most significant difference between the Scales and Pan studies is the type of library which provided the journal use data. The National Lending Library supplies journals to libraries unable to meet requests from their own collections. The journal use data in the Scales study therefore reflected the unfilled requests of the libraries served by the National Lending Library. The journal use data in the Pan study, on the other hand, reflected only the filled requests of the clientele of the libraries participating in the study. The findings of the Scales study, therefore, do not necessarily contradict those reported here. The combined findings of the two studies indicate that citation rankings of journals are reliable indicators of their use in libraries of the type included in the Pan study but not of the type included in the Scales study.

Thus, similar to Rowley and others, Pan based her reasoning on the accepted view that supralibrary use is inherently different than intralibrary use.

Pan was wrong in this deduction. Bensman (2001a) has demonstrated that Scales and Pan came to contradictory conclusions not as a result of the different nature of the libraries under analysis but as a result of the flawed statistical methods utilized by Scales. To do so, Bensman employed Pan's chi-squared technique on the 84 journals, for which Scales (1976, 24-25) had provided rank data on her lists of the 50 journals highest in NLL use and the 50 journals highest in SCI citations. This demonstration will now be replicated here with four use/citation categories instead of the six use/citation categories of the 2001 paper. The first step in the analysis was to classify the 50 journals in both the NLL and SCI rankings according to the subject categories in the 1965-1969 cumulation of the *Science Citation Index*. Due to the fuzziness of citation sets, a number of these journals classified in more than one SCI subject category, so that in each case there were more subject categories than titles. The 50 NLL journals classified in 59 subject categories, whereas the 50 SCI titles were assigned to 65 subject categories.

Inspection of these categories revealed that the probability structure underlying NLL use differed from the probability structure underlying SCI citations. Technology appeared to have a higher probability in NLL use due to the large component of industrial libraries in the NLL's patron base, whereas basic science appeared to have higher probability in

SCI citations. The clearest evidence of this was that thirteen NLL journals classified in engineering categories, whereas no such journals appeared in the SCI list, which for the most part consisted of basic science titles.

The next step in the analysis of the Scales data was to design use/citation categories and determine the number of titles that could be expected in these categories on the hypothesis of no relationship between NLL use and SCI citations. For this paper both the NLL use and SCI citations were divided into low and high categories, and the four categories of analysis became: Low NLL Use/Low SCI Citations, Low NLL Use/High SCI Citations, High NLL Use/Low SCI Citations, and High NLL Use/High SCI Citations. Trueswell's 80/20 Rule, otherwise known as his 75/25 Rule—whereby 25% of the items in a library collection account for 75% of its use—was used as a model to set the dividing line between the low and high categories. Therefore, I decided that the high categories should be the upper quartile and contain 25% of the titles or as near to this percent as the data would permit. Scales reported that her NLL list had 1,571 titles and her SCI list had 880 titles. She ranked them downward in descending order of use and citation, assigning them ordinal ranks of 1, 2, 3, 4, etc. The closest approximation to 25% allowed by the data was 390 NLL titles (24.8%) and 218 SCI titles (24.8%). Equating each rank to one title, I placed any journal ranked 1 to 390 by Scales on NLL use in the High NLL Use category and any journal ranked 1 to 218 by her on SCI citations in the High SCI Citations category. To determine the number of journals expected in each of the four categories on the hypothesis of no relationship of NLL use to citations, I multiplied the size of the sample by the percent of NLL titles and the percent of SCI titles in each category, making the proportion of the sample in the category the same as the proportion of titles in the category. For example, if the hypothesis were true, the number of titles expected in the High NLL Use/High SCI Citations would be $84 \times 24.8\% \times 24.8\%$ or 5.2 titles.

The results of this analysis are presented in Tables 11A and 11B above. Table 11A is a 2×2 contingency table. Here it can be seen that zero titles were observed in the Low NLL Use/Low SCI Citations category instead of the 47.5 (56.6%) of titles expected on the assumption that the 84 titles would be distributed across the categories in proportion to the number of titles in the categories. This was to be expected, as the Scales titles were those with the highest frequencies of NLL use or SCI citations, and it indicates a strong, positive relationship between the two variables. This relationship is validated by the Low NLL Use/High SCI citations categories, where four titles (4.8%) were observed instead of the 15.6 titles (18.6%) expected.

TABLE 11A. 2 × 2 Contingency Table on Relationship of National Lending Library for Science and Technology (NLL) Use to *Science Citation Index* (SCI) Citations for the 50 Journals Found by Scales Highest on Each of These Measures

NLL Use	SCI Citations		Totals
	Low SCI Citations (Ranks 219-880) No. Low Citations Titles = 662 % Low Citations Titles = 75.2%	High SCI Citations (Ranks 1-218) No. High Citations Titles = 218 % High Citations Titles = 24.8%	
Low NLL Use (Ranks 391-1,571) No. Low Use Titles = 1,181 % Low Use Titles = 75.2 %			
No. Observed	0	4 (b)	4
% Observed	0.0%	4.8%	4.8%
No. Expected (a)	47.5	15.6	63.1
% Expected (a)	56.6%	18.6%	75.2%
High NLL Use (Ranks 1-390) No. Low Use Titles = 390 % Low Use Titles = 24.8 %			
No. Observed	18 (c)	62	80
% Observed (a)	21.4%	73.8%	95.2%
No. Expected (a)	15.7	5.2	20.9
% Expected	18.7%	6.2%	24.8%
Totals			
No. Observed	18	66	84
% Observed	21.4%	78.6%	10 0.0%
No. Expected (a)	63.2	20.8	84.0
% Expected (a)	75.2%	24.8%	10 0.0%

N.B. There was an overlap of 18 titles between the rank lists of the 50 journals highest in NLL use and highest in SCI citations, leaving a total of 84 unique titles.

(a) Numbers and percentages expected were calculated by first multiplying the percentage of use titles by the percentage of citations titles at each corresponding use/citations level to obtain the % expected for each cell, which was then multiplied by 84 to obtain the number expected for that cell.

(b) The 4 Low NLL Use/High SCI Citations titles were the following: *Astrophysical Journal*, *Inorganic Chemistry*, *Journal of Experimental Medicine*, and *Virology*.

(c) Of the 18 High NLL Use/Low SCI Citations journals, 12 were engineering titles.

TABLE 11B. Chi-Squared Test of Independence of National Library Lending Library for Science and Technology (NLL) Use from *Science Citation Index* (SCI) Citations for Journals in the High NLL Use Category

	Low SCI Citations		High SCI Citations		Total Chi-Squared
	No. Observed	No. Expected	No. Observed	No. Expected	
High NLL Use	18	15.7	62	5.2	
Chi-Squared	0.3		625.3		625.6

Degrees of freedom = 1. At 1 degree of freedom the null hypothesis of independence is rejected at the 0.005 level at a chi-squared of 7.88 and above.

However, it is the relationship of the high NLL use to citations that is the most interesting. In the High NLL Use/Low SCI Citations category there were eighteen titles (21.4%) observed, which was extremely close to the 15.7 titles (18.7%) expected. But twelve of these journals were engineering titles, of which there were only thirteen in the entire sample, and this category clearly demonstrates the differing probabilities underlying NLL use and SCI citations. The strong, positive association between NLL use and SCI citations is most emphatically proven by the High NLL Use/High SCI Citations category, where 62 titles (73.8%) were observed instead of the 5.2 titles (6.2%) expected. This is demonstrated by the chi-squared test of independence set forth in Table 11B, which shows that there was far less than a 0.005 probability that this distribution of high NLL use titles occurred by chance.

Thus, with proper techniques, Scales' own data clearly reveals that there is a strong, positive relationship of citations to supralibrary use that is equivalent to the relationship found by Pan of citations to intralibrary use. It is also evident that both these measures are sensitive to the probabilistic processes governing the data and can be profitably employed by librarians for the selection of individual titles for their collections.

Corroboration of Urquhart's Law and Its Implications for Library Systems

Urquhart's Law forces a probabilistic re-conceptualization of the functioning of the sci/tech journal system. According to this re-conceptualization, for any library system, all journals have an underlying probability of aggregate use or total number of uses by all the libraries of the

system. During any observation period, this aggregate probability will be expressed in an aggregate number of uses representing the systemic means or Poisson lambdas of the journals. The use of the journals at the individual libraries comprising this system should be considered as samples of their aggregate use, and the probability of the use of the journals at these individual libraries will differ and vary around their aggregate probability or mean due to the different patron bases and other circumstances of these libraries. The variance and confidence intervals around the aggregate mean probabilities are highest for the journals with the highest probabilities of use and shrink as these probabilities become smaller until all the libraries of the system have common zero- and low-use classes of journals. Therefore, in absolute terms the predictive accuracy of the aggregate mean or Poisson lambda is greatest for the lowest use classes, where Bortkiewicz's Law of Small Numbers holds sway. There are a number of ways to estimate the aggregate use value of journals, including supralibrary use, citations, number of holding libraries, and expert ratings.

Over the years studies have been conducted that have tested the validity of Urquhart's Law and demonstrated its implications. One of the most interesting of these studies was that of Salaün, Lafouge, and Boukacem (2000), who analyzed requests made to the Institut de l'information scientifique et technique (INIST), France's equivalent of the British Library Document Supply Centre. This study was similar to that of Scales in that it analyzed the relationship of supralibrary use to citations by correlating these two variables for the 50 journals most frequently requested from INIST during four-week period in January, 1997, and the 50 journals most frequently cited in the 1996 *Science Citation Index*. Salaün, Lafouge, and Boukacem also analyzed the relationship of INIST requests for journals to their number of library holdings listed in the French union catalog, *Catalogue collectif national des publications en série* (CCNPS).

Their sample consisted of some 50,000 requests to INIST, which came primarily from three categories of organizations: (1) public or private sector companies (44.4%); (2) higher education establishments (23.8%); and (3) research organizations (24.2%). This patron base bore a marked resemblance to patron base generating the NLL requests, which Scales analyzed, particularly in respect to the large representation of companies. Nearly all of the requests classed in four scientific disciplines: medicine, pharmacology, biology, and chemistry. Physics was poorly represented, and, in this respect also, the INIST data resembled the NLL data of Scales, whose top 50 NLL titles had only three

physics titles (5.1%) in comparison to nine physics titles (13.8%) in her top 50 SCI titles. Salaün, Lafouge, and Boukacem (p. 569) describe the distribution of the INIST requests as the “Zipfian-type distribution of journal circulation,” but this is only another name for the type of distribution Urquhart found in his analysis of external loans made by the Science Museum Library in 1956.

Following the method of Scales, the authors correlated supralibrary use with citations both for the 50 journals most frequently requested from INIST and for the 50 journals highest in SCI citations. For the 50 journals most frequently requested from INIST the correlation was 0.64, which was significant at the 0.001 level, whereas for the 50 journals most highly cited in the SCI the correlation was 0.60, which was also significant at the 0.001 level. Both these correlations demonstrate a commonality between supralibrary use and citations at the highest levels of INIST and SCI frequencies. However, one of the most interesting findings of Salaün, Lafouge, and Boukacem was that this commonality did not seem to hold for physics and astrophysics, causing them to speculate about the existence of hidden and closed communications systems among researchers in these disciplines that allowed them to bypass regular document delivery channels. Thus, two of the top 50 SCI titles—*Physics Letters B* and *Physical Review D*—were not requested at all from INIST, whereas the *Astrophysical Journal* ranked 18th in citations but 830th in INIST requests.

Salaün, Lafouge, and Boukacem tested the validity of their correlations with the overlap method employed by Scales, ranking the top 100 journals in INIST requests and SCI citations in descending order and then comparing the number of journals common to both rankings at intervals of 10. Unlike Scales, who found it necessary to consider more than 250 journals before 50% appeared in both rankings Salaün, Lafouge, and Boukacem found an approximately 50% overlap at every interval of 10 at every level from 10 to 100.

The work of Salaün, Lafouge, and Boukacem on the relationship of supralibrary use to citations corroborated the validity of Urquhart’s Law for France. However, when they tested the relationship of supralibrary use to number of library holdings, they reported (p. 572), “Contrary to conclusions drawn twenty years ago by Line and others for the UK, there is no obvious relationship between title availability in libraries, as indicated by the French Union Catalogue, and demand at INIST.”

This conclusion was so incongruous with previous findings that it caused this researcher to reanalyze their data pertaining to this question. For the 50 journals highest in SCI citations the initial correlation of

INIST requests with number of French library holdings was 0.33, which was significant at the 0.02 level. However, inspection of the scattergram of these two variables revealed two sets of outliers. First, there were the physics and astrophysics journals—particularly, *Physics Letters B* and *Physical Review D*—whose INIST requests were comparatively far too low for their library holdings. There were eight such journals. Second, *Nature* and *Science* appeared as outliers in the sense that their INIST requests were comparatively far too high for their library holdings. Salaün, Lafouge, and Boukacem (pp. 572-573) reported that INIST requests for these journals were atypical in that 60% of them were for older articles published prior to 1990 rather than for recent articles. This suggested to them that INIST served an archival function for these journals. Removal of these 10 outliers raised the correlation to 0.40 significant at the 0.01 level. For the 50 journals highest in INIST requests the initial correlation was 0.39, which was significant at the 0.01 level.

The reason for this higher initial correlation here was that there was only one physics journal—*Journal of Applied Physics*—among them. Removal of this journal plus *Nature* and *Science* raised this correlation to 0.40, which was also significant at the 0.01 level and the same as the correlation coefficient for the journals highest in INIST use with the removal of the outliers. Given the shortness of the sampling period—four weeks in January 1997—and the truncated distributions restricted to the highest frequency levels, highly significant correlations of 0.40 indicate that Salaün, Lafouge, and Boukacem were wrong in their conclusion, and that there is a strong positive relationship of French supralibrary use to French library holdings.

A study by Tonta and Ünal (2005) indicates that Urquhart's Law also holds for supralibrary use in Turkey. This study analyzes 137,692 document delivery requests to Turkish Academic Network and Information Center (TANIC) between June 26, 2000, and June 30, 2002. Of these requests 91,314 were satisfied from 5,521 journals. Tonta and Ünal fitted the distribution of these 91,314 requests over the 5,521 journals to Bradford's Law, finding that a mere 168 or 3.0% titles of the titles satisfied 30,164 or 33.0% of the requests. They correlated the frequency of the use of the 168 core titles with their SCI total citations, finding only a weak Pearson r of only 0.164 significant at the 0.05 level. This caused Tonta and Ünal to conclude that SCI citations "cannot be used as reliable indicators to predict the frequency of local use of journal titles for document delivery purpose" (p. 89). However, here they made the same mistake that Scales made of correlating only an extremely truncated part of the upper level of the distribution, and it surprising that they ob-

tained any significant positive correlation at all. Probably more indicative of the true relationship of Turkish supralibrary use to SCI citations is that Tonta and Ünal report the mean total citation counts of the 168 highly used titles as 25,722. If this were the citation count of a single journal, it would have been among the top 100 of the 5,748 titles ranked in descending order by total citations in the 2001 SCI JCR. A conclusion of a strong relationship of Turkish supralibrary use to SCI citations is fortified by a glance at the top 11 titles in document deliveries. The subject focus of the requests to TANIC was biomedicine, and two of the top 11 titles were *Lancet* and the *New England Journal of Medicine*. These two titles were among the top 15 titles reported by the study of 1959 interlibrary loan requests to the National Library of Medicine (NLM), which was discussed in Part 2 of this paper.

Urquhart's Law has been validated by studies in the United States other than the analysis of 1959 journal requests to the NLM. The most extensive of these was reported by Wood (1969). This study was conducted at the Chemical Abstracts Service (CAS) of the American Chemical Society. Unlike Urquhart's SML and the NLM studies, the CAS project analyzed not central document delivery but another form of supralibrary use—interlibrary loan—in this case, 70,686 interlibrary requests provided by 19 resource libraries evenly distributed throughout the U.S. Most of these requests were made in 1967, and they originated from persons at 3,363 organizations. The CAS findings were similar to those of Urquhart in two respects. First, the distribution was the same, with 1.6% of the titles accounting for 25.1% of the requests, and 6.9% of the titles accounting for 50.5% of the requests. Second, there was also the same predominance of standard titles held by most libraries, with *Nature* and the *Journal of the American Chemical Society* being among the three most requested titles.

Two U.S. studies are of extreme interest when considered in relationship to each other, because they validate Urquhart's Law at both ends of the frequency distribution. The first of these was reported by Stewart (1976), and it caught the attention of Urquhart (1977) himself. Stewart described the requests filled by the Periodical Bank of the Associated Colleges of the Midwest, a consortium of ten liberal arts schools. He related the number of requests for titles in the period 1969-1972 to the number of libraries of the consortium holding the titles, showing that the bulk of the requests—6,010 out of 15,996 (37.6%)—were for titles held by all ten member libraries. Stewart also showed that the average number of requests per title skewed rapidly downward in direct relationship to number of holdings, from 71.55 for titles held by all ten li-

braries to 0.01 for titles held by only one library. Stewart states that this phenomenon was totally unexpected when the Periodical Bank was established.

The validity of Urquhart's Law at the lower end of the frequency distribution was demonstrated by Price and Carey (1993) in their analysis of the results of the participation of Montana State University (MSU) in a program of the cooperative holding of scientific journals with four other universities of the Pacific Northwest. For its part, MSU Libraries purchased 86 serials with a pledge to make them readily available to the other universities. Price and Carey monitored both the MSU intralibrary use of 84 of these titles as well as their supralibrary use by the other four universities participating in the project for nine months in 1991. Of the 84 titles, 30 had no intralibrary use and—to the evident surprise of the researchers—no supralibrary use either. These results were a function of the systemic operation of Bortkiewicz's Law of Small Numbers, and it caused Price and Carey to question the value of the cooperative holding of scientific journals.

For his part, the author of this paper has twice tested whether Urquhart's Law is applicable to journal usage at Louisiana State University (LSU). The first occasion was when Bensman and Wilder (1998, pp. 193-199) analyzed the utilization of the UnCover document delivery system by LSU as part of a project to explore the potential for improving the scientific and technical serials holdings of LSU Libraries. To do this, they gathered a sample of all documents delivered to LSU Libraries by UnCover during the two-year period July 1, 1994-June 30, 1996 from serials classed in LC subject classes Q (Science), S (Agriculture), and T (Technology). This sample comprised 847 serials accounting for 2,909 document deliveries, and these serials were analyzed in terms of measures constructed on the basis of LSU faculty ratings and citation impact factor. The latter is a measure invented at the Institute for Scientific Information (ISI) to gauge the importance of the journals covered by its *Science Citation Index* (SCI) and its *Social Sciences Citation Index* (SSCI). It was found that 135 of these 847 titles (15.9%), accounting for 250 document deliveries (8.6%), were on current subscription at LSU Libraries despite such titles being blocked from the UnCover system.

Subsequent analysis of these 135 titles revealed that 45 (33.3%) were in the highest category of the faculty rating measure and 109 (80.7%) were in the highest category of the citation impact factor measure. These titles were stripped from the sample, leaving 712 titles accounting for 2,659 documents. The remaining titles were then grouped into

three ordinally ranked use classes: low—310 titles (43.5%) accounting for 310 documents (11.7%); medium—323 titles (45.4%) accounting for 977 documents (36.7%); and high—79 titles (11.1%) accounting for 1,372 documents (51.6%). From the nature of these classes it is evident that the underlying distribution was similar to the one underlying 1956 SML external loans. Various tests revealed that both the LSU faculty rating and the citation impact factor measures were positively associated with UnCover document deliveries. These results demonstrate some of the factors operative at the local level in the functioning of Urquhart's Law.

In his second test of Urquhart's Law, Bensman (2001b) utilized its basic principles to compare the quality of the journal coverage of three bundles being marketed by EBSCO, Gale, and ProQuest for the Louisiana Academic Library Information Network Consortium (LALINC). Aggregators such as EBSCO and Gale provide bundled collections of electronic journals with their own indexing and abstracting services. The bundles in question did not contain the more academic journals but ones of the popular type. Therefore it was thought inappropriate to utilize citation measures to assess the quality of their journal coverage.

Instead Bensman utilized the quality ratings published in *Magazines for Libraries* (MFL) edited by Katz and Katz (2000). These ratings were considered flawed for two reasons: (1) they only represented the opinion of individual subject experts; and (2) one company was utilizing MFL as a selection tool, giving it an unfair advantage. To provide a different measure of quality, EBSCO, the main library subscription agency, supplied a list of the 1,000 titles most purchased from it by libraries, and it was decided to assess the quality of the aggregator journal coverage by the proportion of titles on this list. This measure was considered a more valid one for the following reasons. First, on the basis of Urquhart's Law, number of library holdings is a general measure of intralibrary as well as supralibrary use, and the aggregated collections were to be utilized by all the libraries in LALINC. Second—and this is a major reason behind the validity of Urquhart's Law—number of library holdings actually represents the collective judgment of the library profession as to the importance of journals, and this was deemed a more valid measure than the individual expert opinions, on which the MFL ratings were based. Much to Bensman's surprise, the aggregator, which used *Magazines for Libraries* as a selection tool, scored highest on the new quality measure. This not only validated *Magazine for Libraries* as a selection tool but also demonstrated that the opinion of individual sub-

ject experts is an excellent gauge of the collective judgment of the profession.

Urquhart was correct—his law is “one of the most useful laws of library science.” It has been seen that this law has many implications for such diverse areas as journal evaluation and selection, collection management, resource sharing, document delivery, journal sales, etc. Nevertheless, despite its importance, this law has not been widely known, understood, and accepted. For example, in their massive textbook on collection development, Evans and Zarnofsky (2000) never mention Donald J. Urquhart and only briefly discuss the Newcastle study (p. 422). As a result, much work remains to be done on elucidating and understanding the ramifications of Urquhart’s Law. One important issue is the implications of this law for the transition from the era of individually held paper copies, in which it was developed, to the new era of shared electronic databases. Urquhart’s Law seems to indicate two things of importance for this transition. First, access is not the primary determinant factor in journal use. Second, supralibrary use and aggregate intralibrary use are very much the same. The logical consequence of Urquhart’s Law is that there should be no change in journal use in the transition from individually held paper copies to shared electronic databases, which entail nothing more than a merger of supralibrary use with intralibrary use. But this is merely a hypothesis that requires testing.

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