Book Reviews

Concerning Bottlenecks

Elements of Queuing Theory. With applications. Thomas L. Saaty. McGraw-Hill, New York, 1961. xv + 423 pp. Illus. $11.50.

Stochastic Service Systems. John Riordan. Wiley, New York, 1962. x + 139 pp. Illus. $6.75.

Queues. D. R. Cox and Walter L. Smith. Methuen, London; Wiley, New York, 1961. xii + 180 pp. Illus. $3.75.

Introduction to the Theory of Queues. Lajos Takács. Oxford University Press, New York, 1962. x + 268 pp. Illus. $7.50.

As more and more industrial, civic, and military operations are studied quantitatively, the importance of those elements of the operation where congestion occurs are attracting increasing attention, and the study of their characteristics becomes more and more fashionable. Interest in the behavior of congestion elements, variously called bottlenecks, stochastic service systems, or simply queues, has grown by leaps and bounds in the past decade. The bibliographies in the volumes reviewed here include about a thousand references, most of which are to papers published since 1956. These four books, published in one year, are another indication of the growth.

Basic parts of a queuing situation are a series of units (ships, customers, messages, and the like) that arrive at a facility for servicing (unloading-loading, goods to be sold, messages to be transmitted, and so forth). If the service facility is busy, the incoming unit either departs (a lost unit) or waits quietly until it can be serviced (a unit bound in queue). The combinations and variations that are possible in a simple queuing system, both those that can be imagined and those that are encountered in practice, are myriad. Arrivals can be regularly or randomly spaced in time; service times can be all equal, or they can be of random lengths, with any of a variety of distributions; rules for choosing the next waiting unit to be serviced (the queue discipline) can be on the basis of first-come-first-served, last-come-first-served, or random choice—or one class of arrivals can be given priority over the others; and there can be one or several channels, operating in parallel or in series.

Queuing theory must be able to translate these various situations into equations, and it must solve the equations to obtain design formulas that can guide operations managers in alleviating bottlenecks or in reducing costs, or in both. Useful formulas are those for the mean number of units waiting in the queue or for the mean number of units lost to service, if there is no queue, and for the mean time spent by a unit waiting for service and the mean lengths of those periods when the service facility is busy or is idle. Probability distributions for those quantities are sometimes needed, and transient solutions are occasionally necessary, to analyze cases where the rate of arrival or of service changes suddenly with time.

In the literature on queuing, as in the whole burgeoning field of operations research, reports tend to divide into two disparate types. On the one hand are the strictly practical reports of investigations of actual operations, which often fail to utilize the aid that queuing theory can now provide. At the other extreme are the purely mathematical treatises, which finish off a sequence of theorems and lemmas with a formula for the Laplace-Stieltjes transform of a waiting-time distribution, without ever explaining its importance or its meaning in terms of any actual queuing situation. The four volumes reviewed here are nearer the latter extreme than the former. They are not recommended for those who quail at generating functions or Laplace transforms, though at least two of them do spend time discussing the practical implications of their formulas. Each of the four will have its value for professional systems engineers and operations research workers, or for mathematicians who are looking for interesting applied fields.

The little monograph by Cox and Smith has the most down-to-earth attitude. Adequate space is devoted to a discussion of various kinds of arrival and service-time distributions. Illustrations of these and of various queue disciplines are provided. The standard case of the single server with random, bound arrivals is discussed at some length (it is in all four volumes) for various service-time distributions. Many-server and transient behavior have less complete treatment, and the effect of giving one class of arrivals priority in service is touched on. Special techniques for calculation are dealt with in a chapter; the section here on Monte Carlo methods of simulating queuing behavior is particularly welcome. There is also a chapter on "machine interference," the special queuing situation that develops when the "arriving" unit is one of a group of machines which breaks down and must be serviced by a repair crew.

The volume by Riordan is somewhat more mathematically slanted and somewhat more restricted in its subject matter, but it is, perhaps for this reason, very well organized and easy to read. The emphasis is on the applications in telephone systems, though not to the exclusion of other topics. Since the publication of the first paper on queuing theory, A. K. Erlang's paper on telephone traffic congestion, this aspect of the theory has played an important part in its development. Here the system that has no queues is of interest, the arriving calls being lost if the line is busy. Such systems, as well as those systems with queues, are discussed by Riordan. The distribution-in-time of the lost calls is also discussed. Single and multiple-channel service facilities are treated, and different queue disciplines are treated in detail.

The volume by Saaty attempts to cover the whole field and, as a result, is rather uneven and lacks unity. The book is a progress report, with all the virtues and defects of such a work. It is organized in four parts: the first on definitions and basic theory, the second on systems with random arrival and exponential service, the third on other

arrival and service distributions, and the fourth on queue discipline, priorities, and other special cases. The bibliography is extensive.

The work by Takács is at the same time the most mathematical and the most unified logically of the four. It has all the formalisms dear to the mathematicians heart (but to no one else!) and no discussion whatever of the practical implications (or often even of the meaning) of the formulas that fill its pages. Yet I believe it will be a mine of useful technical suggestions for those queuing specialists with sharp picks and strong shovels. It deals in turn with the single-server, then the many-server system, for different arrival and service statistics and with formulas for transient behavior as frequent as with those for steady-state. Telephone traffic problems are treated next, then machine repair, and finally the behavior of electronic radiation counters, devices that also have their congestion problems. Here, we are pleased to see, operations research has begun to repay physics.

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A Productive Compromise

A General Pattern for American Public Higher Education. T. R. McConnell. McGraw-Hill, New York, 1962. xi + 198 pp. $4.95.

Higher education in this country faces rapidly accelerating demands that arise from growth in population, the increasing percentage of college-age youth seeking collegiate education, and society's expanding need for professionally trained specialized manpower. In addition, universities are under mounting pressure to expand their research and technical services to help the nation meet its local, regional, national, and international responsibilities.

What kind of institutional structure for public higher education would best serve these needs? This is the essential question considered in this timely addition to an outstanding series of studies from the University of California's Center for Research in Higher Education at Berkeley, whose chairman, T. R. McConnell, is the author of the present volume.

Two major assumptions underlie McConnell's analysis: first, that the problems created by the rising demand for higher education are not to be solved by making education more selective; second, that the brunt of expanding enrollment will be borne by public rather than private institutions. Although he recognizes the important role of private institutions, McConnell decided to limit this volume to a discussion of the structure of comprehensive, statewide systems of public colleges and universities.

With respect to selectivity, he thinks that, while shortages of facilities and staff might lead to short-range restrictions on admission, the long-run trend will be toward broadening the population base of higher education. Convincingly, McConnell rejects Havighurst's contention in a recent volume that declining occupational demand for people with college education will reduce, and perhaps even reverse, the trend of increasing enrollment. With John Gardner, McConnell believes that American society requires increasingly greater "training in depth"—involving many types and levels of talent—rather than a highly educated elite separated by a great intellectual gulf from "the meagerly educated masses."

The diversity of student attributes and the heterogeneity of social demands would seem logically to call for an appropriate division of labor among institutions of higher education—with universities, 4-year colleges, junior colleges, and technical institutes performing somewhat distinctive functions for typically different kinds of students. Instead, McConnell notes, the trend is toward convergence among institutions, with the 4-year colleges striving to become universities, junior colleges pressing to become 4-year institutions, and technical institutes trying to become comprehensive junior colleges. The striving for higher status in the institutional hierarchy reflects the attitudes and values of students, parents, faculty, and alumni—not to mention the economic and political interests of local and regional groups. The author's account of developments in California emphasizes the power with which such forces oppose plans for the division of responsibility among institutions in a statewide system.

Nevertheless, McConnell believes that the growing shortages of funds and staff, as well as the failure to provide the varied types and levels of education needed to meet the diverse needs of our complex society, will require some form of statewide coordination among public institutions: voluntary coordination, compulsory coordination, or centralized operating control. His preference is for voluntary coordination, which seems to offer the best possibility for "productive compromise" between the values of autonomy (initiative, flexibility, experimentation, the quest for institutional excellence) and those of coordination (economy, improved specialization of function, better correlation between needs and programs).

Although many "state planners" of higher education will not find the evidence, to date, convincing, this view has the great merit of recognizing the dynamic, "dialectical" nature of the process of social change in a democratic society. Somewhere between the chaos of laissez-faire competition and the enervating rigidity of the legislated blueprint, an appropriate pattern for American public higher education will be found; McConnell, in this book, has made a notable contribution toward the identification of its essential character.

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Precursors of a New Era

The Correspondence of Isaac Newton. vol. 3. 1688–1694. H. W. Turnbull, Ed. Published for the Royal Society. Cambridge University Press, New York, 1961. xviii + 445 pp. Illus. $25.

In this third volume of the monumental Newton correspondence, we reach the years 1688 to 1694, when the *Principia* has been published and the hero has entered into his most diversified period. Here are letters from his life as a member of the Convention Parliament, his patient explanations to Samuel Pepys about the mathematical probability of throwing sixes at dice, essays on theology and chemistry, and material related to the famous episode of psychotic delusion when, amongst other things, he accused John Locke of attempting to embroil him with women and to sell him an office. There is perhaps more human interest and less mathematics in this volume than in the preceding two, but when one is dealing with a Newton, even the lesser items may be of the deepest interest.