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 17. H. P. Luhn, "Selective Dissemination of New Scientific Information with the Aid of Electronic Processing Equipment," *International Business Machines Corp. Rept.* (1959).
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 19. I. A. Melchuk, *Computers and Automation* **8**, 23 (1959).
 20. C. Cleverdon, *Aslib Cranfield Research Project*. The report is available from College of Aeronautics, Cranfield, England (September 1960).
 21. In a faceted classification (as distinguished from a hierarchical classification) terms are grouped into categories. B. C. Vickery, in a book entitled *Classification and Indexing in Science* [Academic Press, New York; Butterworths, London; 1959], p. 12], offers the following explanation: "Instead of trying to construct from the 'original universe' one vast tree of knowledge, facet analysis first groups the terms into categories—kind, state, property, reaction, operation, device and so on—and then arranges the terms within each category into the form of a classificatory map." He points out, for example, that within the field of chemistry, "alcohol" is a *kind* of chemical substance, "liquid" is a *state* of that substance, "volatility" is a *property* of it, "combustion" is a *reaction*, "analysis" is an *operation* performed by man, and "burette" is a *device* for carrying out an operation.
 22. J. W. Perry and A. Kent, *Tools for Machine Literature Searching* (Interscience, New York, 1958).
 23. S. R. Raganathan, *Depth Classification* (Indian Library Association, 1953); *Ann. Library Sci.* **5**, 33 (1958).
 24. "The Need for a Faceted Classification as the Basis of All Methods of Information Retrieval," *Library Assoc. Record* **57**, 262 (1955).
 25. J. B. Wiesner, *IBM J. Research and Develop.* **2**, 269 (1958).
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Book Reviews

Arms and Insecurity. A mathematical study of the causes and origins of war. Lewis F. Richardson. Nicholas Rashevsky and Ernesto Trucco, Eds. Boxwood Press, Pittsburgh, Pa.; Quadrangle Books, Chicago, Ill., 1960. xxv + 307 pp. \$10.

Statistics of Deadly Quarrels. Lewis F. Richardson. Quincy Wright and C. C. Lienau, Eds. Boxwood Press, Pittsburgh, Pa.; Quadrangle Books, Chicago, Ill., 1960. xlv + 373 pp. \$12.50.

The English physicist and mathematician Lewis F. Richardson (1881-1953) was engaged for many years on the monumental task of constructing a purely objective, mathematical and physical theory of peace and war. These volumes, previously available only on microfilm, are now submitted to the public substantially as Richardson left them. During the author's lifetime only a small sample of his work in this field was published, but this sample included a notable essay entitled "Generalized foreign politics"

(1939). *Arms and Insecurity* presents in full a model of armament races and wars outlined in this essay; *Statistics of Deadly Quarrels* takes up the problem of war from a different point of view, also adumbrated in short, early publications.

Arms and Insecurity traces the phenomenon of war to the breakdown of international equilibrium, as evidenced by runaway armament races. Richardson works here with an equilibrium model based upon the idea that changes in one power's military spending over a certain period of time are directly proportional to a potential enemy's actual military expenditures during the same period. The system of interacting powers is at equilibrium when the rate of change in spending is zero for each.

The model specifies the conditions under which such a state of equilibrium can be reached. In fact, the functional relationship between the *change* in *A*'s expenditures over time and *B*'s *actual* expenditures is not such that the former must be positive when the latter

is; in other words, it is not the case that *A* is compelled to *increase* his spending as long as *B* spends anything, and vice versa. Rather, the function determining a power's spending differentials contains parameters that can bring the latter down to zero, even when the potential enemy is arming. For example, spending becomes onerous when it rises above a certain level. Having reached that stage, *A* will tend to slow down its armament efforts, and this will have a dampening effect upon *B*'s arming. Richardson postulates, moreover, that the relationship between potential enemies need not be one of pure hostility. While arming against each other, two powers or coalitions can also engage in cooperative activities, such as trade. This will counteract the hostile impulses ("grievances") that induce the powers to arm against each other in the first place. The question in each situation is whether the stimulus for increased spending, that is, spending by the other side, will be sufficiently counterbalanced, by the onerousness of spending and by the prevailing degree of cooperativeness, to result in the stabilization of military expenditures. The volume of trade, serving as a measure of cooperativeness, is crucial in this respect. If it is too small in relation to military spending, the latter will grow to infinity. Such an irreversible trend means war; stabilized military spending means peace.

Richardson's model is deterministic. When the crucial quantities, military spending and trade in particular, show

such and such correlations, war or equilibrium will be the inevitable result. Or rather, the model predicts this inevitable result unless, as Richardson puts it, the policymakers of the powers "stop to think." "Thinking" means, in this context, that the policymakers know Richardson's model and apply their knowledge intelligently, changing certain parameter values under their control so as to avert war.

This type of deterministic model is familiar in applied natural science. One predicts what will "inevitably" happen when certain measurable, variable quantities assume certain values. It is understood, however, that some of the variables are subject to human control. This permits intelligent intervention, steering the course of events in a desired direction. But the deterministic model, as such, yields no prediction whatever about this intelligent intervention itself. In technology, the theory that we work with deals only with phenomena other than our own intelligent, goal-directed decisions. We do not predict what we ourselves will do but only what will happen, depending on whether we do one thing or another.

The *Arms and Insecurity* model attacks the problem of war and peace in this "technological" vein. It yields no predictions about any policymaker's intelligent decisions regarding peace and war. Decisions of this type are envisaged only as a possibility outside the purview of the theory itself. Thus, regardless of whether the model is correct as far as it goes, it cannot be accepted as a theory of peace and war, once it is understood that such a theory must account for meaningful, intelligent war and peace moves. Richardson's theory does not explain war as an institutionalized human activity; nor does it show how political decisions affect the state of equilibrium of a system of interacting powers. It only suggests possible peace policies that have their origin outside the deterministic model with which the theory itself is concerned.

In this connection, Richardson has done fine destructive work on some rationalizations prevalent in political discourse—for example, that a proposed increase in armaments is both necessary and sufficient to maintain peace, and that a proposed increase serves no other purpose than that. His devastating critique of such notions is eminently useful in enforcing honesty in dis-

course, compelling statesmen to admit that peace is not their *only* objective. But once honesty is restored and the existence of objectives other than peace is admitted, thinking about war and peace must go beyond the model of *Arms and Insecurity* with its "technological" orientation.

Richardson himself adopts a radically different approach in his second study, *Statistics of Deadly Quarrels*. Here he treats war as a statistical phenomenon, subsuming it under a broader category, that of the "deadly quarrel": murders, riots, civil disturbances, and the like, as well as large-scale revolutions and wars. Richardson breaks this over-all category into subclasses according to the "magnitude" of quarrels—that is, the logarithm of the number of deaths caused by each—and examines the statistical distribution of the various subclasses.

The basic idea underlying Richardson's statistical treatment of war consists of constructing a framework of equal physical opportunities for fighting and then of finding out from the record whether wars have been "random" occurrences in the sense that the same number of physical opportunities has always been associated with the same frequency of wars in every part of the universe. The implication is that where significant deviations from a uniform frequency are found, one has to assume the presence of some factor specifically related to warlike-ness and peacefulness, respectively.

Richardson's analysis of an enormous collection of data leads to the conclusion that the assumption of randomness indeed represents a good first approximation. At least, he finds no statistical support for hypotheses asserting either a clear-cut temporal trend toward more (or fewer) wars or the existence of few villains, "warlike" nations responsible for a disproportionately large number of wars. Concerning religious and economic factors, his conclusion is also fairly skeptical. Only a relatively small proportion of wars can be traced to economic causes, and while religious differences did lead to more wars between Christians and Moslems than one would have expected on the basis of sheer physical opportunity, the two groups' propensity for fighting each other has not been stable.

Still, Richardson finds enough deviations from a uniform frequency of wars (given equal physical opportunities) to reject the hypothesis of pure

randomness. Thus, he finds that the probability of any nation's going to war goes up when *others* are fighting: fighting is "infectious." On the other hand, governments exert a local "pacifying" influence: with the same physical opportunities for fighting, groups living under the same government are less likely to engage in "deadly quarrels" among themselves than they are to fight outsiders. Richardson considered this to be the most vital conclusion suggested by his statistical study; it pointed to world government as the most promising solution of the problem of war.

Political scientists are apt to find this last revelation vacuous. To them it is axiomatic that the existence of governmental authority extending over a domain means a significant degree of peace and order. The question is not *whether* uncontested governmental authority exerts a pacifying influence but *how* governmental authority is established and maintained, or, respectively, challenged and undermined. In this respect, then, starting from uniform physical opportunities and noting deviations from a random pattern of fighting merely helps us discover something obvious; it does not significantly increase our knowledge of peace and war. Some other parts of Richardson's statistical analysis, however, are extremely instructive; here too, he is most effective in demolishing tendentious political myths, such as that of the "aggressor nations."

The greatest significance of Richardson's work lies not in his conclusions but in his determination to analyze the phenomenon of war purely in terms of objective, factual, measurable data, eschewing all subjective interpretations. Both his industry in collecting a comprehensive array of factual material and his virtuosity in the mathematical treatment of the data are truly stupendous. To be sure, a satisfactory objective treatment of political phenomena, such as war, is not possible as long as we have no mathematical models powerful enough to encompass intelligent behavior in complex real-life situations, and it is not clear, at this point, whether such models can be constructed. But in any case, it is desirable to develop the objective approach as far as possible, and Richardson's monumental work is an important landmark in this quest.

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