

**A RAND NOTE**

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RAND, 1968–1988**

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**April 1989**

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## Operations Research and Policy Analysis at RAND, 1968-1988

By Louis Miller, Gene Fisher,  
Warren Walker, and Charles Wolf\*

This paper discusses the development of policy analysis at The RAND Corporation over the last two decades. When this period began, two changes were under way bearing on the practice of operations research (OR), management science (MS), and policy analysis at RAND. First, RAND's client base expanded. RAND, initially solely an Air Force resource, decided to devote a portion of its effort to nondefense research. As a consequence, RAND undertook a number of ambitious, complex and "messy" policy projects addressing nonmilitary issues.

The second development was a reduced emphasis on "hard" technology, and increased attention to behavioral considerations in higher-level policy analysis. This had a marked effect on the practice of OR and MS at RAND. In its early years, RAND played a prominent role in the development of OR mathematical paradigms. During its first two decades, RAND significantly advanced a surprising number of topics now found in standard OR textbooks (e.g., mathematical and dynamic programming, game theory, inventory theory, simulation, and decision analysis). By the 1960s, fundamental research in these topics became well-established in universities and other centers, and RAND's activities turned toward broader policy analysis.

The following account forgoes a chronology of events, focusing instead on two related themes: The section

"Views of Problems" categorizes reasons why RAND analysts increased the complexity of their projects; the section "Analytic Schemes" relates some of the methodological innovations brought to bear on the resulting problems. Both sections refer to specific projects, but the examples are only illustrative and by no means constitute a complete inventory. The next section, "Formal Education in Policy Analysis", describes the RAND Graduate School's interdisciplinary Ph.D. program in policy analysis.

We begin with a brief introduction on RAND itself.

### **RAND and Its Mission**

RAND supplies information to improve the quality of decisions and policy choices. It endeavors to address problems of national significance and to reach individuals at high levels of responsibility. RAND is nonprofit, does no proprietary work for the private sector, and its national security projects are carried out under Federally Funded Research and Development Center (FFRDC) status. RAND is not a consulting firm. These circumstances permit RAND to set quality and objectivity as its major objectives.

Instead of having a profit motive, RAND is concerned about using public funds wisely. The FFRDC arrangement allows us to make long-term commitments to important research, to have considerable influence in determining topics and directions, and to

report findings that may not always please our clients. RAND's unclassified work is in the public domain, and wide dissemination of its research is an important corporate objective.

### **Views of Problems**

Supporting high-level decisions has meant enlarging the ways in which problems are viewed.

*More meaningful criteria.* As the level of decision making escalates, often so does the difficulty of specifying appropriate operational criteria. RAND research to improve logistics operations in the United States Air Force is an example of implementing continually improved criteria. The pioneering METRIC (Multi-Echelon Technique for Recoverable Item Control)<sup>1</sup> model of the mid 1960s, which computed stock levels of items, focused on common measures of supply system performance such as backorders and fill rates. While, in general, the fewer backorders the better, the mission-capable status of squadrons is more pertinent. Therefore, this is the measure used in later developments such as the Dyna-METRIC<sup>2</sup> model, which allows the driving parameters to vary with time in recognition that wars are not steady state.

*Broadening the context.* Over time, RAND analysts enlarged boundaries by taking account of political, economic, sociological, psychological, organizational and distributional considerations in research design. What in earlier studies would have been taken

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\*The authors are senior staff members of the RAND Corporation.

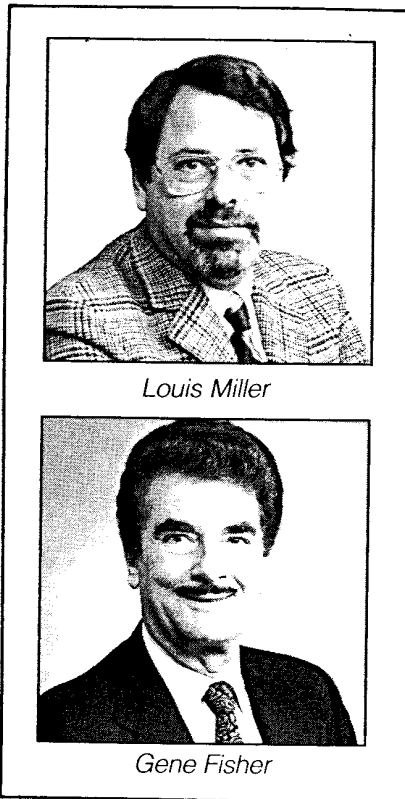
as fixed or given were now regarded as variables to be manipulated. As a consequence, a wider range of outcomes is considered.

A good example from the mid 1970s is the Policy Analysis of the Oosterschelde (POLANO)<sup>3</sup>, a comprehensive examination of alternative ways to protect a Dutch estuary from floods. This work contributed to the selection and design of the enormous storm-surge barrier that the Dutch recently completed in south western Netherlands. The analysis dealt with impacts of the alternatives on flood security, ecology, the fishing and shipping industries, and recreation, as well as the public budgets and the economy.

One of RAND's most dramatic efforts to broaden the context of policy analysis was the establishment and operation of the New York City-RAND Institute (NYCRI)<sup>4</sup>, a joint venture between RAND and the New York City government, from 1968 to 1975. The institute's work focused on the problems of particular city agencies—e.g., the Fire Department and Health Services Administration, while considering the numerous interest groups in the city (including labor unions), and addressing questions of political feasibility and implementation in its analyses. In addition to operations researchers, the institute's staff included city planners, sociologists, engineers and lawyers.

*Multiple objectives.* One consequence of broadened contexts is an expanded set of criteria to reflect multiple objectives. For example, the Short-Haul Transportation R&D Study (STAR Project)<sup>5</sup> in the early 1970s examined the costs and benefits of advanced transportation systems, including STOL, VTOL, tracked air-cushion land vehicles, and autotrains. Alternative mixes of modes were evaluated not only in terms of travel time and dollar costs, but also impacts on air quality, noise pollution, and distributional effects on various income and ethnic groups.

A fascinating example of multiple objectives arose in the early 1970s when RAND was asked to look at the



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interface between operations and maintenance at Strategic Air Command bases. The operations organization and the maintenance organization, each tending to focus on separate objectives, had to negotiate mutually acceptable sets of interacting schedules. An in-depth examination revealed dozens of performance dimensions that had to be considered.

Because algorithmic optimization appeared unworkable, the solution proposed was a heuristic scheduling system whereby the two organizations could view schedules constructed by a computer and adjust the schedule rules according to value judgments. A prototype was constructed that contained many ideas included in what we now call decision support systems and rule-based systems. Unfortunately, the system, called DOSS (Decision Oriented Scheduling System), was not adopted because it required an economical source of interactive computing, which was not then available.

*Enlarging the number of alternatives.* The PAWN project<sup>6,7</sup> completed in the

early 1980s was a comprehensive policy analysis of water management in the Netherlands. It addressed four broad classes of problems: shortage, salinity, quality, and flooding. To organize alternatives, the analysts introduced a hierarchical taxonomy. A tactic was defined as a single action such as building a canal, taxing a particular use, or changing a facility's operating rules. There were four kinds of tactics: technical, managerial, pricing, and regulation. A combination of tactics (such as regulations on water use or discharge) was called a *strategy*. A *policy* was defined as a particular combination of strategies.

*Recognizing uncertainty.* Many RAND studies have dealt with uncertainties that could not be associated with specified probabilities. This is true, for example, in military logistics. Obviously, planning for wartime operations is highly uncertain. But even peacetime operations are sufficiently uncertain that standard modeling approaches are of limited usefulness. Inventory models, which would seem applicable to logistics problems, start with the assumption that one can specify probability distributions for demands of items. But when one observes zero demand for an item over eight months followed by 23 demands in a week, what does one say about demand distribution?

The POLANO study represented a different kind of uncertainty. The Dutch government specified that the barrier should protect against storm surges of such intensity that they would be exceeded only once in 400 years. Since storm data had been collected for only a century or so, estimating the intensity of a once-in-400-year storm posed a considerable challenge.

### Analytic Schemes

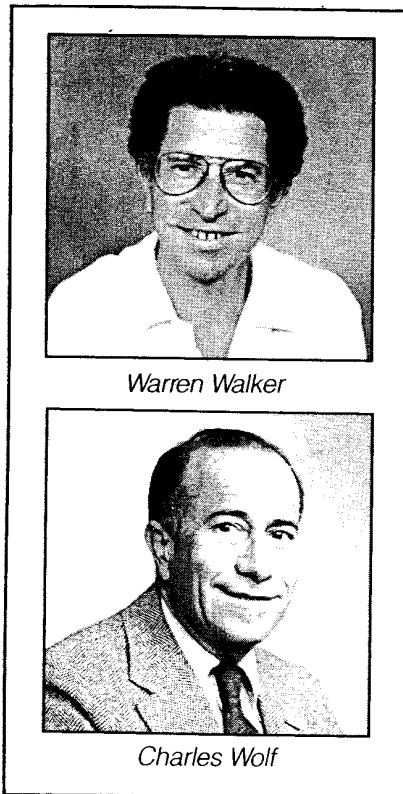
The vast literature of OR and MS abounds with elegant theory and neat solutions for isolated problems. But much of this material is of limited usefulness for real-world problems. This section recounts some ways in which RAND analysts have tried to

meet the challenges of expanded views.

*Complexes of models.* As a rule, no single model is capable of representing more than a few situational aspects. An attempt to construct a large comprehensive model would probably break down before the model were even built; if it were finished, it would probably be too costly and time-consuming to use and would defy attempts to understand the results. As an alternative, RAND analysts constructed collections of relatively small and simple models linked together by data; the models could be used separately or in combination, depending on the part of the problem being investigated.

Frequently, sequences of models are employed to evaluate alternatives. One example is the Army Logistics Assessment - Extended (ALA-X)<sup>8</sup> development to support high level, long term budgeting decisions. The model complex consists of many "logistics functional models," implemented as spread sheets, that relate expenditures on logistics resources to abilities to carry out logistics functions, such as amounts of ammunition moved per day. To relate such abilities to more pertinent criteria, the outputs of the functional models are used in the "Logistics Decision Model" (LDM), which, given a scenario, estimates combat outcomes such as weapons engaged, resources consumed and destroyed, and movement of the front lines. Similarly, sequences of perhaps five models have been used to evaluate mixes of weapons systems in terms of meaningful battle outcomes.

*Repro-modeling.* Even when analysts have a valid model, it may be too slow and clumsy to be useful when exploring a great many alternatives. An important idea in policy analysis is to create a simple, fast model that mimics or reproduces the outcomes from the original. This "repro-model" is scaled from runs of the original. Although missing some detail and sensitivities, the repro-model is adequate for assessing policies. The "Logistics Decision Model" mentioned above is an exam-



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ple. The original is a very large, complex Army model called FORCEM (Force Employment). The LDM, on the other hand, runs quickly on a microcomputer.

*Structuring analysis.* Complex policy analyses require carefully designed frameworks that reflect an overall research strategy. This is partly achieved by designing a coherent set of models that usefully relate to one another. Another important aspect is the screening of alternatives. To make an in-depth analysis of the costs, benefits, and risks of each of many tactics would be impossible if not done systematically. In RAND work on overseas bases, the screening was accompanied by comparing a range of alternative base locations in terms of the costs and military effectiveness of relocating the operational functions that the existent bases perform.

*Scorecards.* Cost-benefit analysis and decision analysis are traditional methods for dealing with multi-criteria decision studies that try to aggregate

many consequences into a single index. RAND analysts, however, have been uncomfortable with such techniques, particularly in questions of public policy where the policy choices are made through a political process involving many heterogeneous stakeholders. (The notion that there exists a single identifiable decision maker may be the greatest fallacy held in the fields of OR and MS.)

To present and compare various alternatives' consequences, a number of RAND studies have employed a "scorecard"<sup>9</sup>. Consequence values (numbers or words) are summarized as entries in a table, each row representing one consequence and each column representing a policy alternative. Entries are colored or shaded to indicate each alternative's ranking for a particular consequence: best, worst, or intermediate. Experience has shown that stakeholders quickly grasp the idea and find it helpful in recognizing patterns and trading off disparate consequences.

*Dealing with uncertainty.* Because denial of uncertainty seems to be a part of human nature, analysts have a special obligation to deal with uncertainty. RAND analysts give it major emphasis through several methods. One is the extensive and judicious use of sensitivity analysis, in both military and non-military RAND studies, to determine which uncertainties really matter.

When sources and consequences of uncertainty are identified, research can be undertaken to reduce important areas of uncertainty, provide hedges, and preserve options. In recent logistics work, RAND developed recommendations that de-emphasize forecasting in favor of systems, organizations and planning that stress flexibility and responsiveness—recommendations such as intelligent prioritization of repairs and adaptable transportation instead of costly stockpiles of parts.

*Simulation and gaming.* RAND has a long history of involvement in simulation and gaming, early highlights

being the creation of the SIMSCRIPT programming language and the "Logistics Problem" exercises in the 1950s and early 1960s. These are still important vehicles for analysis, and RAND is currently engaged in research to advance methodology.

The largest undertaking is the RAND Strategy Assessment System (RSAS)<sup>10</sup>. This endeavor has developed a new framework for strategic analysis that seeks to combine many of the subtle, nonquantitative aspects of human war gaming with the efficiency, rigor, and reproducibility of analytic modeling. The RSAS provides a structure and tools for analyzing strategic decisions at the national command level and, at the same time, provides the capability for addressing operational-level issues. An interesting aspect is that the RSAS provides great flexibility in choosing which roles are to be played by people and which by machines. The RSAS is operational, and an effort is under way to strip away

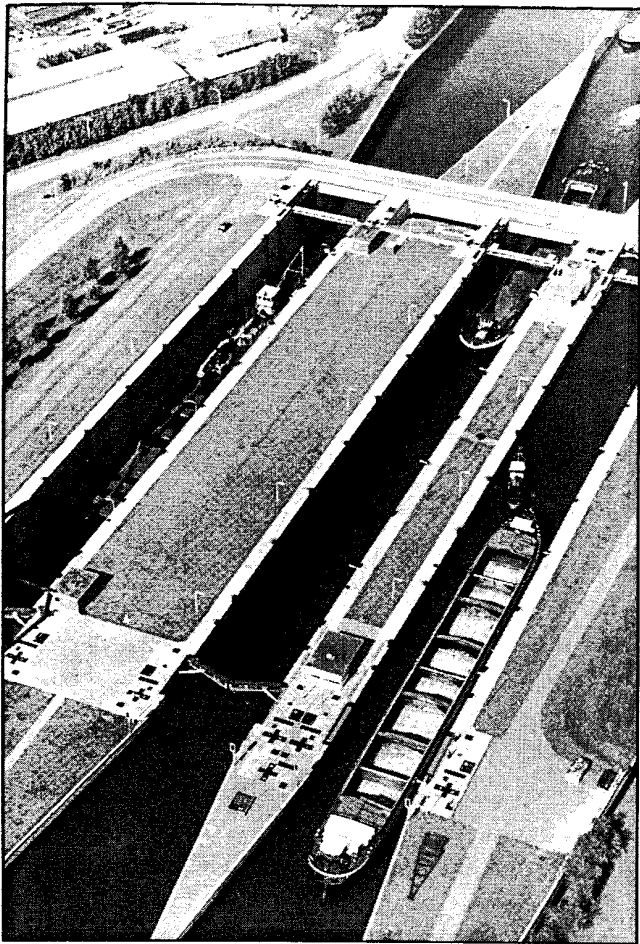
the domain-specific components to provide an instrument useful in other kinds of research.

*Mathematics.* Thus far we have not mentioned any specific mathematical developments, which to some is the essence of OR. RAND retains an interest in this capability. A most important development has been the SAGE (Sequential Analytic Game Evaluation) algorithm<sup>11</sup>, which finds strategies for the allocation of resources in a conflict when the objective of both sides is to "win" on some measure of merit. An application might be allocation of various kinds of aircraft to differing classes of targets day by day in a 30-day conflict. Although the idea of such a sequential, game theoretical model is not new, until SAGE no one had developed a computationally tractable method for its solution. Used in complexes with other models, SAGE provides RAND with a unique ability to analyze important conflict situations.

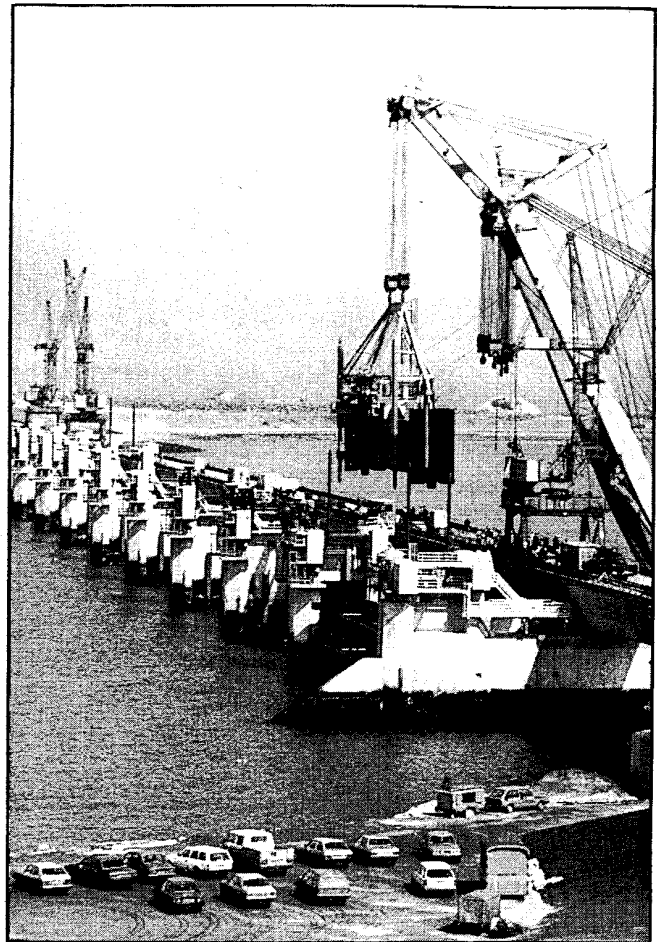
*RAND-Sponsored Research.* Earnings from RAND's endowment fund allow RAND to develop important research themes and innovative ideas, apart from contract funding. A current example began with the recognition that dealing with AIDS presents a set of public policy issues of immense importance. Thorough, epidemiological understanding of the dynamics of HIV-1 and related viruses is central to all sound AIDS strategies, projections and policies. All point projections of the cumulative caseload 4 to 5 years out must be treated with skepticism, and the need for prompt analysis is evident.

Proceeding on this premise, RAND has supported more than a year of intensive work on a computer-based mathematical model that now supplies the most revealing perspective available on the complex process by which the infection is spread. It can be used to identify alternative scenarios, estimate the effects of medical or policy inter-





For The Netherlands' PAWN locks project, RAND analysts needed to address four problem areas—shortage, salinity, quality and flooding. To do so, Rand introduced a hierarchical taxonomy to organize alternatives. The project was completed in the early 80s.



RAND did extensive analyses dealing with alternatives on flood security, ecology, the fishing and shipping industries, recreation, budgets and the economy for The Netherlands' POLANO project. The now-completed project protects a Dutch estuary from floods through the use of enormous storm-surge barriers.

ventions, make more reliable cost estimates, anticipate future resource requirements, and more. Although this work illuminates the mechanisms of spread, it also underscores the importance of specific parameters in understanding the epidemic, and the vast uncertainty surrounding the future proportions of the problem.

### Formal Education in Policy Analysis

Advanced training of RAND staff members was always an important by-product of RAND research. Often the by-product was as influential as the particular projects themselves because staff members moved from RAND to other venues—in government, universities, or other research organizations—where the added analytic expertise acquired at RAND had further and multiple effects.

In its first decades RAND was

sometimes described as a graduate school without students. Staff members acquired additional skills in the course of their research. Some thought this was an ideal situation: the advantages of a university environment without its drawbacks. Others thought the extra stimulus that would be provided by bright and questioning graduate students from outside RAND would be beneficial. In 1970, after a year-long internal study, RAND embarked on a formal Ph.D.-awarding educational program in policy analysis, embodied in the RAND Graduate Institute (subsequently renamed the RAND Graduate School). The reasons for this innovation were numerous: a perceived national need for advanced interdisciplinary training in analytic methods which the institution was well-equipped to provide; strong staff interest in teaching; a sense of purposeful

challenge; and growing management support.

The RGS curriculum, like RAND itself, is highly interdisciplinary. The core curriculum is built around four required areas: *quantitative methods*, including statistics and data analysis, OR, decision analysis, and econometrics; *micro- and macro-economics*; *social science*, including social science methods and perspectives, organization theory and behavior; and *technology*. Finally, the RGS offers subspecializations in health policy, Soviet studies, and national security policy.

Currently, RGS has approximately 65 graduate students and has conferred a total of 63 doctoral degrees in policy analysis. Commenting on the RAND Graduate School in 1985, a report by the Carnegie Foundation for the Advancement of Education observed:

“The RAND Ph.D. is [an] example

of high level academic work given by a corporation...it is an integral part of the parent company although autonomous in setting its standards and curricular program. The RAND Graduate Institute (School) presents a relatively rare opportunity in this country on the Ph.D. level; just three other comparable schools of public policy exist—at Berkeley, Harvard and

Carnegie Mellon... More research universities could well take up the challenge of relating various fields of study with new tools and techniques of analysis to the multi-disciplinary problems confronting all societies."

### Conclusion

This brief sketch of RAND's activities in OR, MS, and policy analy-

sis over the past two decades has emphasized research as well as educational efforts that deal with complicated policy issues. Common to these projects has been a movement toward interdisciplinary methods and broader problems, as well as a willingness to forgo mathematical elegance and precise optimization to deal with more pressing and more complex real-world issues. □

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