REPORT ON ACTIVITIES TO THE NATO ADVISORY PANEL ON OPERATIONS RESEARCH

David S. Stoller

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PREFACE

This paper covers the activities of the author while under appointment as a Consultant in Operations Research by the NATO Advisory Panel on Operations Research, and as a Visiting Professor at the University of Rome, 1961-62.

The information was prepared at the request of the NATO Scientific Affairs Division and is primarily intended for distribution to NATO offices and agencies and to offices and agencies of governments which are NATO members.

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1961-62

I. INTRODUCTION

This paper covers the author's activities during his period of appointment as a Consultant in Operations Research, NATO Advisory Panel on Operations Research, chaired by Professor Philip M. Morse, Massachusetts Institute of Technology. Permission to accept the appointment was granted by The RAND Corporation, and in particular by Dr. Charles J. Zwick, Head, Logistics Department of RAND. The location of the assignment was Rome, Italy. The program coordinator for Italy on behalf of the Advisory Panel on Operations Research was Professor Giuseppe Pompilj, University of Rome; the program coordinator on behalf of the Italian Government was Professor Benedetto Barberi, Director-General of the Bureau of Statistics.** The point of contact

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*Any views expressed in this paper are those of the author. They should not be interpreted as reflecting the views of The RAND Corporation or the official opinion or policy of any of its governmental or private research sponsors. Papers are reproduced by The RAND Corporation as a courtesy to members of its staff.

**This organization's exact name is: Istituto Centrale di Statistica, and the official abbreviation is ISTAT.

in NATO Headquarters was Dr. John Rothberg, Scientific Affairs Division, and later, Dr. Enzo Aparo, of the same office.

The goal of the program of Consultants in Operations Research established by the Advisory Panel is the stimulation of growth in Operations Research capabilities in the NATO countries. My mission was to work toward this end primarily in Italy, but also in other countries as deemed appropriate. By consultations with Professors Morse, Pompilj, and Barberi, it appeared that my mission would best be served by pursuing the following activities:

1. Establish a course in Operations Research Methods at the University of Rome.

2. Advise military and non-military governmental organizations on Operations Research studies.

3. Participate in professional activities with Operations Research colleagues in all sectors.

4. Stimulate an interest in Operations Research technology in industrial sectors.

5. Participate in NATO conferences directly concerned with or pertinent to Operations Research technology.

6. Give occasional lectures and talks on Operations Research topics in other parts of Italy and in other NATO countries.

7. Continue an appropriate amount of activity in scientific professional societies, both national and international.

II. INITIAL PHASE

Together with the other two appointees in the program, Professor Maurice Sasieni, Case Institute of Technology, Cleveland, Ohio, and Dr. Erwin Baumgarten, Operations Evaluation Group, U. S. Navy, I participated in an orientation program established by Professor Morse. This consisted of briefings by and discussions with Professor Morse and personnel of the office of the Director of Defense Research and Engineering, Department of Defense; Weapon Systems Evaluation Group, Department of Defense; Operations Evaluation Group, Department of the Navy; and Operations Research Center, Massachusetts Institute of Technology. This served to acquaint us to some degree with the working environment and technical problem areas pertinent to our respective assignments.

En route to Italy, I was able to obtain further guidance from Professor Bernard Koopman and Dr. Emory Ellis of the Operations Research Liaison Office, U. S. Embassy, London. During this period I also obtained welcome advice on Operations Research educational needs from Dr. A. Melbye, Head of the Operations Research Group of the Danish Computing Center, and from Professor H. Kunzi, and staff, of the Operations Research Institute, University of Zurich.

III. THE 1961 NATO COURSE IN OPERATIONS RESEARCH, VENICE, ITALY

Prior to establishing residence at the University of Rome, I participated as an instructor in the 1961 NATO Course in Operations Research, Venice, Italy, July 31 - August 11. The staff for the course was as follows:

Professor Bernard Koopman, Columbia University (U.S.)
Course Director and lecturer on search operations

Professor Giuseppe Pompilj, University of Rome (Italy)
Administrative Director

Dr. Pierre Rosenstiehl, C.I.R.O. (Interservice Operations Research Center) (France)

M. Charles Salzmann, C.F.R.O. (French Operations Research Center) (France)
Lecturer on Operations Research case studies

Dr. David Stoller, NATO (U.S.)
Lecturer on decisions, gaming, and queuing

Dr. Steven Vajda, Admiralty Research Laboratory (U.K.)
Lecturer on linear programming

A description of my contribution to this training program is given in Appendix A.

My participation in this course also served as a means of becoming acquainted with several of my future associates in the Italian military, governmental, industrial, and educational areas, who were attending the course either as observers or students.

Subsequent to the Venice course, Professor Pompilj and I attended a meeting of the International Statistical Institute, Paris. Also, I read a paper in Operations Research to a meeting of The Institute of Management Sciences, Brussels. The paper was entitled, "On the

Determination of Occupational Categories in an Organization."* An abstract of this paper is given in Appendix B.

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*D. S. Stoller, On the Determination of Occupational Categories in an Organization, The RAND Corporation, P-2362, June 27, 1961.

IV. INSTRUCTION AT THE UNIVERSITY OF ROME

A major activity for me while in residence at the University of Rome was to create a one-year course of graduate instruction in the subject matter of "Methods of Operations Research." This, together with the courses in Probability, Statistics, and Stochastic Processes offered in the Faculty of Statistics by Professor Giuseppe Pompilj and colleagues, constituted a foundation upon which to build a future curriculum in Operations Research.*

Although it is inevitable that a great deal of mathematical context is needed to develop such a course, I endeavored to emphasize the principle that Operations Research is concerned with application of scientific methods to the study of operations--governmental, military, or industrial. Topics covered included: History of Operations Research, characteristics of Operations Research problems, models of military operations, queuing theory and applications, game theory and applications, linear programming, and decision theory and applications. The instruction was in Italian, somewhat labored at first, but readily decipherable by the students later on.

The minimum prerequisites for the students in my course were roughly the equivalent of first year graduate status at an American university. Professor Pompilj and I made every effort to encourage enrollment by those students who perhaps did not meet this requirement formally, but who had equivalent mixed backgrounds, such as educational

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*By fortuitous circumstance. Professor Herman Chernoff of Stanford University (U.S.) spent a portion of his sabbatical year on the Faculty of Statistics of the University of Rome and offered a few lectures in Decision Theory which further strengthened the curriculum in Operations Research.

and industrial research experience, etc. Initially, there were 31 students enrolled. The healthy diversity of interests that one would hope for in the Operations Research field is indicated by the classifications below:

Classification of students by academic degree (or field of specialization)	
Statistics and Mathematics	12
Social Sciences	7
Military Sciences	5
Miscellaneous	7
Total	31

Classification of students by national sectors	
University*	20
Military	5
Governmental agencies, exclusive of military	4
Industry**	2
Total	31

Attendance throughout the year did not equal the original enrollment, of course, but the average attendance was ten to fifteen. (In June 1962 only five zealots were present.) Because new courses cannot be taken for credit, the occurrence of examination periods in other courses had a marked influence on the attendance in my course, especially in June 1962. The fact that only certain courses are accredited for degree work has had a deleterious effect not only on

*This category includes both those who in the near future would take jobs in the other three categories and those who either were in permanent academic careers, or intended to be.

**The Rome area does not possess the kind of heavy industrial complex from which many graduate students interested in industrial Operations Research could be drawn.

the efforts of Professor Pompilj and his colleagues to establish an Operations Research curriculum at the University but indeed hampers the introduction of recent developments in every field of knowledge.

Frequent out-of-classroom guidance for individual students occurred, and since included among the students were personnel from the military Operations Research organizations, this served to meet a part of the goal of serving these organizations in an advisory capacity.

My lecture notes were assembled, edited, and published by the University of Rome in paperback binding under the title: I Metodi della Ricerca Operativa. (Also included were some of Professor Chernoff's lectures in Decision Theory.) A description of the contents is given in Appendix C. At this point it is appropriate to acknowledge the valuable assistance of Dr. Franca Baldessari, without whose labors the lectures would never have been printable.

V. CONSULTING AND ADVISING, ROME AREA

Throughout the year I participated in study group meetings pertaining to some of the Operations Research studies in which the Bureau of Statistics (ISTAT) was a participating organization, as deemed appropriate by Professor Benedetto Barberi, the Director General. The scope of these meetings ranged from the preliminary discussions of problem areas to the detailed considerations of analysis and recommendations for future lines of investigation. Frequent contact was made with the military Operations Research offices headed by:

Lieutenant Colonel Enrico della Rocca
Defense Headquarters

Colonel Cesare Pavoni
Army Headquarters

Commander Walter Bisi
Navy Headquarters

Major Antonio Cimaglia
Air Force Headquarters

In particular, Captain Bruno Mazzurini, the chief of the Statistics Division of Navy Headquarters, to which the Navy Headquarters Operations Research Office reported, took frequent and personal interest in such contacts. The scope of these contacts ranged from discussions of the role of Operations Research in military organizations and the selection of personnel for such work, to detailed discussions of problem structure. The discussions of problem structure were confined to technical considerations of methods of analysis.

Frequent discussions of Operations Research methods occurred by the "out-of-class" contacts discussed on page 8, since personnel from the military Operations Research offices were also students in my class

at the University of Rome. Further collaboration with the Navy Operations Research Office and colleagues from the Bureau of Statistics (ISTAT) occurred in the problem method area of search theory. A description of the problem method area investigated is given in Appendix D.

I was invited to participate in meetings of the Regional Planning Study Group of the Institute of Regional Planning, a national professional society devoted to the study of the improvement and optimization of industrial plant location, housing development, transportation networks, and related aspects of metropolitan regions and other integrated regions. Another advisory activity in which I participated was that of consultant to the Advisory Committee on Rome Area Traffic Studies.* The membership of this committee was drawn from the University of Rome, the Bureau of Statistics (ISTAT), and the Automobile Club of Italy (ACI). During the period of my participation, the Advisory Committee completed a survey study on the problem definition and methods of attack. This study was published by the Automobile Club of Italy under the title: Il Problema del Traffico Nell'Area di Roma. (The table of contents of this study is summarized in Appendix E.) A proposal to establish a Rome Area Traffic Study Group was formally submitted to the municipal and regional governmental agencies which had requested the formation of the Advisory Committee.

At the end of the academic year, I assisted Professor Pompilj and Professor Sylvos-Labini, the latter of the Faculty of Economics,

*This committee was chaired by Professor Pompilj of the University of Rome and guided by Professor Barberi, Director General of ISTAT, and Dr. Mungo, Secretary General of ACI.

University of Rome, in formulating a tentative curriculum for the guidance of students who wish to specialize in Operations Research. A working paper version of this curriculum is given in Appendix F.

Pertinent to the activities reported upon in this section was a discussion between myself and the Honorable Franco Malfatti, Chamber of Deputies (Italy). This meeting took place in Los Angeles just prior to my departure for Italy, and the subject matter under discussion was the interrelationship of science and national policy. A part of this discussion was devoted to the impact on national policy and vice versa of the scientific discipline of Operations Research.

VI. PARTICIPATION IN PROFESSIONAL ACTIVITIES WITH ITALIAN OPERATIONS RESEARCH COLLEAGUES

During my period of appointment, AIRO, the Italian Operations Research Association (Associazione Italiana di Ricerca Operativa), held its inaugural meeting at the Torino Industrial Association Building, Torino, on December 11 and 12, 1961 and elected the following officers:

President	Professor Benedetto Barberi, ISTAT
Vice President	Dr. Augusto Bargoni, Torino Industrial Association
Vice President	Professor Giuseppe Pompilj, University of Rome

My Italian colleagues did me the honor of inviting me to read a paper at this historic occasion. The title of the paper was "An Industrial Application of Queuing Theory." (An abstract of this paper is given in Appendix G.) Papers read at the meeting covered a wide variety of topics: Operations Research in government, in business administration; airline operations; agricultural planning; the aircraft and electrical industries; steel and petroleum industries; studies of human ecology; sales planning; inventory theory; graph theory; data systems; traffic flow; and naval port operations.

Professor Barberi, the President of AIRO, very courteously invited me to participate directly in the business meeting as well as the technical meeting and to present to the AIRO membership some of the organizational experiences of the Operations Research Society of America (ORSA). I briefly traced the history of ORSA. At the same time I took this opportunity to indicate that AIRO would very likely

experience a rapid growth in membership and would therefore be faced with the problem of establishing qualifications for membership and also would be faced with all of the problems of operating a large professional organization in contra-distinction to the present ease with which, with their present membership of seventy, they could pass on membership applications, transact business, and make decisions.

From the point of view of inter-disciplinary balance, the present membership of AIRO has done very well: physicists, engineers, mathematicians, statisticians, economists, etc. From the point of view of the geographical distribution of members, it would seem that more interest needs to be generated in the heavily industrialized areas in the north of Italy which are potentially capable of supplying a great many more members to AIRO. The new Italian Operations Research Association is receiving strong support from significant sectors of the economy through institutional memberships, a list of which is given in Appendix H.

Also during my residence at the University of Rome, I served on an interim basis as Editor for Italy for the International Abstracts in Operations Research, published by the International Federation of Operations Research Societies, while AIRO members were in the process of organizing their society and affiliating it with IFORS.

VII. PARTICIPATION IN NATO ACTIVITIES LOCATED IN ITALY

Throughout the year I was in frequent contact with Colonel Norman Locksley, U.S. Army, Head of the Planning Office, Headquarters Allied Forces Southern Europe, Naples. With the assistance of Professor Philip Morse, Chairman, Advisory Panel for Operations Research, NATO, and by the courteous invitation of Admiral J. Russell, U.S. Navy, Commander-in-Chief, Allied Forces Southern Europe, Colonel Locksley and I organized a two-day Conference in Military Operations Research, held for the benefit of the NATO officers at Headquarters AFSE, on June 26 and 27, 1962. Major General J. Seitz, U.S. Army, Headquarters AFSE, Major General E. Pistotti, Italian Army, Headquarters AFSE, and Colonel Norman Locksley, U.S. Army, Headquarters AFSE spoke to and participated in the Conference. The valuable contributions to the success of the Conference of the individuals and organizations listed below cannot be over-emphasized:

Captain Robert Jeffery, U.S. Navy, Anti-Submarine Warfare Research Center, La Spezia, Italy

Professor Bernard Koopman, U.S., Weapons System Evaluation Group, Department of Defense

Dr. George Lindsey, Canada, Anti-Submarine Warfare Research Center, La Spezia, Italy

Dr. Kenneth Yudowitch, U.S., Research Analysis Corporation

The program of the Conference is given in Appendix I.

By courteous invitation of Captain Jeffery and Dr. Lindsey of the Anti-Submarine Warfare Research Center, I read a paper entitled "Statistics and Decisions in Operations Research" to the research staff of that organization. Professor Pompilj and I were also invited

at that time to participate in an Ad Hoc Advisory Committee meeting to discuss the Operations Research program at the Center.

I was appointed a delegate to the NATO Conference on Education in Operations Research held in Venice, Italy and participated in the deliberations there. Sufficient comment has been made in the report by Dr. M. Sasieni, NATO Consultant in Operations Research in Oslo, to which I would like to add one more comment as follows: There seemed to be some unnecessary confusion on the part of the discussants between the desirability of discussing the content of Operations Research training curricula, which I would deem highly desirable, and the concept of establishing a standard curriculum in the training of operations research, which I would deem relatively undesirable. It seemed to me that the contention of some of the discussants that each institution should feel free to develop its own form of curriculum was phrased in terms of a <u>non sequitur</u> that institutions should not even attempt to find points of agreement about the contents of curricula in Operations Research.

VIII. OCCASIONAL LECTURES AND TALKS ON OPERATIONS RESEARCH TOPICS

Through the courteous invitation of Ing. Ezio Camatini I gave a few lectures at the Institute for Advanced Study of Petroleum Technology (Scuola di Studi Superiori Sugli Idrocarburi), Milano. The lectures were entitled "Theory and Applications of Waiting Lines." These lectures were open to the technical public and drew an audience of about thirty research and administrative personnel from various industrial organizations in the Milano area. Opportunity was given to the listeners to avail themselves of individual consultation; several Operations Research problems of interest to the individual members of the audience were discussed in detail.

I submitted a paper entitled "La Ricerca Operativa Sussidio all 'Atto delle Decisione" (Operations Research as an Aid to Decision-Making) to the journal Scuola in Azione, and it was accepted for publication.

To the degree feasible I visited a number of my Italian colleagues in Operations Research for the purpose of learning about the Operations Research problem areas of interest to them, in such organizations as Olivetti, FINSIDER, Edisonvolta, FIAT, etc. Also on occasion I provided liaison for contacts with the Italian military Operations Research officers for the Operations Research Liaison Office, U.S. Embassy, London. (This only repaid in very small measure the support of the Consultant Program made available by Dr. Emory Ellis of the Operations Research Liaison Office during the year.)

IX. PARTICIPATION IN GREEK OPERATIONS RESEARCH ACTIVITIES

The Ministries of Defense and of Coordination of the Greek Government invited me to deliver a series of lectures on Operations Research in Athens. The arrangements leading to this invitation were made by Professor Pompilj of the University of Rome on behalf of the Advisory Panel for Operations Research, Professor E. Steriotis of the University of Athens, Mr. Stavrianopoulos, the Director of Technical Assistance, Greek Ministry of Coordination, and Colonel Kozonis of the Greek National Defense General Staff. Orientation material prior to my visit was provided by Lieutenant Colonel Donald P. André, U.S. Air Force, of the NATO Advisory Group for Aeronautical Research and Development.

Lectures were given at the Athens Institute of Technology to an audience of forty to fifty listeners drawn from many different governmental, military, educational and industrial organizations. The intent of the lectures was to demonstrate the nature of Operations Research problems and indicate usefulness of such methods--the lectures were not intended to provide instruction in methods. In addition to the lectures, conferences with individuals in small groups were arranged.

I discussed with General Spanogiannakis, Greek Army (Retired), the role that an Operations Research program could play in augmenting the capabilities of the various sectors of Greek economy and in particular, the military.

At the invitation of Professor A. Pappas of the Athens Institute of Technology, I met with him and a small group of university and

industrial people for an informal discussion of the fields of application of Operations Research methods.

Colonel Kozonis of the Greek National Defense General Staff invited me to his office to discuss with him and Major Dokas the problems associated with organizing a military Operations Research team.

In addition there were many other brief discussions with individual members of the audience. An abridged version of my lectures was sent to Professor Steriotis for translation into Greek and dissemination to the audience.

X. OTHER OPERATIONS RESEARCH ACTIVITIES OUTSIDE OF ITALY

By invitation of Dr. William Nierenberg, Assistant Secretary General for Scientific Affairs, NATO, I attended the NATO War Games Symposium in Paris, November 1961, and at that conference I read a paper entitled "An Example of a Logistics Game."

By invitation of Professor Henry Goertler, University of Freiburg; Professor Martin Beckmann, University of Bonn; and Professor Guenter Menges, University of Saarland, I gave guest lectures on the topic of "An Operations Research Application of Queuing Theory" at the abovementioned universities.

By arrangement with Dr. E. Baumgarten, the NATO Consultant in Operations Research assigned to Bonn, I met with some of the German Ministry of Defense officials, including Ministerialrat J. Luetzow, Ministerialdirigent T. Benecke, and Mr. K. Kaufmann, whose responsibilities were directly or peripherally concerned with Operations Research methods.

Also during this period I visited Mr. Donald Sunde, and staff, of the Operations Analysis office of Headquarters U.S. Air Forces in Europe, Wiesbaden, and briefed them on my activities and also discussed various Operations Research problems of interest to that office.

Through the courteous invitation of Professor H. Kunzi, University of Zurich, I read a paper entitled "On the Simulation of Operations" to a joint meeting of the Swiss Operations Research Society and the Swiss Industrial Engineering Society.

I also was delegated to attend the NATO Conference on Military Logistics held at the SHAPE Air Defense Technical Center, The Hague, Netherlands, and participated in the discussions there.

Professor Pompilj and I participated in the International Conference of Mathematicians, Stockholm, Sweden, and I also attended the International Conference on Information Processing, Munich, Germany

XI. THE 1962 NATO COURSE IN OPERATIONS RESEARCH, VARENNA, ITALY

I assisted Professor Morse and Professor Pompilj in organizing the 1962 NATO Course in Operations Research, September 3-14. The staff for this course consisted of:

Dr. Steven Vajda, British Admiralty, U.K.
Technical Director and lecturer in linear programming and game theory and applications

Professor Giuseppe Pompilj, University of Rome, Italy
Administrative Director

Mr. Charles Salzman, CFRO (French Center for Operations Research), France
Lecturer in case studies in Operations Research

Dr. David Stoller, NATO Operations Research Consultant, U.S.
Lecturer in queuing theory and applications

Professor George Wadsworth, Massachusetts Institute of Technology, U.S.
Lecturer in stochastic processes and non-linear programming applications

There was a very healthy diversity of sectors of national activities represented by the attendees, with very strong representation from the industrial sector in particular. The topics covered included mathematical programming, theory of games, queuing theory and applications, transportation, allocation of resources, inventory control, maintenance models, scheduling and case histories. See Appendix J for a description of my contributions to the program of instruction.

A very significant feature of the 1962 NATO Course in Operations Research is that a major part of the financial support came from Italian national sources. This is a splendid demonstration of how

the program of the Advisory Panel on Operations Research stimulates self-supporting activities in Operations Research.

XII. CONCLUSION

I would like to take this opportunity to make some comments on the nature of the program of Consultants in Operations Research. There seems to have been much debate on relating the need for such a program to the general level of capability in Operations Research in a NATO country. The emphasis in the past has been on encouraging flow of technical personnel from those countries which to some degree are more advanced in Operations Research technologically to those which are not as advanced. However, I wish to suggest that the interchange of Operations Research personnel can be useful for all the NATO countries quite independent of their technological capability in Operations Research, because such interchanges serve to strengthen the cultural and technical ties among the NATO countries. Therefore, I feel that the Advisory Panel on Operations Research should also consider the possibility of interchange of Operations Research personnel among the NATO countries, without necessarily considering the relative needs of the various countries, but simply in pursuance of the concept of the strengthening of NATO.

Naturally, allocation of funds must take some account of the relatively urgent needs and desires of certain of the NATO countries to develop a capability in Operations Research, and it is evident that there will be a great deal of return per dollar spent for programs in these countries.

A program of interchange of technical personnel is immediately faced with the question of the selection of the types and numbers of personnel to be interchanged, given that there is a fixed (or at least

bounded from above) budget available for such interchange. The type of personnel interchanged can range all the way from undergraduate science students to highly-experienced Operations Research scientists. It seems evident to me that a balanced* program of interchange is required, and that neither end of the spectrum described above should be selected as the most desirable policy to adopt. Again, the matter of priority enters into the question, and certain of the NATO countries will benefit the most per dollar spent by being provided with an experienced Operations Research scientist who will (1) provide training for a relatively large number of students in the country of assignment without the necessity for removing the students from the country of assignment; and (2) provide advisory services at <u>all</u> managerial and technical levels in university, government, military, and industry. In short, a senior Operations Research scientist will deal with the totality of Operations Research problems and programs in the country of assignment, as compared to the student who will work under the direction of one or two analysts on a particular problem. The undergraduate or graduate student who is involved in this program represents a much more long-term investment for the country <u>from</u> which he is assigned, and in fact represents in the short term a net loss of technical capability to the country <u>from</u> which he is assigned. A balanced program requires interchange at all levels of the spectrum, but it is clear that to concentrate the program on the interchange of students alone is not the best policy to use.

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*I do not wish to imply that this is equivalent to a uniform distribution over the spectrum.

In some of the NATO countries a deterrent to the development of university level training in Operations Research lies in the attitude that many European universities have toward new subject matter courses. In contrast to a perhaps over-enthusiastic acceptance by American universities of new subject matter courses into the accredited list of courses in their catalogs, many European universities regard their list of accredited courses as an educational tradition which should be changed only with caution and after much consideration. This means that all new subject matter fields, not only Operations Research, have great difficulty in developing representation on the university faculty. The same phenomena inhibited the acceptance of modern statistical methods and the growth of statistical faculty in Europe, and we see the same symptoms with respect to the new field of Operations Research. A further difficulty for the field of Operations Research is that an exposure to interdepartmental disciplines is highly desirable, and in many European universities, the historic evolution of highly autonomous faculties is a barrier to establishing interdepartmental programs.

Despite the difficulties with which my Italian colleagues in Operations Research have been faced, I believe that the further development of an Operations Research capability in that country will be strong and vigorous. The appropriate technical, economic, and social factors which are needed to produce a rapid growth of a strong capability in Operations Research are present. The technological backbone of the country is strong, and there is an explosive increase in capacity in vital sectors, such as petroleum, steel, electronics,

automotive, and plastics. The government is entering upon large-scale programs of economic growth in various regions to encourage new industries, better housing, greater transportation capacity, etc. Increased opportunities for education are being made available to the talented youth of the country. Also, most importantly, there are to be found vigorous and dedicated political, military, scientific, and industrial leaders who sincerely desire to accelerate the rate at which technology and industry in Italy can utilize scientific knowledge to the ultimate benefit of the economy of Italy and the economy of Western Europe.

Professional collaboration is never a one-way street. Whatever the benefit my colleagues in Italy and elsewhere in NATO gained from my activities there, I am sincerely grateful for the professional benefits to me derived from the wide diversity of problems encountered, the stimulation provided by serious students, the knowledge and insight of my colleagues, and the acquaintanceships and friendships formed throughout the year.

Appendix A

OUTLINE OF LECTURES GIVEN AT NATO SHORT COURSE
IN OPERATIONS RESEARCH, VENICE, ITALY,
July 31-August 11, 1961

1. Statistics and Decisions

The decision-making process; the impact of uncertainty; statistical description of uncertainty; binary decisions; Bayesian decisions.

2. Queuing Theory and Applications, I

Queuing phenomena; elements of a queuing model; appropriate frequency distributions; the single-channel queue.

3. Queuing Theory and Applications, II

An application of the single-channel queue; evaluative criteria; the role of management.

4. Queuing Theory and Applications, III

The application of queuing theory to maintenance analysis; an example of the single-repair maintenance facility; an example of the multiple-repair maintenance facility; maintenance resource allocations.

5. Management Information Systems

Information criteria; decision areas; data input; data flow; management uses of data; system design considerations.

6. Inventory Operational Game, I

Simulation methods; description of the inventory problem; description of the simulation of the inventory problem.

7. Inventory Operational Game, II

Instructions of play; the play of the game; evaluation of results; comments on operational gaming.

Appendix B

ABSTRACT OF PAPER: "ON THE DETERMINATION OF OCCUPATIONAL CATEGORIES IN AN ORGANIZATION"*

An attempt to determine the number of occupational categories of repair men in an organization by analyzing the implications of three types of personnel policies. The first is a completely task-oriented personnel policy, which assumes that each specialty covers one or more kinds of tasks to be performed and that these tasks do not differ very much over the different specialties. The second is a specialty-oriented personnel policy, which assumes that each subsystem of the equipment to be repaired represents a complex task which can be performed only by highly specialized personnel. The third policy recognizes that equipments to be repaired are composed of subsystems that often require different specialties, but that at the same time the occupational categories can reflect a greater versatility, which can be achieved by the cross-training of personnel.

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*D. S. Stoller, On the Determination of Occupational Categories in an Organization, The RAND Corporation, P-2362, June 27, 1961. 10 pp. Presented before The Institute of Management Sciences at Brussels, Belgium, August 23-26, 1961.

Appendix C

TOPICS CONTAINED IN I METODI DELLA RICERCA OPERATIVA, LECTURE NOTES (IN ITALIAN)

History of Operations Research, Military and Non-Military

Models of Military Operations--Lanchester Equations

Industrial Operations Research Models

Characteristics of Operations Research Problems

Statistics and Decisions in Operations Research

Binary Decisions

Bayesian Decisions

Mathematical Representation of Operations

The Relationship of Data and Statistical Analysis to Operational Analysis

The Elements of Queuing Models

Frequency Distributions of Arrival and Servicing

Gamma (Erlang) Distributions

Single-Channel Queues

Probability Derivations

Evaluntive Criteria

Applications of the Single-Channel Queue

Multiple-Channes Queues

Probability Derivations

Applications of the Multiple-Channel Queue

The Principle of Stochastic Balance

Application of the Principle of Stochastic Balance to a General Class of Queuing Problems

The Single-Channel Queue Constrained to a Finite System

An Application to Maintenance Analysis

Approximation of Complex Queuing Phenomena by Means of the Gamma (Erlang) Distribution

Probability Derivations

An Application Utilizing the Gamma (Erlang) Distribution

The Gamma (Erlang) Distribution Applied to a Finite System

Introduction to the Theory of Games of Strategy

Strategies and Utilities

Example of Simple Games of Strategy

Study of the Fundamental Nature of Strategies

Simple Matrix Games

Pure and Mixed Strategies

Minimax Strategies

A Military Example of a Minimax Strategy

Characteristics of Pure Optimal Strategies

Solving Matrix Games with Pure Optimal Strategies

Characteristics of Mixed Optimal Strategies

Solving Matrix Games for Mixed Optimal Strategies

Elements of Resource Allocation

The Formulation of Resource Allocations as Problems in Linear Programming

The Solutions of Linear Programming Problems

The Relationship Between the Theory of Games of Strategy and the Theory of Linear Programming

Appendix D

TACTICS OF RECONNAISSANCE, DETECTION, PURSUIT, AND EVASION THEORY AND APPLICATIONS

The study of single- and multiple-element reconnaissance and pursuit of single- and multiple-hostile elements. Analysis of evasive strategies.

This type of study is typified by the single-searcher, single target case as described in OEG Report No. 56 (Unclassified), by B. O. Koopman, published by the U.S. Navy.

Emphasis in this study would be given to seeking new results in the situations wherein searchers and targets use randomized strategies.

This consideration puts the analysis into the framework of the theory of games of strategy (see for example, The RAND Corporation Report R-360 (Unclassified) by M. Dresher). If the target uses an evasion pattern, specified by the correlation function of a time series, and the searcher uses a search pattern with a given correlation function, the distance between searcher and target is a randomized time series of derivable correlation function. This establishes a basis for calculation of probability of discovery of target within a specified time, and other parameters of interest, depending on the speeds of the searcher and target, the nature of the detection apparatus, etc.

The goal of the study is twofold: (1) to expand the knowledge about time series analysis by studying specific cases of value to the study of the tactics of reconnaissance, pursuit detection and evasion, and (2) derive practical results based on the characteristics of present day and near future ships and airplanes and detection apparatus.

Appendix E

OUTLINE OF IL PROBLEMA DEL TRAFFICO NELL'AREA DI ROMA

I. Problem Definition--geographical area of study, traffic conditions present and future, statistical needs, fundamental studies, economic projections.

II. Land Use Studies--the utilization of land for different economic ends, the characteristics or urban land use, data needs and census (sampling) requirements.

III. Traffic Flow Studies--classification of traffic, data needs and sampling requirements.

IV. Transportation Systems--determining the capacity of public and non-public carriers, data needs, sampling requirements, short-term and long-term planning of the systems.

V. Funding, Staffing and Scheduling of the Study.

Appendix F

PROPOSED CURRICULUM FOR SPECIALIZATION IN OPERATIONS RESEARCH

1. Probability
2. Statistics
3. Economics
4. Stochastic Processes, Theory and Applications
   - (a) Queuing
   - (b) Continuous Processes
5. Theory of Games
6. Mathematical Programming
   - (a) Linear
   - (b) Non-linear, Dynamic, etc.
7. Digital Computing Machines
   - (a) Theory
   - (b) Coding
8. Industrial Applications
   - (a) Production
   - (b) Inventory
   - (c) Reliability and Quality Control
   - (d) Industrial Experiments
9. Business Administration*
10. Industrial Engineering and Industrial Psychology*
11. Thesis

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*As appropriate to the student's intended field of specialization.

Appendix G

ABSTRACT OF PAPER: "THE INDUSTRIAL APPLICATION OF QUEUING THEORY"

This paper was read to the inaugural meeting of AIRO, the Italian Operations Research Association (Associazione Italiana di Ricerca Operativa), Milano, November, 1961.

Industrial applications of queuing theory ordinarily pertain to factory or office operations in which congestion is observable. The analyst must devote some time to studying the actual operation. He then recognizes that the theory of queues provides a description of the operations being studied. In order to investigate the nature of congestion in the industrial operation it is necessary to ascertain: (1) the statistics of arrivals into the system, (2) the behavior of individuals during congestion, and (3) the statistics of completions of the operations. Thus statistical measurements of the operations are required.

The data and the queuing theory permit the analyst to investigate the congestion in terms of parameters, some of which may be changed by management action. Criteria based on cost and the effectiveness of the operation must be established to assist management action. A case history by G. Brigham, in Operations Research, November 1955, is cited.

Appendix H

INSTITUTIONAL MEMBERS OF THE ITALIAN OPERATIONS RESEARCH ASSOCIATION

Association of Italian Industry

Edisonvolta

FIAT

FINSIDER

IBM-Italia

Institute for Industrial Reconstruction

Istituto Centrale di Statistica (ISTAT)

Ministry of Transport

Montecatini

National Committee on Nuclear Energy

National Research Council

Olivetti Company

Torino Industrial Association

Torino Institute of Technology

University of Genoa

University of Rome

Appendix I

PROGRAM OF CONFERENCE ON MILITARY OPERATIONS RESEARCH HELD AT HEADQUARTERS ALLIED FORCES SOUTHERN EUROPE, NAPLES, ITALY
June 26-27, 1962

June 26

Welcoming Remarks
Major General J.R.F. Seitz, U.S. Army

Introduction to Military Operations Research
Colonel N. Locksley, U.S. Army

A Military OR Case Study
Dr. K. Yudowitch, Research Analysis Corporation (U.S.)

Questions, Discussion

War Games and the Play of a Logistics War Game
Dr. David S. Stoller, NATO (U.S.)

Questions, Discussion

June 27

OR Studies of Search Operations
Professor B. O. Koopman, Weapon Systems Evaluation Group, Department of Defense (U.S.)

Questions, Discussion

ASW Operations Research
Captain R. E. Jeffery, U.S. Navy
& Dr. G. Lindsey, Anti-Submarine Warfare Research Center (Canada)

Command and Control Systems
(Film, The RAND Corporation, U.S.)

Questions, Discussion

APPENDIX J

OUTLINE OF LECTURES GIVEN AT NATO SHORT COURSE IN OPERATIONS RESEARCH, VARENNA, ITALY, September 3-14, 1962

1. Elements of Queuing

   Congestion phenomena; elements of a queuing model; arrival and servicing time distributions.

2. Single-Channel Queues

   Arrival and servicing probabilities; servicing factor; system probabilities; system averages.

3. Evaluative Criteria for Queuing Models

   System congestion; number serviced; queue length; process time; delay time; safety factors.

4. An Operations Research Application of the Single-Channel Queue

   A case study of a communications system.

5. Multiple-Channel Queues

   Arrival and servicing probabilities; servicing factor; system probabilities; system averages.

6. Applications of the Multi-Channel Queue

   Examples.

7. Machine Maintenance Models

   Elements of repair system; use of queuing in studying repair systems; example.