



Operations Research

Publication details, including instructions for authors and subscription information:
<http://pubsonline.informs.org>

Fifth Annual Meeting of the Society, Philadelphia,
Pennsylvania, May 9–10, 1957

To cite this article:

(1957) Fifth Annual Meeting of the Society, Philadelphia, Pennsylvania, May 9–10, 1957. *Operations Research* 5(4):569–602. <https://doi.org/10.1287/opre.5.4.569>

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Fifth Annual Meeting of the Society

PHILADELPHIA, PENNSYLVANIA, MAY 9-10, 1957

THE FIFTH ANNUAL MEETING of the OPERATIONS RESEARCH SOCIETY OF AMERICA was held at the University of Pennsylvania on May 9 and 10, 1957. The Penn-Sherwood Hotel was headquarters. There were 468 registrations, of which 288 were members and 180 nonmembers.

Eleven sessions were devoted to invited and contributed papers as follows:

<i>Symposium. A Summary of Progress in Operations Research</i>	Chairman, RUSSELL L. ACKOFF, Case Institute of Technology
<i>A. Models in Industry</i>	Chairman, WILLIAM E. BRADLEY, Philco Corporation
<i>B. Observation and Measurement in Operations Research</i>	Chairman, HUGH J. MISER, Operations Analysis Division, Headquarters, U.S.A.F.
<i>C. Operations Research in Marketing</i>	Chairman, WROE ALDERSON, Alderson and Sessions
<i>D. Case Histories in Operations Research</i>	Chairman, MELVIN E. SALVESON, General Electric Co.
<i>E. Communication and Organization</i>	Chairman, JOSEPH F. McCLOSKEY, Case Institute of Technology
<i>F. Operations Research in Hospitals</i>	Chairman, CHARLES D. FLAGLE, The Johns Hopkins University and Hospital
<i>G. Transportation</i>	Chairman, REGINALD V. HOBACH, Operations Analysis Division, Headquarters, U.S.A.F.
<i>H. Papers on Linear Programming and Military OR</i>	Chairman, J. PARKER BURSK, University of Pennsylvania
<i>I. Models in Industry—Continued</i>	Chairman, H. NEWTON GARBER, Radio Corporation of America
<i>J. Contributed Papers</i>	Chairman, NEWTON ABLAHAT, General Electric Company

The social functions consisted of a mixer and banquet held on the evening of May 9th. The Lanchester award was presented by P. STEWART MACAULAY, Provost, The Johns Hopkins University, to RICHARD E. ZIMMERMAN.

Members of the Program Committee for the Fifth Annual Meeting were: J. G. BRAINERD, *Chairman*, CHARLES D. FLAGLE, *Chairman, Papers Committee*, EDWARD L. BRINK, *Chairman, Local Arrangements Committee*, WILLIAM E. BRADLEY, MERRILL M. FLOOD, JOSEPH F. McCLOSKEY, and HUGH J. MISER. The Philadelphia Convention Bureau provided registration clerks for the meeting.

The panel members who participated in the *Symposium on Progress in Operations Research* were PHILIP M. MORSE, LeROY A. BROTHERS, ELLIS A. JOHNSON, RUSSELL L. ACKOFF, BERNARD O. KOOPMAN, and MELVIN E. SALVESON. Abstracts of the papers presented in the other sessions follow the reports of the Secretary and of the Lanchester Prize Committee.

REPORT OF THE SECRETARY

THE MEMBERSHIP OF THE SOCIETY on April 30, 1957, was 2,009, as compared with 1,508 on the same date of the previous year. Of the April 1957 membership, 150 were Fellows, 539 were Members, and 1,320 were Associate Members or Student Associate Members. At its meeting on May 8, 1957, the Council elected the following 27 new Fellows and 122 new Members:

Fellows

PHILIP S. BALL, JR.	FLOYD I. HILL
ALEXANDER W. BOLDYREFF	PAUL A. HOWER
FRANK E. BOTHWELL	DANIEL LEIVICK
GEORGE BOTT	S. B. LITTAUER
JOHN K. BRAGG	JACOB MARSCHAK
CARROLL W. BRYANT	LEO S. MASON
THOMAS W. CHAPPELLE	THOMAS EDMOND OBERBECK
A. CHARNES	MAX S. OLDHAM
ROGER R. CRANE	EDWARD S. QUADE
W. P. CUNNINGHAM	LAWRENCE G. STARKEY
JAMES F. DIGBY	PETER FALLIS STRONG
ROBERT DORFMAN	GEORGE W. TYLER
SHERWOOD C. FREY	RICHARD E. ZIMMERMAN
H. KENNETH GAYER	

Members

RALPH W. ALLEN	WILBUR N. CHRISTENSEN
CLINTON J. ANCKER	ROBERT S. CHUBB
LELAND D. ATTAWAY	J. C. R. CLAPHAM
FRANK P. BALLANTYNE	FREDERICK W. CLEAVER
CARTER L. BENNETT	ROGER H. COLLCUTT
EDMUND C. BERKELEY	S. L. COOK
CHARLES A. BICKING	G. N. CORNELL
ROBERT O. BLANCHARD	ROBERT N. CREEK
WILLIAM F. BLAYLOCK	ROBERT E. CRISPEN
MELVILLE C. BRANCH, JR.	BURTON V. DEAN
KIRK BUCHAK	MOHAMED IBRAHIM DESSOUKY
C. W. BURLIN, JR.	LOUIS P. DIAMOND
GERALD A. BUSCH	DANIEL J. DUFFY
RICHARD A. BYERLY	ALAN EAGLE
CARL A. CARLSON	EDWIN O. ELLIOTT
GEORGE CHANE	IRVING FEISTER
IVAN G. CHASALOW	JOSEPH W. FISCHBACH

RICHARD A. FITZGERALD	RUSSELL A. NELSON
KIRK FOX	WALTER G. NILSEN
RAOUL J. FREEMAN	G. C. NOONEY
WALTER J. GAILUS	CHARLES W. OLIPHANT
HERBERT P. GALLIHER	GIRARD L. ORDWAY
JAMES J. GEHRIG	J. T. OVERBEY
BERNARD GIFFLER	NAPOLÉON PERKOWSKI
JOSE GIL-PELAEZ	RAYMOND P. PETERSON, JR.
GEORGE GLINSKI	ROYAL W. RANDALL, JR.
MINA H. GOURARY	GEORGE C. REINHARDT
FRED B. GRAHAM	G. TRUXTON RINGE
ROMAN V. GROCHOLSKI	HAYDEN N. RINGER
HERBERT J. GROELINGER	ROBERT E. ROBERSON
ARTHUR D. HALL	HERBERT W. ROBINSON
FRANK R. HARRISON	ROBERT W. ROOP
REGINALD V. HOBBAH	H. M. ROSENSTOCK
JULIAN L. HOLLEY	DANIEL J. ROSS
WILLIAM GRADY HOWARD	MORTON J. ROSSMAN
DANIEL HOWLAND	KIYOZO SATO
HARRY HULL	F. L. SAWYER
ELMER HUTCHISSON	WILLIAM H. SHIELDS
ROBERT E. JOHNSON	RALPH M. SHOWERS
LOUIS B. KAHN	HERBERT SOLOMON
EUGENE B. KANIA	MARTIN KENNETH STARR
MARTIN N. KELLOGG	ARTHUR STEIN
JOSEPH J. KNOPOW	GEORGE W. SUMMERS
R. STANLEY LAVALLEE	JAMES L. TAYLOR
C. E. LEMKE	DANIEL TEICHROEW
ANDRE LEROY	ALAN T. THOMAS
JACK R. LIND	CHARLES E. TILLMAN
JOHN L. LITTLE	RALPH M. TUCKER
B. H. LLOYD	UMBERTO TURELLO
H. T. LOEHR, JR.	HOMER A. TURPIN
RICHARD M. LONGMIRE	FUAT ULUG
JOHN F. LUBIN	MICHAEL VERHULST
RICHARD H. MAGEE	EUGENE P. VISCO
GEORGE MARTIN	LOUIS B. WADEL
ROBERT A. McDOUGALL	JAY T. WAKELEY
SAMUEL R. MEAKER	MERRILL B. WALLENSTEIN
DONALD A. MELNICK	JOHN WALTER
HAROLD R. MITCHELL	OSCAR M. WELLS
MORTON MITCHNER	JOHN W. WESTER, JR.
WAYNE R. MOORE	PHILLIPS WHIDDEN
WILLIAM B. NEFEDOV	BERNARD WHITNEY

During the year ending April 30, 1957, nonmember subscriptions to the JOURNAL increased from 1,159 to 1,514.

Meetings of the SOCIETY were held in San Francisco on November 14-15, 1956; and in Philadelphia on May 9-10, 1957. Attendance at both meetings ran between 450 and 500.

Future meetings are planned in Pittsburgh, Pennsylvania, November 14-15,

1957, and in Boston, Massachusetts, May 15-16, 1958. The Meeting Committee Chairman for the Pittsburgh meeting is PROF. W. W. COOPER, and for the Boston meeting, DR. H. P. GALLIHER, JR.

At the Business Meeting on May 9, 1957, the election of Officers for the year ending with the 1958 Annual Meeting, and of Council Members for a three-year term, were announced as follows:

B. O. KOOPMAN	<i>President</i>
J. B. LATHROP	<i>Vice-President</i>
M. L. ERNST	<i>Secretary</i>
W. F. OFFUTT	<i>Treasurer</i>
J. F. McCLOSKEY	<i>Council Member, 1957-1960</i>
J. W. ABRAMS	<i>Council Member, 1957-1960</i>

JACINTO STEINHARDT completed his term as Past President and retired from the Council; E. A. JOHNSON and G. D. CAMP retired from three-year terms on the Council.

Also, at the Business Meeting, discussions were held on certain proposed amendments to the Constitution, the details of which had been mailed to the membership earlier. At a Council Meeting following the Business Meeting, a decision was reached to submit a modified set of amendments to the membership for voting; this voting will have been completed by August 1.

The third award of The Johns Hopkins University Lanchester Prize was made to RICHARD E. ZIMMERMAN for his paper published in *Operations Research for Management*, Vol. II (Johns Hopkins Press), entitled "A Monte Carlo Model for Military Research." Honorable Mention was given to RUSSELL L. ACKOFF for his paper entitled "The Development of Operations Research as a Science," published in *OPERATIONS RESEARCH*.

Standing Committees of the Society for the coming year are as follows:

<i>Membership:</i>	O. A. HOFFMAN, <i>Chairman</i> R. G. TUTTLE P. J. ROBINSON W. C. CUNNINGHAM M. ASTRACHAN B. H. P. RIVETT, <i>Special Advisor</i>
<i>Nominating:</i>	D. A. KATCHER, <i>Chairman</i> L. C. EDIE R. S. WEINBERG T. E. CAYWOOD W. F. PLATT
<i>Education:</i>	E. L. ARNOFF, <i>Chairman</i> A. W. BOLDYREFF J. H. ENGEL O. M. SOLANDT C. D. FLAGLE

J. O. HARRISON
B. H. P. RIVETT

Publications:

GEORGE SHORTLEY, *Chairman*
J. W. ABRAMS
T. E. CAYWOOD
C. GOODEVE
W. J. HORVATH
B. O. KOOPMAN
J. F. MAGEE
H. J. MISER
T. L. PAGE
E. W. PAXON
W. F. PLATT
A. S. SCHULTZ, JR.
J. STEINHARDT

Other Committee appointments include:

<i>Auditing:</i>	C. D. FLAGLE, <i>Chairman</i>
<i>Constitution and By-laws:</i>	J. M. DOBBIE, <i>Chairman</i>
<i>Prize:</i>	R. L. ACKOFF, <i>Chairman</i>
<i>Professional Relations:</i>	H. I. ANSOFF, <i>Chairman</i>
<i>International Conference:</i>	T. L. PAGE, <i>Chairman</i>
<i>Program Chairman Manual:</i>	H. B. WISSMAN, <i>Chairman</i>
<i>Representative to the AAAS:</i>	P. M. MORSE
<i>Representative to the NRC:</i>	R. F. RINEHART

During the Council Meeting, authorization was granted, subject to final approval of Section By-laws, for the formation of a Philadelphia Section of the OPERATIONS RESEARCH SOCIETY OF AMERICA.

Preparation for the International Conference on Operations Research continues, and the Council approved the proposed list of ORSA attendees.

Other Council action included the establishment of a Long-range Planning Committee, composed of E. A. JOHNSON, J. STEINHARDT, G. E. KIMBALL, and W. N. TUTTLE. This Committee will seek to formulate a long-range, constructive publications program for the SOCIETY, based on its determination of what additional publishing effort will do the most good in the field of operations research. The Committee will also investigate the desirability of new and different types of awards for publications and other activities in the field of operations research.

In another area, several steps were taken to improve the planning and the quality of SOCIETY meetings. In order to assist Meeting Committee Chairmen to plan more realistically, they will be authorized to adopt policies which will stimulate early registration, such as using a differential between the preregistration fee and the registration fee at the meeting. Future Meeting Committees are also authorized to limit the number of contributed papers, if there are too many for a well-balanced meeting, and to reject papers that are not in consonance with the general themes of the meetings.

As a result of increasing interest in the international spread of operations re-

search, a special committee was established to investigate practical means whereby the SOCIETY can assist nations interested in developing operations research. Possibilities in this direction include providing operations-research training teams and technical consultants, and assisting key institutions by providing them with publications and other documentary material. This committee is to provide the Council with recommendations for possible SOCIETY action, through nongovernmental agencies, with emphasis on aid to underdeveloped countries.

In the area of domestic activities, R. L. ACKOFF and P. M. MORSE were designated a committee to organize SOCIETY participation in a session of the AAAS meeting to be held in Indianapolis on December 27-28, 1957. It was also decided that the SOCIETY may collaborate with Section P of the AAAS, and other societies subsequently invited to participate, in a symposium on decision theory.

During the course of the Council Meeting, the extremely fine functioning of certain committees was specifically noted and commended. These included:

The Membership Committee, for the tremendous effort and devotion applied to improving Committee procedures, and to ensuring that qualified persons were able to achieve advancement in membership status.

The Professional Relations Committee, for developing effective policies to be followed in collaborating with other societies, as regards both notification of meetings and participation and cosponsorship of meetings on subjects of common interest.

The Publications Committee, for continuing to improve the quality and the coverage of the SOCIETY's publishing effort.

MARTIN L. ERNST, *Secretary*

REPORT OF THE 1956 LANCHESTER PRIZE COMMITTEE

THE 1956 Lanchester Prize Committee decided to follow the procedures evolved by the two preceding committees, with minor modifications. It appeared to the committee that the procedures which had been evolved were quite satisfactory.

PROCEDURE USED

THE EXPERIENCE of the previous committees had indicated clearly that it was desirable to have each paper appearing in the recognized operations-research publications read by at least three screeners. In addition, it was deemed desirable to have other journals in which operations-research papers appear occasionally screened by at least two members of the screening group. It was also felt that the list of such journals should be expanded somewhat. This required a large group of screeners. The committee's request for assistance in screening the literature met with very gratifying results. Some sixty or so people were asked to help and 57 actually helped. The panel of screeners, without whom the committee could not have done its job, follows:

DR. JOHN W. ABRAMS
Royal Canadian A.F. Hdqs.

DR. RUSSELL L. ACKOFF
Case Institute of Technology

- DR. E. LEONARD ARNOFF
Case Institute of Technology
- DR. MAX ASTRACHAN
Air Force Institute of Technology
- MR. ROBERT A. BAILEY
Lockheed Aircraft Corporation
- DR. DONALD Y. BARRER
Weapons Systems Evaluation Group
- MR. J. H. BATCHELOR, CONSULTANT
St. Louis, Missouri
- DR. GLEN D. CAMP
George Washington University
- DR. T. E. CAYWOOD
Caywood-Schiller Associates
- DR. LEE S. CHRISTIE
The Rand Corporation
- MR. PAUL B. COGGINS
Operations Evaluation Group
- DR. RUSSELL C. COILE
Operations Research Group, USN
- DR. ROGER CRANE
Touche, Niven, Bailey & Smart
- DR. JOHN M. DANSKIN
Institute for Advanced Study
- DR. DAVID F. DEBEAU
Battelle Memorial Institute
- DR. JAMES M. DOBBIE
Operations Evaluation Group
- DR. JACK W. DUNLAP
Dunlap & Associates
- DR. CHARLES D. FLAGLE
The Johns Hopkins University
- MR. D. L. GERLOUGH
Inst. of Transportation & Traffic Eng.
- DR. JOSEPH O. HARRISON
Operations Research Office
- DR. REGINALD V. HOBBAH
Operations Analysis, Hq, USAF
- DR. OSCAR A. HOFFMAN
American Machine & Foundry Co.
- DR. WILLIAM J. HORVATH
Airborne Instruments Laboratory
- DR. C. C. HURD
International Business Machines Corp.
- DR. BERNARD O. KOOPMAN
Weapons Systems Evaluation Group
- DR. TJALLING C. KOOPMANS
Cowles Foundation for Research in Economics
- MR. JOHN G. LATHROP
Lockheed Aircraft Corporation
- MR. DANIEL LEVICK
Operations Analysis, Hq, USAF
- DR. JOSEPH H. LEWIS
Weapons Systems Evaluation Group
- MR. JOHN F. MAGEE
Arthur D. Little, Inc.
- MR. DONALD G. MALCOLM
Booz, Allen & Hamilton
- DR. LEO S. MASON
Operations Evaluation Group
- DR. JOSEPH F. MCCLOSKEY
Case Institute of Technology
- DR. HUGH J. MISER
Operations Analysis, Hq, USAF
- DR. A. M. MOOD
General Analysis Corporation
- DR. PHILIP M. MORSE
Massachusetts Institute of Technology
- DR. N. W. MORTON
Canadian Army Headquarters
- DR. GEORGE E. NICHOLSON
University of North Carolina
- DR. THORNTON L. PAGE
Operations Research Office
- DR. E. W. PAXSON
The Rand Corporation
- MR. WILLIAM PLATT
Stanford Research Institute
- DR. ROBERT A. PORTER
Operations Analysis, Hq, APGC
- DR. ROBERT F. RINEHART
Case Institute of Technology
- MR. B. H. P. RIVETT
Operational Research Society
- DR. ROBERT H. ROY
The Johns Hopkins University
- DR. THOMAS L. SAATY
Operations Evaluation Group
- DR. DONALD H. SCHILLER
Caywood-Schiller Associates
- DR. ANDREW S. SCHULTZ, JR.
Cornell University
- DR. GORDON D. SHELLARD
Metropolitan Life Insurance Co.
- DR. SEYMOUR SHERMAN
University of Pennsylvania
- MR. RICHARD C. SINGLETON
Stanford Research Institute
- DR. L. H. THOMAS
Watson Computing Laboratory
- DR. W. NORRIS TUTTLE
General Radio Corporation
- DR. ALFRED N. WATSON, CONSULTANT
Bexley, Ohio
- MR. ROBERT S. WEINBERG
Operations Evaluation Group
- MR. HERBERT K. WEISS
Northrop Aircraft Corporation
- MR. ROGER I. WILKINSON
Bell Telephone Laboratories

PUBLICATIONS REVIEWED

THE LIST of journals and publications screened follows. This includes certain publications containing individual articles recommended by members in response to the committee's request for such recommendations, which was published in the December issue of OPERATIONS RESEARCH.

Annals of Mathematical Statistics
Behavioral Science
Biometrika
Econometrica
Factory
Industrial Quality Control
Journal of Farm Economics
Journal of Industrial Engineering
Journal of the American Statistical Association
Journal of the Royal Statistical Society
Journal of the Society for Industrial and Applied Mathematics
Management Science
Naval Research Logistics Quarterly
Office Work and Automation, HOWARD S. LEVIN, John Wiley & Sons, 1956.
Operational Research Quarterly
Operations Research
Operations Research for Management, Vol. II, The Johns Hopkins Press, 1956
Proceedings and Bulletins, Highway Research Board, National Research Council
Proceedings, Automatic Data Processing Conference, Harvard University
Proceedings, 11th Annual Management Engineering Conference, sponsored by SAM and ASME
Proceedings of the Conference on Case Studies in Operations Research, Case Institute of Technology
Proceedings of the Institute of Radio Engineers
Studies in the Economics of Transportation
Symposium on Monte Carlo Methods
The American Economic Review

CRITERIA USED

THE COMMITTEE used the same broad criteria developed by the two preceding committees, namely:

For a research paper representing new results:

1. The magnitude of its contribution to the advancement of the state of the art of operations research.
2. The originality of its ideas or methods.
3. New vistas of application opened up by it.
4. Expository clarity.

For a primarily expository paper:

1. The degree of unification or simplification of existing operations-research theories or methods.
2. Expository clarity and excellence.

In addition to these broad criteria the committee judged each research paper on the basis of the following:

1. Importance of the problem.
2. Magnitude of the problem.
3. Appropriateness of the methods used.
4. Presentation of methods and results in form useful to other analysts.
5. Evidence of thorough understanding of the problem.
6. Completeness of exploratory investigation, data gathering, etc.
7. Choice of measure(s) of effectiveness.
8. Formulation of model.
9. Testing of model, including sensitivity of measure of effectiveness to major variables.
10. Derivation of results.
11. Formulation of recommendations.
12. Resulting action.
13. Results of action.

As is likely to be the case, each paper considered fell short on one or more of our criteria. Thus our task reduced to the selection of the paper that fulfilled the largest number of the most important of our criteria. The choice was by no means easy, as there were in 1956 many very good papers—research papers, expository papers, and some papers that essentially belong in both these categories.

The committee believed it desirable to award the prize for a paper that described an operations research study, although we would have been willing to recommend that the prize be given for an expository paper if we had found a dearth of research papers or if we had found an exceedingly strong and outstanding expository paper. Since there were many good papers of both kinds but there was not an expository paper that was an obvious and outstanding choice, we selected the research paper that came closest to meeting all of the criteria for a prize winner.

RECOMMENDATION OF THE PRIZE COMMITTEE

THE COMMITTEE selected as winner of the 1956 Lanchester Prize the paper, "A Monte Carlo Model for Military Analysis," by RICHARD E. ZIMMERMAN. The winning paper appeared as Chapter 21 of *Operations Research for Management*, Volume II, Johns Hopkins Press, 1956. The committee recommended that Honorable Mention be given to the expository paper, "The Development of Operations Research as a Science" by RUSSELL L. ACKOFF. This paper appeared in the June 1956 issue of OPERATIONS RESEARCH.

The committee considered Zimmerman's paper outstanding with respect to each criterion applying to an operations research paper of its type, except that the paper did not describe the application of the method to a real problem. The committee selected the paper in spite of this fault because we have learned that the method is now being applied to real problems by two military operations-research groups. It is our belief that the method will prove highly useful in the solution of practical problems.

There were a number of excellent expository papers published in 1956. The best of these, in the opinion of the committee, was the one by Ackoff. It was deemed desirable by the committee that this type of paper be recognized and it is our opinion that Ackoff's paper, in addition to being very well written, makes major contributions to the understanding of the progress of operations research as a scientific activity. It is a stimulating paper, and has proved very useful in indoctrinating new analysts.

GEORGE SHORTLEY

JACINTO STEINHARDT

LEROY A. BROTHERS, *Chairman*

ABSTRACTS

A1. Top Management Decision Simulation, CLIFFORD J. CRAFT, *American Management Association, 1515 Broadway, New York, N. Y.*

A multiphase multiperson game has been developed which simulates the problem of allocating limited funds to the factors of production. This game has been played many times, including recent plays involving operating executives. To play the game a group of executives is divided into companies each with the same initial assets. At the beginning of each period each company independently allocates its funds to production, marketing, research and development and plant investment, and establishes a price for its product. Each company's decisions are then fed into an electronic computer which calculates income and balance statements for each company for the period. Each company's performance is determined by mathematical models of the market or production systems within each company which account for the interactions between the different decisions of the various companies. After receiving the income statement, each company independently budgets for the next period (based upon its new asset position) and sets a price for the product. The game is thus played for many periods thereby simulating within a few day's time the equivalent of years of experience in a competitive market. The game also enables N-person games to be studied in terms of specific informational models.

A2. Determination of Feasible Shipping Schedules for a Job Shop, WILLIAM KARUSH, and L. A. MOODY, *The University of Chicago and The Ramo-Wooldridge Corporation, 5730 Arbor Vitae St., Los Angeles 45, California*

This paper is concerned with the determination of shipping schedules for commodities which are manufactured by job shop production processes. Manufacturing requires use of various machine classes (or labor classes); we know by machine class what capacity has already been committed to production plans and, hence, what remaining capacity will be increasingly available as time goes on. The problem then is to determine shipping schedules which can be supported by this available capacity and will make good or best use of this capacity. The type of commodity considered is an end product of an interrelated series of indentured parts and sub-assemblies, and the manufacture of each of these consumes machine capacity. Under realistic and simplifying assumptions involving (1) set-backs from shipping date for the manufacturing operations of indentured parts, and (2) lot quantity, the problem emerges mathematically as a linear programming problem of particular form. Exploiting this particular form, several special methods of solution are developed which are computationally much simpler than the standard simplex method, and which are of considerable use in practical problems of determining shipping schedules.

A3. A Manual Optimization of a Non-Linear System with Numerous Feasible Solutions, M. J. ROSSMAN, and M. N. KELLOGG, *Peat, Marwick, Mitchell and Company, 10 S. LaSalle St., Chicago 3, Illinois*

This study presents a manual solution for a non-linear system of discrete non-monotonic functions which describe a projected system of origin point, interme-

diate staging points, and final destinations. The origin and final destinations are fixed; the number and location of intermediate staging points and routes are of a magnitude of number that complete iterative techniques are impractical. The transportation costs are variable with distance at two rates (Carload-origin to intermediate points; LCL-intermediate points to destinations). The establishment of an intermediate point creates a large fixed cost and introduces non-linearity into the system.

The solution which determines the optimum number and location of intermediate points is based on a manual method to balance costs incurred and costs relieved by the activation of an intermediate point. Each feasible solution is reached in such a way as to eliminate from further consideration all other feasible solutions of a lower rank.

A4. Long Range Planning and Operations Research, EARLE STEWART, Vertol Aircraft Corporation, Morton, Pennsylvania

Keen interest in long range planning has been shown in recent years. OR techniques have been proposed and in some cases are currently being utilized in industry, particularly in airplane manufacturing. This paper proposes correlation in econometric analysis, long range planning and operations research.

A5. A Model for Product Diversification, H. I. ANSOFF, Lockheed Aircraft Corporation, Burbank, California

The paper will (1) briefly trace the history of product diversification in the U. S.; (2) define and describe the phenomenon of diversification; (3) construct a mathematical model of diversification action; (4) show that diversification problem is one of allocation of resources under uncertainty; (5) illustrate the allocation problem with numerical examples.

A6. Operations Research in Life Testing, LEONARD G. JOHNSON, General Motors Corporation, Detroit, Michigan

The cost of a life testing program is resolved into two components. They are Cost No. 1: The total cost of waiting. Cost No. 2: The total cost of the specimens and test facilities. For a given degree of testing reliability these components of cost are inversely related, i.e., any attempt to reduce cost No. 1 will require more specimens or equipment, thereby increasing cost No. 2. Furthermore, it is not possible to reduce cost No. 2 without increasing cost No. 1, unless reliability is sacrificed. It follows therefore that we should, if possible, design a life testing program in which costs 1 and 2 are such that their sum is a minimum. The author arrives at such a minimum for specimens having a Weibull life distribution.

A7. Continuous Production and Emergent Demand, T. A. GOLDMAN, The Rand Corporation, 1700 Main St., Santa Monica, California

The manufacturer of machinery or other equipment will usually undertake to supply spare parts for such equipment to his customers. The demand for a spare part is a random event in time, which may be described by a demand probability function. If holding costs for spare parts are large, it may be desirable to avoid

maintaining an inventory of such parts. One alternative is to supply spare parts, on demand, from the manufacturer's current production of parts for the assembly of new equipment, colloquially referred to as "robbing the production line."

A model of the real and monetary costs involved in supplying spare parts from current production is presented. The model leads to a cost function for each part individually depending on its production characteristics and its demand probability function, and on certain policy variables. By choosing appropriate values for the policy variables, the cost function for each part can be minimized independently of the others.

Applications and eventual refinements of the model are discussed.

A8. An Economic Model for Petroleum Exploration, ROBERT B. GRANT, and JOHN W. LOY, *Phillips Petroleum Company, Bartlesville, Oklahoma*

The search for oil is a business enterprise with significant elements of a game of chance. Minimizing the hazards of the game is a prerequisite to successful commercial operation. A model utilizing a Monte Carlo approach to develop optimization criteria is described.

Petroleum industry factors pertinent to the development of the model are discussed to provide orientation and understanding for those not familiar with the industry. A detailed mathematical description of the model construction is given. Typical results of the model study to date are presented. Improvements to be added in the continuing program are outlined.

B1. The Measurement of Independently Occurring Human Handling Operations of Short and Variable Duration, P. F. DUNN, and E. W. GIRARD, *Operations Research Office, 7100 Conn. Ave., Chevy Chase 15, Maryland*

A particular problem in the measurement of simultaneous or sequential and overlapping human handling operations is described. Specifically, the statistics of such operations occurring in an Army Message Center were desired, where the requirement existed for the observer to be able to record start and end signals for two or three independent individuals working in parallel. Alternatively, it was desired that the observer measure three independent consecutive operations which may overlap. Equipment is described which has been developed at the Operations Research Office enabling an observer to do this practically using a small hand-held device for furnishing coded signals representing the start and stop data to a remote recording system. The observer was thus able to keep up with the operations of at least two persons without distraction due to the presence of recording apparatus.

B2. A Laboratory for Combat Operations Research, FRANKLIN C. BROOKS, and FLOYD I. HILL, *Technical Operations, Inc., Monterey, California*

The Combat Development Experimentation Center, established by the U. S. Army in November 1956, has the following facilities for operational experiments: A regiment of troops, a vast land area with varied terrain, experienced military and scientific personnel. The composition and operation of the Center will be described briefly.

The Center is conducting two types of experiments: (1) those needed to get basic operational data for use in analytic models and war games, (2) experiments in which Army organizations in simulated combat in the field serve as the model of the combat operation being studied.

In the later type of experiment, precision umpiring and competitive scoring techniques are being developed to make the model as 'realistic' as possible. These techniques will be described as will those used in the design of experiments and collection and analysis of data.

B3. A Proposal for the Collection and Analysis of Maintenance and Reliability Data on an Airborne Weapon System, W. A. K. CHAMBERS, and W. R. HOSSACK, Avro Aircraft Limited, Malton, Ontario, Canada

The authors were called in by the Company's Logistics and Maintenance Group to assist in setting up an optimum system for the reporting, recording on punched cards, and analysis of field defect data on an airborne interceptor weapon system. The task of the field representative has been specially studied, to make more practical the collection of statistics required to study and improve maintenance and reliability of the system in service. The parameters available are discussed, and the methods and objectives of analysis are sketched out. Since it is intended to stimulate the interchange of recent ideas among practical workers in this field, the paper describes current rather than completed work.

B4. Information-Collection Procedures, ARTHUR J. YASPAN and MICHAEL HALBERT, Case Institute of Technology, Cleveland, Ohio

An *information-collection situation* is said to arise when a sample is to be taken from some universe, observations are to be made on the elements of the sample, and action is to be undertaken on the basis of these observations with the expectation of return. An *information-collection procedure* in such a situation is specified by assigning values to the following two quantities:

n : the number of elements in the sample

t : the resources expended in making an observation on one element of the sample.

An information-collection procedure is considered optimal, in this paper, if the expected return from its use is no smaller than the expected return from the use of any other admissible information-collection procedure.

This optimization problem differs from the ones usually discussed in sampling theory, in that observational error is treated as a random variable. In most works on sampling theory, either the possibility of observational errors is ignored, or observational errors are assumed to cancel one another out. The inclusion of t as an explicit element of the information-collection procedure, in this paper, permits the consideration of observational error in the following sense. The planner may increase t , at his discretion, weighing the cost of such an increase against the advantages from the resulting expected decrease in observational error.

Information-collection situations are classified in two independent ways—quantitative vs. qualitative, and collective vs. distributive. This leads to a four-

fold classification of information-collection situations, viz.:

Qualitative—Distributive
Quantitative—Distributive
Qualitative—Collective
Quantitative—Collective

The main body of the paper consists of a detailed examination of each of these four sub-classes of information-collection situation, including a mathematical treatment of the optimization question and examples.

B5. Measurement Problems in Business Applications of Operations Research, ERNEST H. WEINWURM, *DePaul University, Chicago, Illinois*

The paper will analyze the significance of the data which have to be used to implement the mathematic-logical formulas developed by operations research studies if these shall be useful for managerial decision making. An assumption is made that (1) appropriate data will be available and (2) that these data will be significant for the desired purposes. However, very serious measurement problems arise in the accumulation and interpretation of monetary data, particularly accounting data which shall be used to implement the work of the operations research man. A number of related problems will be discussed and attention will be called to frequently overlooked limitations to their use. Reference will be made to a recently published Statement of Cost Concepts by a committee of the American Accounting Association.

B6. Observation and Measurement in Air Development, JOHN L. OVERHOLT, *MIT Operations Evaluation Group, Washington 25, D. C.*

Operations research analysts can contribute to development programs only by close cooperation with participants. If statistics and experimental designs are used, the participants should be convinced that it is advantageous to do so by informal or formal discussions. Talks given to pilots are summarized, using examples which are familiar to them. A step-by-step account is given for developing a procedure to aid a pilot who must decide whether to try to reach an alternate landing field or bail-out.

B7. Observation and Prediction in Military Operations Research, ROY P. BRADY, *Lockheed Aircraft Corporation, Burbank, California*

Long range military operations research is concerned with the prediction of the nature and behavior of future military systems. This paper argues that it is not, in some of its most essential aspects, so closely akin to the physical sciences as is generally supposed. The paper discusses some of the kinds of observations which are relevant to military operations research and compares these to observations in the physical sciences. It also discusses the casual observations which are sometimes more or less unwittingly inserted into such research, and it considers pseudo-observations and the results of imaginary experiments. The prediction of technological trends is shown to depend upon observations beyond those of the operation of weapons, and the adequacy of this prediction is an important factor in military operations research.

C1. Accumulative Models for Marketing Decision-Making, SIDNEY SCHOEFFLER, *General Electric Company, 570 Lexington Ave., New York 22, N. Y.*

The decision-making problem in marketing is characterized, to a greater degree than is usually the case in OR applications, by the following troublesome factors:

- (1) most of the strategic variables are beyond the control and even beyond the knowledge of the decision-maker;
- (2) The relevant variables are so large in number and so complex in their interaction that the "true" structure of the pay-off-generating reality is always largely unknown;
- (3) the "information" that is available is quite heterogeneous in its reliability, accuracy, form, and coverage; and
- (4) The structure of the pay-off generating reality is variable in unpredictable ways; and hence most information pertaining to it is subject to decay.

The paper will outline the form of a decision-model that is suitable to this situation. The model should be able to (a) operate with "much" or with "little" information, (b) take account of the "reliability coefficient" of information, and of the decay rate of that coefficient, (c) digest information of all logical kinds, and (d) operate under conditions of continuous revision and updating.

C2. The Impact of Opening and Closing of Branch Warehouses Upon Sales, R. A. BYERLY, and M. J. ROSSMAN, *Peat, Marwick, Mitchell and Company, 10 S. LaSalle St., Chicago 3, Illinois*

This case study involved compilation and indexing of actual sales from customer records for given periods by county and for the entire United States.

Extraction, interpolation and indexing of population figures was also performed.

Trends and confidence limits of indexed per capita sales were computed and extrapolations of trend from the point of opening or closing of the branch were compared with actual results obtained.

C3. A Study of the Relationship Between Customer Service and Company Sales, R. A. BYERLY, and M. J. ROSSMAN, *Peat, Marwick, Mitchell and Company, Chicago, Illinois*

This case study involved accumulation of sales and population figures by county.

Counties were grouped according to total days of service from servicing branch (in accordance with the results of a survey conducted to analyze orders received).

Sales and population figures were summarized with respect to the counties falling into each interval and coefficients of determination were computed.

Coefficients of determination were also computed between per capita sales and total days of service to provide a check on the original computations.

C4. An Application of Operations-Research Techniques to Department Distribution in a Chain of Stores, J. BARACHE, and J. MELESE, *A.U.R.O.C., 23 Rue Fortuny, Paris 17, France*

The dimension given to each department reacts upon the sales;

Every store disposes of a fixed set of furniture, not very variable;

Which distribution, i.e., the repartition of items on furniture, would maximize the total store sale?

At first sight, the problem consists in searching for the laws of variation of a department sales as a function of its dimension. But statistical analysis of the past events, and experiments carried out according to a factorial design have not made it possible to establish these laws.

A solution has been obtained by a method of simultaneous research for both the results and the data. This method minimizes the risks of mismanagement, and moreover makes clear a policy for department seasonal setting.

The probable data are condensed into a set of hypothesis-graphs: electronic computations on a sample, out of several thousands of cases built from the various assumptions, have permitted to draw out the laws of sale variations, the distribution, and its sensitiveness to these assumptions.

C5. Some Applications of Operations-Research in a Large Problem of Integrated Distribution of Food Products, J. BARACHE, and J. MELESE, A.U.R. O.C., Paris, France

The studies described are the development of a method for finding out the number, size and best location of store-houses which ensure the minimum cost of distribution. There are several factories in given places, and customers are both wholesale and retail dealers.

Products are transported from the factories to the store-houses by rail, and from the store-houses to the customers by a fleet of trucks.

The method involves both graphic and analytical solutions, and the utilization of a pattern of delivery by trucks in different types of regions.

C6. A Test for Determining an Optimum Point of Quality, PURNELL H. BENSON, Drew University, Madison, N. J., and FRANCIS J. PILGRIM, Quarter-master Food and Container Institute, Chicago, Illinois

The search for an optimum product form frequently consists of trial and error consumer testing of alternatives thought to be near the optimum. Since the alternatives often appear almost alike, statistically significant differences in preference may not be found, and if found, it is uncertain whether the alternatives compared include the optimum.

An OR approach is to measure consumer preference at different points along qualitative dimensions and to establish a function relating degree of preference to various amounts of product qualities. The maximum of this function specifies the optimum qualities for the product. Computation of the standard error of the optimum in terms of sample variances defines confidence limits for the test.

An OR study is reported in which the optimum time-temperature integral (F_0 value) for canning pork and gravy is determined for maximum palatability on the hedonic preference scale.

D1. Control of Finished Goods Inventory in a Distribution System—A Case History, D. G. MALCOLM, Booz, Allen and Hamilton, 135 S. LaSalle St. Chicago 3, Illinois

This study describes the development of a system for determining optimum finished goods inventory levels in a national distribution system. Levels for each item in inventory based on the criterion of least total cost are determined from the model used which includes simultaneous consideration of inventory carrying, ordering and runout costs. Variable lead time along with a non-normal, non-poisson demand are included in the analysis. The order point and order quantity for the expected ranges of the above parameters have been tabulated.

Presentation of this case history will include discussion of the broad setting of the problem, the preliminary analysis and feasibility study, problems in forming the team and building the model, the nature and collection of cost information and solution of the model. The discussion will also include estimates of the savings from the proposed system and a comparison with other possible systems that might be used. Finally, the education and training employed in the pilot installation and the role of the computer are indicated.

D2. Mathematical Analysis of an Inventory Case, CHARLES E. CLARK, Booz, Allen and Hamilton, Chicago, Illinois

The mathematical difficulties arose from the facts that (1) the demand was skewed, (2) there were many warehouses that could help each other when stock levels became low, and (3) tens of thousands of inventory control levels had to be set each year economically.

D3. Control of Finished Goods Inventory in a Distribution System—An Alternate Solution, CLINTON J. ANCKER, Jr., Applied Research, Inc., 135 S. LaSalle St. Chicago 3, Illinois

A model for inventory control and a numerical solution is described in a paper by D. G. Malcolm entitled, "CONTROL OF FINISHED GOODS INVENTORY IN A DISTRIBUTION SYSTEM—A CASE HISTORY". This paper offers an alternate solution to the same model based on:

- 1) determination of an explicit expression for one of the quantities of the solution in terms of known, tabulated functions.
- 2) a simple graphical presentation of the results.

D4. An Analysis of a Paper Company, ROGER R. CRANE, and JAMES E. SEITZ, Touche, Niven, Bailey and Smart, 1380 National Bank Bldg., Detroit 26 Michigan

This paper includes: (1) an analysis of the interdependency of sales and mill management functions; (2) the development of a model of a paper mill; (3) the use of the model as a technique for centralized production planning and control for: (a) mill loading and scheduling, (b) mill balancing, and (c) long and short range facilities and sales planning.

D5. Scale of Operations—An Empirical Study, EDWARD H. BOWMAN,
Massachusetts Institute of Technology, Cambridge, Massachusetts

The study concerns the optimum size of an ice cream branch plant and territory. The company operated ten plants covering a seven state area. At the time of the study, management was uncertain as to even the approximate size of an optimum plant. The study revealed that about six larger plants would be a better system. The company now operates six plants and is considering cutting this number still further.

E1. Operations Research in the Area of Organization and Communication Theory, ARTHUR A. BROWN,
Arthur D. Little, Inc., Thirty Memorial Drive, Cambridge, Mass.

Every organization is in some sense an organism, which functions in an external environment and reacts to the environment in accordance with a characteristic "physiology". The freedom of the executive to choose and direct a course of action is limited by the capabilities of the organization, and these depend both on the material structure (physical facilities, processes, geographical relationships, etc.) and on the information network, which together determine the physiology of the organization. When the delegation of responsibility and the delineation of limits of action are properly related to the capabilities and structure of the organization as a whole, maximum efficiency can be realized and interpersonal friction kept to a minimum.

The methods and modes of thought of operations research can be, and have been, brought to bear on problems of organization and communication. In particular, study of the probabilistic factors leads to a rational and quantitative definition of limits of action, and study of physical and communication factors leads to a rational and workable timetable for planning and scheduling.

This paper illustrates, by way of a case history compounded from several actual instances, the lines of attack which have proved fruitful. Some tentative suggestions are made as to probable future developments.

E2. On Stochastic Theories of Organizations and the Study of Complex Systems, DAVID ROSENBLATT,
American University, 1901 F St., Washington, D. C.

This paper treats further aspects of a formal postulational system OFK which provides a calculus in which to formulate general models of behavioral interaction of "entities" in organizations. The calculus OFK which is stated in the language of operator theory and of stochastic processes leads to the representation of an organization as a complex whose structure and behavior are governed by interdependent (finite-dimensional) discrete time parameter stochastic processes. The component processes are in general non-stationary and non-Markovian. The general approach may be related to the conception of treating a complex of interdependent stochastic "Turing machines", in which interest centers on the behavioral evolution of the complex in time and on the detailed properties of cross-section and time averages. The consequences of the following result are con-

sidered: all models expressible in the calculus OFK can be essentially formulated in terms of finite Markov chains and their graphs. Expository illustrations are drawn from the following areas: inter-industrial (input-output) and inter-sectoral economic representations; aggregation and consolidation of stochastic and balanced accounting flow systems; response reliability in statistical reporting systems; incentive-learning-control schemata of "work-measurement" variety; dynamic models of interdependent consumer behavior; communication representations; "organizational equilibria"; complex systems.

E3. Operations Research Determines the "Best" Method of Teletypewriter Switching, DONALD J. KRANZ, *Stromberg-Carlson Company, 100 Carlson Rd., Rochester, N. Y.*

A large scale digital computer is used to simulate in detail the switching and processing of teletypewriter messages through a military relay station. The simulation is as nearly on a real time basis as is practical with a digital computer. The number of messages in addition to their characteristics of origin, precedence, length, multiple address, and destination, are determined during the simulation by random number generations associated with either assumed or observed distributions. The simulated switching and processing of messages is performed with detailed adherence to present or proposed electronic techniques. In this manner the operational performance of each of forty-eight possible switching systems is accurately evaluated for any set of traffic parameters.

E4. A Mathematical Model of Static Hierarchy, RAYMOND H. BURROS, *Technical Operations, Inc., Fort Monroe, Virginia*

The model is an admittedly oversimplified description of a real hierarchy. It presents mutual restrictions between some structural variables which would be included among the input variables of a dynamic model. Formulas are deduced for both lower and upper bounds of the total number of echelons and the total number of leaders in a hierarchy. These bounds are functions of the total number of operating units, each reporting to a leader at the lowest echelon, and the lower and upper bounds of the control ratio, i. e., the average number of leaders at any echelon reporting to leaders at the next higher echelon.

E5. On the Application of Dynamic Programming to the Determination of the Utility of a Communication Channel, RICHARD BELLMAN and ROBERT KALABA, *The Rand Corporation, Santa Monica, California*

In this paper we show that the fundamental problem of determining the utility of a communication channel in conveying information may be viewed as a problem within the framework of multi-stage decision processes of stochastic type and as such may be treated by means of the theory of dynamic programming.

Following a brief discussion of some aspects of the general problem in terms of multi-stage decision processes, we discuss a recent model of Kelly's in which it was shown that the capacity of a noisy channel, as defined by Shannon, can be obtained from consideration of a certain multi-stage decision process with an economic criterion. Using functional equation techniques we complete Kelly's analy-

sis in several essential points, and we considerably extend his results. In particular, we show how to treat a variety of complicating features which can be introduced into the models, including correlation of received signals, messages of finite length, time-dependent channels, and a continuum of signals. A uniform method for treating various criterion functions (expected value, probability of exceeding a prescribed threshold, etc.) is provided.

E6. Utility Value Concepts in the Analysis of Communication Systems, L. S. SCHWARTZ, *New York University, Bronx, N. Y.*

Utility value is a number which expresses arithmetically a relation of preferences. In this paper the utility value concept is used to obtain a criterion for selecting, on a cost basis, one system of communication in preference to another. The utility value analysis is conducted with the aid of tables to show relationships on a value basis between reliabilities and operational conditions. It recognizes the influence of two basic costs: (1) communication cost and (2) risk cost. Communication cost is determined by the magnitudes of the elementary communication resources, power, band-width, and time. Risk cost is concerned with the reliability of system operation and also is a function of the basic communication resources. Risk cost is involved in the reception of information over a communication channel, because there must be decisions according to some criterion. The two basic costs determine utility numbers, a lower utility number being associated with a higher cost. It is noted that the properties of communication and risk utilities indicate a trade-off between them, with increasing reliability associated with decreasing communication utility and increasing risk utility. Total system utility is the sum of these two utilities. The better system has the larger total utility number.

E7. Integrated Data Processing and Operations Research, ALAN O. MANN, *Management Consultant, 530 Westview Street, Philadelphia 19, Pa.*

Integrated Data Processing and Operations Research are both directed at overcoming certain *historical* characteristics in past statistical techniques of organizational control. Integrated Data Processing concentrates on providing greater timeliness of the data used in the decision-making process, in order to make decisions *current* rather than historical. Operations Research uses data largely for formulating models from which to determine future probabilities, so that future decision-making will be more timely and effective.

Both approaches toward a common goal seem to bear certain conceptual interrelationships, which should receive more attention in future work. Both approaches break down into two basic areas, one of principle and the other of application. *Time* is a major factor in all of Integrated Data Processing but seems to be excluded from both areas of a major portion of operations research for commerce and industry.

This paper concludes that time is rightfully excluded from much of Operations Research's formulation of principle, but that it is extensively involved in their actual applications, wherein lie most of the interrelationships with Integrated Data Processing.

F1. The Hospital System: A Note on Functions, Assumptions, and Criteria in Hospital Performance, MELVIN SEEMAN, *The Ohio State University, Columbus, Ohio*

This paper presents an initial approach to a systematic view of the hospital problem. The hospital is seen as an instrument for the performance of seven functions: selection; supply; service; control; communication; discovery; and instruction. These functions are carried out within the terms of a set of assumptions (i.e. "decision rules") which are presumed to be characteristic of the hospital world. A preliminary list of ten such assumptions have been specified. An effort to handle the criterion problem—i.e. the assessment of hospital effectiveness—in the light of these functions and assumptions is presented.

This investigation is supported by a research grant #GN-4784 from the U. S. Public Health Service.

F2. Forecasting Hospital Case Loads, MARK S. BLUMBERG, *Stanford Research Institute, Menlo Park, California*

The principal functions and characteristics of hospital activities are described. Their relationship to planning for hospital facilities is demonstrated. The data needed for projecting hospital requirements on an economic basis are specified, and partially estimated. A new method for projecting requirements for hospital beds is developed which is based on the probability of any given case load occurring. Other methods for making hospital forecasts are compared.

F3. The Hospital as a Supply Mechanism, WILLIAM T. MORRIS, *The Ohio State University, Columbus, Ohio*

This paper discusses the problems encountered in the early stages of research on the hospital viewed as a supply mechanism. The main logistic and economic problems which appear to be common to hospitals are identified and some suggestions for their solution are advanced. Attention is given to the rationalization of logistic problems in relation to patient care, the identification of decision variables, value measurement, criterion construction, and the relevance of "classical" Operations Research techniques.

This investigation is supported by a research grant #GN-4784 from the U. S. Public Health Service.

F4. Hospital Admissions and Discontinuous Stochastic Processes, JAMES E. SMITHSON, *The Ohio State University, Columbus, Ohio*

This is an attempt to formulate research problems in the analytical terms furnished by the theory of discontinuous stochastic processes. Starting with a number of objectives, the degree in which a description of hospital admissions by means of a stochastic model allows an approach to the objectives is discussed. Two sets of admissions data are treated as examples to establish the feasibility of this approach. An application of the theory of waiting lines is proposed. Some limitations of these models are pointed out.

This investigation is supported by a research grant #GN-4784 from the U. S. Public Health Service.

F5. Criteria of Effectiveness for Selection, Training, and Motivation of Hospital Personnel, CHARLES D. FLAGLE, *The Johns Hopkins Hospital, Baltimore 5, Maryland*

A symptom of the organizational problem facing most hospitals is an extremely high turnover rate among some categories of personnel. Many leave during or shortly after indoctrination before rendering any useful service, imposing a continuing burden of recruitment and training.

The nature of this turnover is revealed by comparison of some actual distributions of employment duration with two models which bound the phenomenon. The first is a normal attrition model in which probability of termination is constant and not time dependent, leading to a negative exponential distribution of employment duration. The second is a "tribal flogging" model, in which probability of termination is increased markedly at some stage of the employee's career, yielding a hump in the employment duration distribution.

The similarity of some actual distributions to the second model is shown, and the unfavorable implications are discussed.

G1. Models for Line Haul Rail Operations and the Piggyback Problem, ABE CHARNES, R. SAPOSNIK and V. L. SMITH, *Purdue University, Lafayette Indiana*

G2. Allocation of a Resource to Alternative Probabilistic Demands: Transport Equipment Pool Assignment, V. L. SMITH, R. SAPOSNIK and A. R. LINDEMAN, *Purdue University, Lafayette, Indiana*

G3. Some Comments on Rail-Pavement Vehicles, GLEN D. CAMP, *The George Washington University, Washington, D. C.*

Diversion of a significant fraction of truck and bus traffic, from our overloaded streets and highways to our underloaded railroad tracks, is discussed. Possible means include the "piggyback" train, the rail-van train and the single rail-pavement vehicle operated by its own driver. Some of the advantages and disadvantages of each of these alternatives are discussed and, although further study is required, it is tentatively concluded that the latter is most promising if *only* physical and economic factors are considered. However, use of the single rail-pavement vehicle requires radical departures from traditional practices and the cooperation of several interested groups, and hence there are potential psychological obstacles to its acceptance. If these obstacles can be overcome, advantages to the country as a whole may include the following: reduction of the annual national highway bill of a sum of the order of a billion dollars per year, both by reducing the number of lane-miles required and by permitting lighter construction; faster and less costly transport; reduction of traffic congestion and diesel exhaust fumes in cities; order-of-magnitude improvements in the logistic support of our Armed Forces, during peace or war; etc. For these reasons, it is believed that a thorough study of this scheme is imperative.

G4. Logical Analysis of Division in Phases of Cycles of Four Leg Signalised Intersections, RENE MALCOR, *Directeur Des Services Techniques de la Ville de Marseille—12, rue Coutellerie, Marseille*

The study includes the analysis of the different possible arrangements of phases in signalised level intersections; it is shown that right turns can be neglected and that there are only 7 different arrangements of phases.

The reduction of the number of phases when left turns are forbidden or in the case of one way streets is also studied and a method for the determination of the optimum cycle is given.

Attention is drawn to the analogy between this problem and the problem of multilevel intersections.

G5. Choice of Optimal Highway Policy Under the Condition of Uncertainty Regarding Future Traffic Volumes, RAM VASWANI, *John Jay Hall, Columbia University, New York 27, N. Y.*

The economic evaluation of proposals for highways necessitates making traffic predictions. Once the traffic prediction is made deterministically, the problem of estimation of the most desirable set of highway parameter values can be handled as an optimization problem.

However, the use of statistical techniques for traffic predictions results in probability distributions of sets of traffic volumes. In such case, the problem can be formulated as a statistical decision problem and an optimal solution, based on this formulation, can be derived.

G6. A Technique for the Evaluation of Dollar Cost of Transit Time of Passenger Automobiles to be Used in the Economic Analysis of Highways, RAM VASWANI, *John Jay Hall, Columbia University, New York 27, N. Y.*

The Economic analysis of proposals for construction or improvements of highways necessitates assigning a dollar cost to the transit time of private passenger automobiles, which, in most analyses, is chosen arbitrarily. The American Association of State Highway Officials has recommended the figure of \$1.35 per hour per passenger car. This figure is now widely used.

The stand taken in this paper is that there is no single dollar value of transit time of passenger automobiles which can be used correctly all over the country. The problem (of evaluating this cost) is compared with the Box-Wilson Technique of exploration of response surfaces.

Finally, a technique is proposed which is flexible enough to be used in different situations for deriving the value that should be assigned, in any specific case, to the transit time of passenger automobiles.

H1. Difference Equations which Minimize or Maximize a Discrete Sum Subject to Functional Constraints, ROBERT M. OLIVER, *Massachusetts Institute of Technology, Cambridge, Massachusetts*

In certain cost problems, one encounters the problem of minimizing or maximizing a function $J = \sum_{i=a}^b f_i(y_i, \Delta y_i, \Delta^2 y_i, \dots)$ with respect to the sequence $(y_i, \Delta y_i, \Delta^2 y_i, \dots)$ where there may be restrictions upon the function y_i such as

$$g_t(y_t, \Delta y_t, \Delta^2 y_t, \dots) = 0$$

The necessary conditions which make J stationary are difference equations and are analogous to the differential Euler Equations in the calculus of variations which make the integral, $\int_a^b f(y, y', y'', \dots) dt$ stationary. The effect of fixed or free boundary conditions will be discussed and throughout the lecture simple examples will be given to show the effect of certain functional forms f_t upon the optimal sequence y_t . In particular, inventory and production problems which motivated the research will be shown.

H2. An Algorithm for a Restricted Class of Linear Programming Problems, L. G. MITTEN, *The Ohio State University, Columbus, Ohio*

This paper treats the problem of finding values of the variables $x_1, \dots, x_n$ which minimize (or maximize) the linear criterion function $C = \sum_{i=1}^n c_i x_i$ subject to the restraints $\sum_{i=1}^n a_{1i} x_i = b_1$, $\sum_{i=1}^n a_{2i} x_i = b_2$, and $0 \leq A_i \leq x_i \leq B_i$ ($i = 1, \dots, n$), with a_{1i} (> 0), a_{2i} , A_i , B_i , C_i ($i = 1, \dots, n$) and b_1 given real constants. b_2 may be either a fixed constant or a parameter taking on any number of values. The limited class of linear programming problems so defined includes many important resource allocations, product mix, and other problems. The simple algorithm which is presented has several desirable features:

1. It will handle a relatively large number of variables with comparative ease,
2. It is well adapted to simple computing equipment (e.g., a desk calculator), and
3. Solutions are obtained for *all possible* values of the parameter b_2 .

Complete instructions for carrying out the computations accompany an example.

H3. Multi-Stage Allocation and Limited Warehousing Problems, WILLIAM S. JEWELL, *Dept. of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts*

In considering the problem of distributing a product with very high seasonal demand, the availability of intermediate storage is an important factor. By the use of devices due to Orden and Dantzig, the problem of economical distribution with strict warehousing limitations may be solved as a transportation-type problem.

Many multi-stage problems such as this one may be described as optimizing flow over a capacity-limited network; a slight modification of the Hungarian method is being programmed for machine solution of these problems at M.I.T.

H4. Analog Computers Applied to Operations Research Problems, ALBERT S. JACKSON, *Cornell University, Ithaca, N. Y.*

This paper describes (1) the basic concepts of the electronic analog computer; (2) simulation of economic problems, i.e., using the analog computer's linear and nonlinear operational units to build a dynamic model of the situation under study; (3) a detailed example of the simulation of a single product firm; (4) solution of mathematical models, i.e., performing on an analog computer the mathematical operations required for the solution of a mathematical model such as the linear program model; (5) a detailed example of the solution of both a linear and a nonlinear programming model.

H5. Optimum Distribution of Missiles per Salvo in a Multiple Salvo Defense, DAVID L. JOHNSON, Boeing Airplane Company, Seattle, Washington

A mathematical model is developed which describes the total missile requirement against a single attack by enemy bombers as a function of required attrition, missile kill probability, and the number of salvos. Properties of the missile to bomber ratios for the several salvos are used to determine a simple iterative scheme for arriving at the distribution of missiles per salvo which minimizes the total missile requirement.

H6. Generalized Analysis of Aerial Campaigns Against Strategic Targets, RICHARD SCHAMBERG, The Rand Corporation, Santa Monica, California

This paper describes an analytic technique for direct determination of the outcome of optimal aerial bombing or reconnaissance campaigns against strategic targets, without the customary laborious exploration of variations in attack strategy. The scope of this analysis permits wide latitude in the nature of the strategic campaign and its environment, including the following: the criterion defining an optimum campaign may be that of minimum cost, or minimum air crew loss for a fixed level of target destruction, with or without additional constraints such as specified maximum campaign duration; aircraft losses may be due to enemy area and local defenses, non-combat causes, or due to destruction while on their own base. Several examples are used to illustrate how the analytic method presented here leads to a better understanding of the significant features of strategic campaigns, and their sensitivity to variations in assumptions, than can be gleaned from an essentially empirical study of many individual campaigns.

H7. An Analysis of the Human Factors Components of an Anti-personnel Mine System, GEORGE A. PETERS and C. THOMAS GOLDSMITH, Picatinny Arsenal, Dover, New Jersey

This case study report includes (1) a description of the human factors involved in a weapons system analysis of the effectiveness of anti-personnel mines, (2) some a priori (theoretical) solutions for these components of the system, (3) the actual empirical results obtained from a field test of the probability of visual detection of anti-personnel mine tripwires, and (4) the proposed methodology for empirical solution of other human components in the systems analysis of such land weapons systems.

H8. Model Making in Air Force Programming, CAPTAIN HAROLD BECK, Headquarters United States Air Force, Washington 25, D. C.

The study describes a machine computation system now being installed, which schedules the assignment of aircraft by unit and mission for several years into the future. This requires the allocation of newly produced aircraft by type, model and series to fill stated command-mission requirements, together with the reallocation of the aircraft already possessed. Associated with the program of aircraft inventories is a flying hour program.

These two programs are key documents in the entire Air Force Planning-Budgeting-Operating cycle. They determine when and where units will convert from

older type aircraft to newer models. A considerable part of the Air Force Budget for logistic support is based on these documents or others derived from them.

The study shows how complex "judgment" procedures are replaced by a systematic method suitable for preparation on an electronic computer. The major elements of information are specified and decision procedures are reduced to the application of fixed rules.

H9. A Multistage Sampling Model for Weapons Systems Evaluation, C. H. BOLL and E. O. P. KLEIN, Hughes Aircraft Company, Culver City, California

Many weapon systems analyses can be formulated as zero-sum two-person games, wherein a strategy is an allocation of a resource into the components of a weapon system. A pair of strategies, one for each player, determines a probability distribution with a finite number of parameters on the space of outcomes of a duel between two weapon systems.

The model used for this duel can be described by a multistage sampling plan which:

- i) samples without replacement simultaneously and independently from two populations consisting of at least two kinds of objects, and
- ii) at each stage the probability distribution of the sizes of the samples to be taken depend upon the elements remaining in the two populations.

The probability distribution of the outcome of such a sampling plan is readily approximated by Monte Carlo methods. A computer procedure is described, and statistical tests of significance of the results are given. Convolutions may be used to extend results to larger weapon systems.

The variation of the resources and weapons capabilities gives a family of games. Questions about necessary resources, their allocations, and needed weapons capabilities can best be answered from the values of this family of games, and the good strategies of the players.

II. On Warehousing Problems, WILLIAM PRAGER, Brown University, Providence, R. I.

The warehousing problems considered by Cahn* and Charnes and Cooper† are shown to be generalized Hitchcock distribution problems with mixed boundary conditions and non-positive flows along certain routes. The recognition of this fact leads to a simple procedure for the numerical solution of warehousing problems. In addition to the consideration of multi-part pricing and multi-product trading, This procedure allows the inclusion of storage costs.

12. Computing Tetraethyllead Requirements in the Linear Programming Format, GEORGE B. DANTZIG, The Rand Corporation, Santa Monica, California, T. KAWARATANI and R. J. ULLMAN, Richfield Oil Corporation, 555 S. Flower St., Los Angeles, California

In the formulation of linear programming models that include gasoline blending, it is desirable to take into account the non-linear effect of tetraethyllead addition

* A. S. Cahn, Bull. Amer. Math. Soc. 54 (1948) 1073.

† A. Charnes and W. W. Cooper, Operational Res. Quarterly 6 (1955) 131-172.

on the octane of the blend. A simple procedure will be presented that duplicates the technology of ethyl blending charts in computing the tetraethyllead requirements in the linear programming format.

13. A Model for Determining the Average Service Life of Equipment, ROGER B. ORENSTEEN, *International Business Machines Corporation, 624 S. Michigan Ave., Chicago 5, Illinois*

A model is described which makes use of the age-distribution of equipment inventory for the determination of the average age at retirement from productive service. By means of theorems in renewal theory, relationships are established between average service life and the (1) average survivor age; (2) median survivor age; (3) ratio of average to median survivor age; and (4) depreciation ratio. Graphs are presented for determining the average service life when the equipment is known or assumed to have mortality characteristics of the Iowa Type S_3 ; and when, in addition, the equipment inventory is either held constant in total amount or growing at a uniform rate over time.

14. Two Models in Use at American Greetings, MORRIS J. SOLOMON, *American Greetings Corporation, 1300 W. 78th St., Cleveland 2, Ohio*

The classical economic lot size is deficient in that it gives the minimum cost quantity without reference to the permissible range. Let P equal to a proportion which is tolerable, V the variable cost per unit, and A the average cost per unit at the least cost lot size. By setting $\Delta A = PV$ and solving, a formula is formed for constructing tables giving a permissible range quantity. Such a table can guide operating personnel toward low cost production and at the same time preserve their flexibility.

A model of company growth is presented. This model enables policy makers to project company growth on a consistent basis. It facilitates examination of policies bearing on company growth.

15. Some Probability Models for Inventory Control, HERBERT P. GALLIHER and MAURICE SIMOND, *Massachusetts Institute of Technology, Cambridge, Massachusetts*

1. By an (S, s) system for controlling the inventory of a stocked item is understood one in which maximum inventory is S and a lot of size $S - s$ is reordered when pipeline stock drops to s . The typical variability of actual demand and replenishment times weakens least cost determination of S and s by "Wilson formula" methods, and a generally reliable answer is obtainable only by considering the probability distribution for inventory. In this paper we give formulas for these probabilities for two general classes of applications: (1) Poisson demand, any replenishment time distribution, $S - s > s$, and back ordering is refused; (2) Any distribution of demand, constant replenishment time, any values of S and s , with no demand lost.

2. In practice, demand often is not Poisson. Two families of statistics especially useful in providing simple formulas and fast Monte Carlo simulation are described together with simple practical methods for fitting these statistics to the type of data normally collected of demand.

16. The Optimum Lot Size with a Sales Forecast, MYRON J. GORDON and RAY PHILIP, *Massachusetts Institute of Technology, Cambridge, Massachusetts*

The standard lot size formula assumes that sales will take place at a constant rate per unit time. However, a firm often has an item forecast $s_1, s_2, \dots, s_n$ for the next n months and $\bar{s}$ per month for the indefinite future beyond n . In this case the standard formula does not necessarily provide the optimum size for the lot to be produced currently. The model presented yields the sizes of the current, the next, and of all subsequent lots that minimize the discounted expected inventory cost of satisfying the demand for the item, given the information $s_1, s_2, \dots, s_n$, and $\bar{s}$. It is shown that the size of the lot to be produced currently is optimum. If the projected schedule of future lots should become non-optimum in the light of revised sales forecasts, incorporation of the new information into the model, as it becomes available, will yield the appropriate optimum schedule. The application of the model to items with a seasonal demand is discussed.

17. Economic Safety Stocks, ROBERT G. BROWN, *Arthur D. Little, Inc., 30 Memorial Drive, Cambridge 42, Massachusetts*

An empirical distribution of forecast errors is shown to be applicable to all products in a large class, when scaled by the standard deviation of the demand. This distribution is used to derive a decision rule for economic safety stocks. The cost of a back-order is initially imputed from the normal practice of the company in setting order points.

18. Optimal Decision Rules for an Inventory System with Variable Cost of Ordering, ELIEZER NADDOR, *The Johns Hopkins University, Baltimore, Maryland*, and SID SALTZMAN, *Royal Precision Corporation, Port Chester, N. Y.*

This paper discusses an inventory system where the cost per order is not a constant but is dependent on the number of different items on the order. The problem is to determine how frequently an order should be placed and how many different items should be listed on an order so as to minimize the costs associated with the system. An area for application of this study is discussed and models are developed for four different ordering policies.

19. Some Production Control Formalizations Suitable for Electronic Data Processing, BERNARD GIFFLER, *International Business Machines Research Center, Poughkeepsie, N. Y.*

This report reviews the results of work whose purpose was to formalize several production control activities and to explore their mathematical and computational implications. The particular activities considered relate to the explosion of the total inputs needed to fulfil given production demands and the pyramiding of the costs of the intermediate and final production outputs.

Under the work program compact and rapid computational procedures were developed to serve as a basis for the mechanization of the production control activities either by existing or proposed data processors. These procedures were obtained, for the most part, by exploiting the special character and structure of the bill of materials matrices that serve as the primary data-processing inputs. Be-

cause of their sparseness, these matrices afford several opportunities for reassigning rows and columns to produce many null submatrices that can be subsequently disregarded. Other reassignment possibilities permit the bill of materials matrices to be made triangular in terms of their individual elements or even in terms of their submatrices.

A secondary benefit of the mathematical formalizations is the conciseness and completeness with which they describe the required data processing. These characteristics are very helpful in communicating with the mathematicians and programmers responsible for writing the computer programs.

J2. Statistical Forecasting and Control with High Speed Computers, ZENON SZATROWSKI, *The Service Bureau Corporation, 590 Madison Ave., New York 22, N. Y.*

The problems of forecasting and control are closely related. Forecasting may be the prime objective of a basic study but the resulting information may have even greater value in setting up a control system under dynamic conditions.

Models involving multiple and auto-regression may be quite adequate in determining lagged relationships which can be used in forecasting. The applicability of high speed computers, such as the IBM 704, for this kind of analysis is based not so much on the feasibility of processing large quantities of data but on the possibility of using complex models which are realistic. Various large combinations of variables, lags, transformations and interactions can be treated. Also, with high speed computers, it is possible to make more adequate statistical analysis of the suitability of the model and data and the significance of the results. For this purpose an analysis of the residual variance is necessary, but the residual analysis also provides a basis for setting up a control system. Thus, the forecasting formulas yield estimates of what to expect. On the other hand, the analysis of actual developments, in comparison with the calculated results, provides information as to whether actual performance is consistent with expectations. Consistency would imply a system under control, whereas inconsistency would imply either a significant development or inadequacy of the model in describing the new relationships.

Applications of the above approach and analysis have been made in market research, time series analysis, production process control, etc.

J3. Use of the Computer in Computer Design, JOHN H. WAITE, JR., *Radio Corporation of America, Camden 2, New Jersey*

This paper represents an attempt to expand the use of computers as engineering tools. It is in a sense a case of design methods research undertaken jointly by programmers and equipment design engineers.

It appears possible to use a digital computer as a design tool in the following phases of computer design and manufacture.

- (a) Logic synthesis and optimization
- (b) Logic design verification
- (c) Wiring schedules
- (d) Hardware tests

- (e) Error identification and isolation
- (f) Equipment modification and test thereof

From a very practical viewpoint, the problem of creating wiring schedules was first undertaken because the previous methods represented a rather time consuming and tedious use of valuable engineering talent.

J4. Use of Computation Facilities for Mechanized Literature Processing in Research Libraries, RUSSELL COILE and BABA FOSTER, *Defense Research Staff, Massachusetts Institute of Technology, Cambridge, Massachusetts*

Operations research groups and research laboratories usually have modern computers or access to them. These computation facilities might well be examined for possible use in mechanized literature processing. Documentation techniques have been developed for computing machines to carry out routine literature searching and preparation of bibliographies with minimum time and effort on the part of scientific staff members. In the multi-concept post-combination system used, the computing machine searches through a portion or all of the documents listed in its storage and selects only those items with the desired combination of concepts. The measures of effectiveness considered include the efficiency of information retrieval and the signal to noise ratio.

The Harwell punched card indexing experiment and recent operations research in library operations have indicated the importance of analyzing how research personnel use their library. In the present system punched cards are used both for input to computing facilities and for manual card catalogs. Microfilm inserts in the cards allow the equivalent of four pages of abstracts and summary information in graphical or mathematical form to be displayed in card catalogs. The scientific staff can thus be furnished with either (a) title listings; (b) microfilm abstracts; (c) enlargements of microfilm abstracts; or (d) the documents.

J5. An Application of General Plant Account Theory to the Fitting of a Survivor Curve to a Physical Group Property Account Stub Life Table, BARNARD H. BISSINGER, *Lebanon Valley College, Annville, Pennsylvania*

The life table for an actual public utility account is developed by the retirement ratio technique. The data provide only a stub table and the curve fitted by an engineering group is given. In conjunction with a consideration of the trend of the plant balance, a consideration of the limiting age distribution of the exposed dollars may replace the engineering judgment needed to fill out the survivor curve's tail-end for which there is no supporting data. A transform curve of an Iowa curve is used to illustrate the method. Tail-end data is thereby made available for curve fitting.

J6. The Place of Psychology in Operations Research, GEORGE D. CREELMAN and RICHARD WALLEN, *Creelman Associates, 10524 Wilbur Ave., Cleveland 6, Ohio*

The desirability of using psychologists and other social scientists in operations research has been noted from time to time in operations research literature. To date, however, psychology has been neglected by OR workers.

A study of the citations in *Operations Research* shows that articles citing mathematical literature are about six times more frequent than those citing psychological books and papers.

Since human factors are important in OR projects, more use of psychologists should be made. They can contribute to model building by suggesting such variables as rate of learning, subjective probabilities, degree of annoyance, preferences, and values. They can also develop methods for measuring such variables.

In practice, operations research requires careful work with management during the phase of problem identification and formulation. Here, psychologists with clinical diagnostic and interviewing skills can be useful. During the team problem-solving phase, skill in group dynamics training will be helpful. In evaluating the outcomes of decisions, the psychologist's ability to construct questionnaires and tests may be needed.

J7. A Stochastic Model for the Behavior of a Set of Price Index-Numbers and Its Applications, ANDRE G. LAURENT, Michigan State University, East Lansing, Michigan

Let X_t be a non-stationary markovian process with expected value zero defined by the stochastic equation, $dX_t = -a(t)X_t dt + K(t)\lambda\sqrt{dt}$, and its "approximation" during a short interval of time, $dX_t = -aX_t dt + K\lambda\sqrt{dt}$, with λ normally distributed $N(0, 1)$ independent of X_t . There is a strong empirical evidence that, during "normal" periods, the centered logarithms of the price index-numbers of a "homogeneous" set of products tend to behave like replicates of X_t . This makes it possible to describe the evolution of the set by the mean $m(t)$, $a(t)$, and $K(t)$. In case $a \leq 0$ the process tends to explode, in case $a > 0$ there is a tendency to an asymptotic equilibrium. Short periods can be classified according to whether $m(t)$ is increasing or decreasing and whether a is positive or negative; an interpretation of the resulting categories from the viewpoint of economics is suggested and hypotheses about the characterisation of predepression periods are formulated. The problem of estimating the parameters is studied.

J8. Development of Methods for the Estimation of Outcomes of Alternative Techniques of Safety Education, ROBERT J. SCHREIBER, Dunlap and Associates, Inc., 429 Atlantic St., Stamford, Conn.

Every industrial safety administrator is repetitively confronted with the following decision problem: which alternative safety education technique (e.g. poster or film) should be used. The choice is made on the basis of the expected outcomes of each alternative. The objective of this study is to develop methods for estimating one of the more important outcomes of each alternative, the change in unsafe behavior.

The most important outcome is usually thought to be the reduction in accidents, but it is shown that this outcome is a result of both unsafe behavior and unsafe environments, only the first of which is a function of the decision. Therefore, methods of measuring change in unsafe behavior are developed based on observation of the incidence of unsafe behavior. These methods include data collection and analysis procedures.

Several applications are described wherein it is shown that the larger and more frequent changes in behavior follow unplanned events and that the standard safety techniques showed little or no changes.

J9. The Analysis of Engineering Manpower Requirements, SUMNER N. LEVINE, American Machine and Foundry Company, and University of Connecticut, Greenwich, Connecticut

The problems associated with the classification of engineering design and development problems are discussed. (2) The design activities are resolved into certain subtasks which are defined in terms of a manhour probability density function. (3) A model is proposed relating the subtasks. (4) Analysis of the model provides a set of relationships between the assigned manhours and the actual manpower utilization such that a minimum utilization of engineering manhours will be realized. (5) On the basis of this result a general procedure is developed for the planning of design and development programs. (6) Certain problems associated with the utilization of the procedure are discussed.

J10. Three Examples of Operations Research in a Life Insurance Company, LOUIS L. MILLER, Acacia Mutual Life Insurance Company, 51 Louisiana Ave., Washington 1, D. C.

The studies described are (1) the development of models and construction of tables of probability of survival of men hired as life insurance agents, which, together with annual graduated sales volume, subsidy costs, and market differentials, permit highly accurate forecasts of manpower and production results, as well as development costs; (2) the effect of hiring rate and market differential on the probability of survival of new salesmen; (3) determination of the combinations of recruiting (hiring) rate and market environment which results in optimum total development cost.

J11. Use of a Value-of-Money Concept in Operations Research, WILLIAM N. HOSLEY, Eastman Kodak Company, Rochester, N. Y.

This paper suggests that long-range profits is one of the principal goals of every industrial enterprise and that the size of investments in liquid assets, inventories, and capital equipment should be decided with this objective in mind. The value-of-money concept provides an easy method for making profit considerations a part of many operations research projects.

The use of the value-of-money concept is illustrated in the paper by reference to a problem which involves a production unit, the output requirements for which are subject to uncertainty, and which is subject to an uncertain amount of downtime due to mechanical trouble. The solution to this problem prescribes the amount of surplus production capacity, the amount of surplus storage capacity, the personnel complement, and average inventory that are optimum with respect to the profits of the company. The solution is based on the premise that the annual value of money invested in inventories, in storage facilities, and in production equipment is a different and specific percentage of the investment.

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