Operations Research

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

Twelfth National Meeting of the Society—Pittsburgh, Pennsylvania, November 14—15, 1957

To cite this article:
(1958) Twelfth National Meeting of the Society—Pittsburgh, Pennsylvania, November 14—15, 1957. Operations Research 6(1):137-154. https://doi.org/10.1287/opre.6.1.137

Twelfth National Meeting of the Society

PITTSBURGH, PENNSYLVANIA, NOVEMBER 14–15, 1957

THE TWELFTH NATIONAL MEETING of the OPERATIONS RESEARCH SOCIETY OF AMERICA was held at the Penn-Sheraton Hotel in Pittsburgh on November 14–15, 1957, with 383 registrants, of whom 140 were non-members, attending the seven sessions The titles of these sessions are listed below, together with the Chairmen .

A Urban Planning	J DOUGLAS CARROLL, JR * Chicago Area Transportation Study
B Corporate Planning	MELVILLE C BRANCH Ramo-Wooldridge Corporation
C New Developments Theory	GEORGE E KIMBALL Arthur D Little, Inc
D New Developments Applications	E LEONARD ARNOFF Case Institute of Technology
E Research and Development Planning	CHARLES J HITCH The Rand Corporation
F Organization Planning	RUSSELL L ACKOFF Case Institute of Technology
G General	PHILLIPS WHIDDEN Aluminum Company of America

Social functions consisted of a mixer, two luncheons, and a banquet on the evening of November 14 At the banquet, HERBERT A SIMON of the Carnegie Institute of Technology gave an address on *Administration and OR New Directions for Research* A ladies' program was also arranged with guided tours to points of interest, including industrial plants of the H J Heinz Company and Jones and Laughlin Steel Company

Members of the Program Committee were W W COOPER, *Chairman*, PHILLIPS WHIDDEN, *Chairmen of Local Arrangements*, ROBERT J MONTEVERDE, *Treasurer*, JOHN FOCKLER, *Director of Public Relations*, D S MCARTHUR and WILLIAM KEHL, *Meeting Monitors*, PHILIP HERMANN, *Social Activities*, J LEE O'NAN, *Secretary*, CHARLES J HITCH, JOSEPH MCCLOSKEY, and BARRY M ROWLES In addition, KENNETH J ARROW, Stanford University, should be given credit for organizing Session C

Special acknowledgement is due the Aluminum Company of America for its help The Pittsburgh Registration Bureau provided clerical assistance and COLONEL E H GALLUP of the Penn-Sheraton supplied further help and facilities

---

* JOHN DYCKMAN of the University of Pennsylvania served as substitute chairman

FRANK NICOLLAZO administered the press room and helped the monitors when required

Abstracts of the papers presented follow the Reports of the Secretary and of the International Cooperation Committee

REPORT OF THE SECRETARY

THE MEMBERSHIP of the SOCIETY on October 31, 1957, was 2,226, as compared with 2,009 on April 30 of the same year Of the October 1957 membership, 810 were Members, 1,287 were Associate Members, and 129 were Student Associate Members At its meeting on November 14, 1957, the Council elected the following 40 new Members

H C ALBERTS
PHILLIP V ARONSON
WALLACE E BARNES
FREDERICK C BOCK
SALVADOR F CARDONA
R H CASTON
NED CHAPIN
CLIFFORD J CRAFT
SIDNEY DAVIDSON
RICHARD H DAVIS
HARRY D DUNN
STANLEY H GAFFEN
LOUIS A HARTHEIMER
ELTON C HELFRICH
JOHN G HONIG
EDGAR M JACOBS
IRWIN KATZMAN
PAUL E KLEBE, JR
HUBERT W LILLIEFORS
RICHARD F LINK
THOMAS P G LIVERMAN
RICHARD M LONGMIRE
MARVIN L LUTHER
WILLIAM MIEHLE
LOUIS L MILLER
R J MONTEVERDE
L C PLEGER
P RATOOSH
W E REESE
THOMAS C ROWAN
G M SCHROEDTER
K L SHERMAN
R C SINGLETON
ROBERT P SMITH
HILLEL SPITZ
R M WARFIELD
A H WARNER
H R W WATKINS
C G WELLING
H B WOLFE

During the same period, nonmember subscriptions to OPERATIONS RESEARCH increased from 1,514 to 1,915

A meeting of the SOCIETY was held in Pittsburgh, Pennsylvania, November 14–15, 1957, with 383 registrants Future meetings are planned in Boston, Massachusetts, May 15–16, 1958, and in St Louis, Missouri, in November 1958 The Meeting Committee Chairman for the Boston Meeting is DR H P GALLIHER, JR, and for the St Louis Meeting, DR O G HAYWOOD The Annual Meeting in May 1959 is planned for Washington, D C, no meeting chairman has yet been selected

At the Council Meeting in Pittsburgh, several actions were taken to ensure that members of the SOCIETY will benefit to the greatest extent possible from the So-

CIETY's various publishing ventures These included a decision to distribute a copy of the *Proceedings of the International Conference on Operational Research* at Oxford to all members of the SOCIETY at no charge, and a decision to make available to members, at a 25 per cent discount from list price, books in the series PUBLICATIONS IN OPERATIONS RESEARCH being published by John Wiley for the SOCIETY, with this discount applicable to only one copy of each title ordered by an individual member The SOCIETY has also authorized some additional funds to complete the classifications in the *Bibliography of Operations-Research Literature*, being prepared by the Case Institute of Technology, and to prepare this material on IBM cards The printed *Bibliography* will appear in the PUBLICATIONS series, while the sets of cards will be offered for sale by the *Business Manager* of the SOCIETY

Two proposed Constitutional amendments, which are designed to improve the timing of our elections and the voting procedures in cases where the number of candidates for an office is large, were approved for preliminary submission to the membership Material on these proposals will be made available prior to the next Business Meeting

The Council appointed DR T L PAGE as the Representative of the SOCIETY for discussions with the Operational Research Society (U K) and the Société Française de Recherche Opérationelle, concerning the formation of an international federation of operations research societies, and Dr Page was provided with instructions urging that preliminary steps for such a federation be undertaken as soon as practicable Since this matter also affects the attitude of our SOCIETY toward the formation of ORSA Sections outside of the United States and Canada, a general statement of ORSA attitude was passed to the effect that (*a*) Such Sections will be authorized and recognized in accordance with normal procedures (*b*) However, it is generally felt that action by ORSA should seek to encourage the growth of independent national societies, rather than the spreading of international ORSA Sections (*c*) The SOCIETY desires, on an individual basis, to provide practical assistance to national groups seeking to organize such societies

In continuing efforts to improve SOCIETY meetings, a decision was reached to encourage the Chairmen of future meetings to make use of the custom of reading papers by title (and publishing abstracts in the Program), as necessary in order to achieve well-balanced programs It was the sense of the Council that abstracts of *all* papers submitted by, or sponsored by, members of the SOCIETY should appear in the Meeting Program as a matter of record

The Council desired that the excellent work of the Nominating Committee and of the International Conference Committee be noted and commended, and in particular desired that an official expression of appreciation be provided MR J H LEWIS, for his excellent work in providing liaison with the ORS(UK) in connection with the organization of the International Conference held in Oxford, England on September 2–6, 1957

MARTIN L ERNST, *Secretary*

REPORT OF THE INTERNATIONAL COOPERATION COMMITTEE

THE COUNCIL established a Committee on International Cooperation in May of 1957 The task of this Committee is to explore ways in which ORSA can promote the development and use of operations research in other countries, especially those which we characterize as 'underdeveloped ' While some approaches to this work will require help from outside of the SOCIETY, there are at least four areas in which we may be able to operate unaided In order to assess the practicality of these proposals, the Committee is seeking expressions of interest from members of the SOCIETY We will also appreciate hearing from all who are interested in the subject of international cooperation

The four areas for which we need to assess interest are the following

1. *Supplying literature for libraries where a lack of either adequate current interest or foreign exchange precludes purchase of American Journals concerned with operations research* While we hope to be able to arrange for subscriptions of our journal to be sent to a limited number of carefully selected foreign organizations, we do not expect to be able to purchase back issues, or other publications bearing on operations research We would like to know if there are individuals who would be willing to sacrifice their own issues for the benefit of international operations research These volumes could carry a donor's inscription, if desired Transportation responsibilities would be borne by the SOCIETY The Committee would also like to receive suggestions for institutions which might be candidates for assistance in this literature program

2. *Maintaining a roster of Society members' travels abroad* It is felt that such a roster might prove of value in many ways Records of past travels could be of use to future travelers Present and planned itineraries could be used for making contacts and asking that information be gathered In order to estimate the magnitude of the task involved and the usefulness of the roster, we would like to establish it on a trial basis and hence request that individuals who have traveled or are going to travel (excluding trips to Great Britain and France for the time being) inform us of their trip dates, places and individuals with whom they have dealt or expect to deal Individuals desiring to make use of this roster can send their inquiries now, for reply when and if information becomes available

3. *Maintaining a roster of individuals interested in operations research* This roster would have a twofold purpose It could be used by those about to travel in foreign lands, to provide contacts, it would also serve to help identify locations where our literature program might be most profitable, areas in which a nucleus of interested individuals has formed As in the case of Item **2,** we would like to try this roster to see if it warrants recommendation for permanent establishment Anyone knowing of individuals who are interested in operations research and who live outside of the United States, Canada, Great Britain and France, is asked to provide the Committee with appropriate information

4. *Setting up a clearinghouse for foreign job opportunities* It has been suggested that the Society might set up a clearinghouse that would maintain a list of jobs open in foreign lands and a complementary list of individuals possibly interested in such openings At this time, we would simply like to know if there are individuals who would be interested in using such a clearinghouse It would be operated on a basis similar to 'Alumni Placement' organizations

Communications regarding all four of these subjects should be sent to Dr W W Abendroth, Department of Engineering Administration, Case Institute of Technology, Cleveland 6, Ohio

In our search for outside financial assistance for more ambitious projects, it will be of great help to be able to point to substantial accomplishments generated on our own Hence we sincerely hope that those interested will reply, not only with respect to the above proposals, but also with any advice that may assist in carrying out the work of the International Cooperation Committee

W W Abendroth
Glen D Camp
Robert Dorfman
Oscar A Hoffman
Ellis A Johnson
S B Littauer
Charles G McGee, *Chairman*

ABSTRACTS

SESSION A—URBAN PLANNING

A1. Analytic Systems for Metropolitan Planning, RICHARD L. MEIER, *Research Associate in Behavioral Sciences, Mental Health Research Institute, University of Michigan, Ann Arbor, Michigan*

The dominant problem of our burgeoning metropolitan areas is one of growth, growth of population and growth in real income The metropolitan areas are expected to absorb the entire growth of the United States—some 55 million persons by 1957 Real income has shown a growth at the rate of 1¾% per year

The writer's concern is to review the kinds of decisions being made today which are intended to re-integrate the expanding metropolitan agglomeration What are the decisions which seek to bring order out of such growth?

Next then is the problem of strategy for optimizing the development in the future To do this requires a critical review of existing procedures for taking the future into account at the time of decision The importance of proper timing of decisions is considered

Finally, special account is taken of the problems involved in having non-linearities in the usual models used in forecasting urban-metropolitan economic activity

A2. Urban Transportation Planning, HOWARD W. BEVIS, *Transportation Economist,* **and ELIZABETH L. GARDNER,** *Operations Analyst, Chicago Area Transportation Study, 4812 W Madison St, Chicago 44, Illinois*

Decision-making in government becomes more difficult each year as government spending continues to rise and government operations become more complex Hence, greater returns can be expected from the application of modern research methods to urban planning problems This is particularly true of transportation planning because of the accelerated highway-building program and because of the large body of existing techniques

Research in metropolitan transportation has many special problems, however, some of which are covered in this paper Solutions which have been found theoretically sound and practically applicable are illustrated by some of the results of studies in both the Detroit and Chicago areas

Particular attention is given to a statement of the problem The boundaries of the study area and the role of different types of transportation facilities must be defined Objectives and planning criteria must be clearly stated The size of the metropolitan area itself poses many problems in study design, measurement, and data handling

Analyses and forecasts are required of both the level and geographic distribution of the demand for travel, the manner in which people satisfy this demand, and many other tests of urban structure The forecasts must be long-range because of the initial high cost and the long life of the transportation facilities

Finally, given these analyses and forecasts, one must develop a plan that provides the required level of service, maintains an equitable mix of highways and mass transit, provides a balance between high and low speed facilities, and has a least-cost construction schedule

SESSION B—CORPORATE PLANNING

B1. Corporate Long-Range Planning—A Kaleidoscopic Survey, EARLE STEWART, *Senior Engineer, Vertol Aircraft Corporation, Morton, Pennsylvania*

A survey of the field of corporate long-range planning is made in this study of an expanding activity The goals of modern socially responsible corporations are discussed Time-span and organization for long-range planning are brought into the picture Procedures of formalized planning are presented This paper, primarily for management consumption, points out profitable and interesting activities for the mathematician in correlating econometrics, operations research and corporate long-range planning

B2. Prediction and Feedback in Business Planning, W D McEACHRON, Standard Oil Company of Indiana

B3. Relationship between Long- and Short-Range Planning in a Ceramics Factory, MICHEL VERHULST, *Professor of Political and Social Science, Ecole Nationale des Ponts et Chaussées, Paris, France (temporary address, 728 Nottingham Rd , Wilmington, Delaware)*

The comparison of the production scheduling systems which can be visualized in the ceramics factory under study is instructive from the point of view of the accuracy of the determination of the date of delivery and of their influence on the level of inventories The determination of the delivery date should be dependent on the long-range forecasted load of ovens But the short-range scheduling of operations must take into account the precise situation of the resources available and try to insure full use of capacity The distortion between actual and forecasted production influences the level of inventories A method is proposed which brings this distortion to a minimum

B4. Practical Applications of the New Differential Accounting for Planning, BERNARD WHITNEY, *Scientific Business Programs, Inc , 2742 Hollyridge Drive, Hollywood 28, California*

By recording in addition to debits and credits a third entry, namely the differential balance, accounting will reflect business activities in dynamic form With this feature incorporated, financial reports can show the flow of assets and liabilities and the causation of every change They become a better management tool for analysis and prediction Actual application in several large companies will be demonstrated

SESSION C—NEW DEVELOPMENTS: THEORY

C1. The Influence of Time Lags on Inventory Policies, HERBERT SCARF, *The RAND Corporation, 1700 Main Street, Santa Monica, California*

One of the most important reasons for holding inventories is the existence of a time lag in delivery In some cases, when this lag is sufficiently short, the inventory problem may be replaced by one in which no lag exists In general, however, time lags must be taken into consideration in the selection of an inventory policy

The influence of a time lag is crucially dependent upon the treatment of excess demand over supply If we assume that excess demand may be deferred until future supply is available, then the optimal inventory policy is a function of stock on hand plus total incoming stock, and its determination may be reduced to a problem in which essentially no time lag exists On the other hand, if excess demand is either lost or satisfied by priority shipment, the optimal policy is considerably more complex In this case, if the time lag is moderately long, the calculation of optimal inventory policies exceeds the capacities of high speed computing machines, and other procedures must be used

C2. The Coordination of Interacting Decisions: An Employment, Production, and Inventory Example, CHARLES C. HOLT, *Associate Professor, Carnegie Institute of Technology, Pittsburgh 13, Pa*

When a large number of interacting decisions need to be made in a situation involving dynamic costs and an uncertain future, the problem of making good decisions tends to become complex and unwieldy even when mathematical methods are used Quadratic cost functions are unique in facilitating in a number of important respects the solution of such decision problems Their mathematical simplicity and flexibility enables the analyst to concentrate his attention on the decision problem at hand without great risk of becoming involved in an intractable mathematical problem Usually linear decision rules can be obtained that with a few minutes of calculation will yield optimal decisions

A decision method that is based on quadratic cost (criterion) functions will be illustrated by applying it to certain operating problems which have been encountered in several factory warehouse systems involving production, employment, and inventory control decisions

C3. Quadratic Programming and Its Application, H. S. HOUTHAKKER, *Professor of Economics, Stanford University and Massachusetts Institute of Technology*

Quadratic programming is concerned with maximizing a quadratic function constrained by linear equalities and inequalities, usually including a restriction to non-negative variables It is a natural extension of linear programming, but more in accordance with traditional economic theory because it permits attention to the demand side as well as to technological characteristics Algorithms for quadratic programming have been proposed by Dorfman, Frank and Wolfe, Markowitz, and the author They may be interpreted as parametric variants of the simplex method based on duality

Quadratic programming can be applied to a great variety of problems, mostly arising from output planning under monopolistic competition or monopoly Important applications are the allocation of capacity costs in public utilities and railroads It is also relevant to the planning of economic development on a national scale

C4. Application of Linear Programming to the Determination of Information Rate of a Communication System, LENARD S. SCHWARTZ, *Project Director, College of Engineering, New York University, New York 53, New York*

This paper considers a linear programming method for determining the information rate of a communication system when the messages consist of symbols of

unequal importance, i e , of unequal utility If the probabilities of alteration by noise are the same for all symbol positions, alterations of symbols in positions of greater importance result in greater loss in utility value than alterations in positions of lesser importance The paper shows how the utility value associated with symbol importance can be given an information measure and how this measure can be used to find the conditions under which losses in information resulting from noise can be made the same for all symbol positions This condition is achieved by an appropriate allocation of power, bandwidth, and time Once the conditions for error equalization have been formulated and the total available power, bandwidth, and time given, the most efficient division of the message time among the different categories of symbol importance can be specified This is done by the method of linear programming It is shown that this procedure is equivalent to a maximization of the information rate for a prescribed reliability

C5. Jockeying in Queues, HERBERT GLAZER, *Touche, Niven Bailey & Smart, 233 Broadway, New York 7, New York*

The state probability method considers changes in queue size to be state changes of a system It is possible to consider the system in the presence of an external "field" which can interact with the system and result in transitions between adjacent states The external field is here considered to be the presence of other queues The state transitions in the queue in question will be a result of customers switching or "jockeying" between queues

It is assumed that the strength of the external field will be a function of the line lengths of adjacent queues and that transitions will occur when there is a difference between the lengths of adjacent lines The rate at which transitions occur will be governed by the line lengths The equations of chemical kinetics (Moelwyn-Hughes, Physical Chemistry, Cambridge 1951) are used to describe a number of transition mechanisms and their rates

SESSION D—NEW DEVELOPMENT: APPLICATIONS

D1. Application of Operations Research in Farm Operations and Agricultural Marketing, CHARLES E. FRENCH, MILTON M. SNODGRASS, and JAMES C. SNYDER, *Agricultural Economics Department, Purdue University, Lafayette, Indiana*

Use of operations research, particularly linear programming, in agriculture generally dates back to 1951 However, in the last two or three years rather broad applications have been made on farm problems Also industrial management and marketing problems of agricultural processors and marketing institutions have been tackled Purdue University, Iowa State University, and University of Illinois have probably done the most The paper gives a rather complete general survey of these agricultural applications including the game theory studies at Oklahoma A and M College Although it does not go into detail, the paper will be thoroughly referenced and the authors stand ready during the discussion period to answer any detailed questions

D2. The Determination of Optimum Lot Sizes in the Aircraft Industry, **JOHN C. CHAMBERS and ANGUS F. BOND,** *Case Institute of Technology, Cleveland, Ohio,* **and JAMES H. LEAKE,** *North American Aviation, Inc , Columbus Division, Columbus, Ohio*

A case study conducted at North American Aviation, Inc , concerning the determination of lot sizes for detailed aircraft parts is described In most inventory situations, obsolescence is either ignored or a constant factor is included in the inventory-carrying cost to account for obsolescence However, the high obsolescence rate of detailed parts in the aircraft industry necessitates a more precise consideration of obsolescence A method is developed for evaluating and including obsolescence costs in an inventory model Other important and unusual factors in this inventory situation are (1) a demand rate that increases irregularly until the maximum rate is reached and (2) splitting of lots in the shop

D3. The Organization and Operation of a Taxi Fleet, **RICHARD F. MEYER and HARRY B. WOLFE,** *Arthur D Little, Inc , Cambridge, Massachusetts*

In dispatching a taxi fleet in order to meet random customer demand, two types of strategies must be defined

1 The "idle time strategy", which determines how the idle taxis are to be distributed most advantageously for meeting future demand, and

2 The "dispatching strategy", the rule which chooses the taxi to satisfy a given call

The effect of dispatching and idle time strategies on taxi utilization and on passenger service is demonstrated under three conditions of operation In Part I, the simplest of all possible taxi models is examined random demand between two points serviced by one taxi Part II considers the effect of different strategies on the operation of a taxi fleet which is experiencing demand uniformly distributed in a two-dimensional region Part III compares the main features of these simplified models with the results of a Monte Carlo simulation of taxi service between a number of discrete points

The purpose is to provide methods to determine the payoff in customer waiting times and/or taxi savings resulting from more sophisticated dispatching and idle time strategies

D4. An Aircraft Engine Overhaul Model and Its Application in Airline Operation, **T. K. KOLNER,** *Supervisor of Power Plant Engineering, Trans World Airlines, Inc , Mid-Continent International Airport, Parkville, Missouri*

The paper outlines the construction of a model for aircraft engine overhaul The model is constructed from performance factors generally used in the air transport industry and unit overhaul costs Application of model

1 Forecast amount of gain (or loss) resulting from extending the maximum permissible operating time between overhauls

2 Determine what maximum permissible time between overhaul yields the lowest overhaul cost

3 Justify corrective actions to improve engine performance

4 Determine when overhaul in place of repair is economically advantageous

D5. A Model of Heterogeneous Transportation Costs, MORTON J. ROSSMAN, and RAYMOND J. TWERY, *Peat, Marwick, Mitchell & Co , 10 South LaSalle Street, Chicago 3, Illinois*

This case study involved shipments by rail, truck, parcel post and third class mail Rail and truck shipments were made on a carload (truckload) basis or by LCL (LTL) Minimum freight charges were also involved

The problem was complicated by a large number of origins and destinations, and a still larger number of potential origins The volume of shipments runs into hundreds of thousands per year

The techniques of statistical sampling were used in the development of a model to limit the actual examination of individual shipments to a relatively small number

D6. A Dynamic Programming Model for Optimal Manpower Loading in a Large Aircraft Company, ALBERT B. BISHOP, *Ass't Prof , Department of Industrial Engineering, Ohio State University, Columbus 10, Ohio*

A dynamic programming model is developed for the determination of optimal manpower schedules in a large aircraft plant The basic model consists of a cost equation representing the weekly costs of obtaining, utilizing, and disposing of various categories of personnel Losses in efficiency in weeks following transfers among jobs or hiring of new men are included The optimum schedule is that which minimizes the sum of the weekly costs over an arbitrary scheduling period for a given forecast demand Computation of the minimum-cost schedule is accomplished by use of dynamic programming This formulation of the problem

1 leads directly to the optimum solution,
2 is independent of the functional form of the cost equation,
3 can utilize tabular data directly without the necessity of curve-fitting,
4 permits ready adjustment for changes in process parameters and demand forecasts, and
5 is readily programmed for computer solution but if need be can be carried out manually with some simple computational aids

The procedure is illustrated for a hypothetical demand curve and a representative cost equation

D7. Application of Queuing Theory to Plant Design and Operation, ALBERT M. STOVER, *Ass't to Director of Research and Development, Naugatuck Chemical Division, United States Rubber Company, Naugatuck, Connecticut*

In one of the production plants, a battery of reactors discharges batches in a random pattern to a bank of stills for further processing for variable time intervals Any one batch from the first bank of reactors could be routed to any one of the 13 stills in the second bank

Theoretical plant capacity was never obtained because quite often all 13 stills were busy and a batch had to wait in the first reactor, thus causing lost production time

This is similar to a queuing problem with 13 service stations

Application of queuing theory equations accurately predicted the probable total lost time in machine hours per month due to this clogging

The production expansion proposed more reactors in the first bank and shorter cycles, both of which would aggravate the problem It was also proposed to shorten the cycles in the second part of the operation to improve the situation, and to install holding tanks so as not to tie up reactors in the first bank if all 13 stills in the second bank were busy

Feeding data on a proposed plant expansion into *modified* classical queuing equations predicted that the new arrangement should operate at design capacity

SESSION E—RESEARCH AND DEVELOPMENT PLANNING

E1. Operations Research and the Planning of Communication Systems, BROCKWAY McMILLAN, *Bell Telephone Laboratories, Inc , New York, New York*

An important element in planning the development program of the Bell Telephone Laboratories, Incorporated, is the selection of specific communication systems to be developed for manufacture and use Responsibility for the required planning and analysis falls upon the Systems Engineering Organization

Planning usually follows a regular pattern (i) study of current and expected needs, (ii) synthesis of alternative systems to meet these needs, (iii) study of expected performance and cost of these systems (iv) A favorable alternative is recommended for development (v) Important decisions made during development, and the final design itself, must be approved by the Systems Engineering Organization

Statistical techniques currently identified with operations research find extensive use in phases (i) and (iii), where basic data about the environment—e g , traffic, radio fading,—must be developed Here analytical models are used extensively Since, in large systems, requirements on any particular element can be altered at the expense of compensating changes elsewhere, the problem in phase (ii) is one of allocating a reservoir of different but partially interchangeable resources so as to bring several criteria simultaneously into a jointly desirable or optimal region In practice, the exchange relations are so complex that general analytical models do not suffice for the detailed comparisons which must be made among alternatives

E2. Application of Operations Research to Development Decisions, BURTON KLEIN and WILLIAM MECKLING, *The RAND Corporation, 1700 Main St , Santa Monica, California*

It is the main argument of this paper that an efficient allocation of the development budget is a very different sort of problem from the efficient conduct of a current operation An attempt is made to show that, because of uncertainty, the problem is not one of choosing among specific end product alternatives, but rather a problem of choosing a strategy initially consistent with a wide range of such alternatives, and of narrowing the choice as development proceeds This has important implications for the analyst Because it cannot tell the decision-maker which among several alternatives is in fact preferable, the role played by the typical analysis comparing end-products is altered materially Moreover, if the analyst wants to be of more direct assistance in making development budget decisions, a very different kind of analysis is required

E3. An Historical Approach to the Direction and Control of the Research and Development Function, JOSEPH F. McCLOSKEY, *Director of Operations Research, Haskins and Sells, New York, New York*

Several attempts have been made to use the history of machines as a basis for predicting their maturation rates Here, "machine" represents a whole class, like "automobile" and not a particular model or single item of machinery Such prediction has obvious value in setting research and development (and production) levels This paper presents a refinement of the historical approach to include a tendency of a machine to "plateau" about midway in time between its inception and the onset of obsolescence Tentative extensions of the approach indicate that there may be some basis for predicting obsoletion of a machine by its successor

E4. The Role of Industry in Weapons System Planning, SHERWOOD C. FREY and P. R. CARLSON, *Military Operations Research Division, Lockheed Aircraft Corporation, Burbank, California*

Long-range weapon systems planning has become so complex that it is no longer possible for the military to do it unassisted Government policy, industry, and military planning are so strongly interrelated that it appears essential for the three to plan together Present communication among the three is shown to be hopelessly inadequate resulting in unacceptably long decision times and development It is appropriate that industry should provide bases for decision, coordinating with Government policy and with the military while so doing

E5. An Operational Analysis of Industrial Research, RAOUL J. FREEMAN *Statistical Mathematician, Defense Studies Department, Stanford Research Institute, Menlo Park, California*

In this paper the author attempts to solve the problem of how much a profit-maximizing firm should spend for research and how this amount should be allocated among competing projects The building blocks of the system presented are "temperized" estimates of net worth of projects, called "atoms" From these "atoms", by means of discrete programming, we manage to derive the "value function", showing the relationship between the net worth of the research program and the amount the firm spends for research The "value function" provides essential data necessary for top management to decide the optimal research expenditure Once this has been done, the previous systems analysis work yields the optimal set of projects for this amount of research cost (i e , solves the allocation problem)

E6. A Suggested Role for Operations Research in Corporate and Research and Development Planning, HENRY C. ALBERTS, *Group Leader, Systems Analysis, Research and Advanced Development Division, AVCO Manufacturing Corporation, 20 South Union St , Lawrence, Massachusetts*

The planning function of a diversified corporation is discussed in terms of suggested roles for operations research at corporate and research and development division levels Some interactions of corporate and research and development

planning are discussed, and a detailed discussion of research and development planning is presented with emphasis on the integration of operations research techniques at the management level

SESSION F—ORGANIZATION PLANNING

F1. Experimental Techniques and Research on Organizational Planning, RICHARD S. RUDNER, *Professor, Department of Philosophy, Michigan State University, Lansing, Michigan*

The difficulties involved in undertaking experimental research on phenomena associated with and comprising organizational planning, constitute a special case of the general difficulties of experimental research in social science In the main, these difficulties stem from the fact that the objects of primary interest in such experimentation are human beings and human behavior There are a great many circumstances under which it will be morally undesirable to employ humans as experimental subjects, but there are also a great many circumstances when such experimentation may be ethically innocuous and yet closed to us because of *technical* difficulties especially associated with observation and manipulation of human interaction An obvious desideratum of this situation is the use of our ingenuity to its fullest in the invention or provision of a body of experimental techniques for application to humans The use of these techniques may invarying and significant degrees be independent of the specific problem instigating the research

The remainder of the paper is given over to detailed consideration of experimental techniques, developed in the Tuft's Naval Systems Analysis Project and in the Case Operations Research Group, which have application to a wide variety of problems that are of interest in research on Organizational Planning

F2. Some Effects of Decentralization on the Research and Development Activity, ALBERT H. RUBENSTEIN, *Ass't Professor of Industrial Management, Massachusetts Institute of Technology, Cambridge, Massachusetts*

This project is one phase of a long term program of research on the research process It is directed at the growing concern with the deployment of Research and Development resources in decentralized companies The trend toward management decentralization is clear A large percentage of our large corporations have gone over or are considering going over to the "GE" or "DuPont" or "GM" type of organization structure more-or-less autonomous operating divisions and a large support staff

In carrying out this decentralization (or evolving into it through mergers or growth), the question of how R+D should be organized is critical

Preliminary evidences indicates that either "pure" decentralized R+D activities (all R+D done in the operating divisions) or "pure" centralized R+D activities (all R+D done in one central lab) can lead to difficulties in communication, duplication of effort, overlooking of possible new fields, unbalanced emphasis on long-and-short-run problems, etc

Combination forms (a central lab and divisional labs) do not automatically solve these problems The critical issues involve the actual behavior of the R+D personnel and the people who control their programs and activities

The study is an attempt to identify and evaluate effective and ineffective working patterns of decentralized R+D through examining these kinds of factors project selection and programming procedures, constraints on communication imposed on R+D labs, actual project portfolio of divisional and central R+D labs, actual information output, and some gross measures of technical and economic effectiveness

The techniques employed include a series of questionnaires to approximately 150 companies in six industry groups, extensive interviews with a sample of these companies and several intensive case studies of companies undergoing decentralization of their R and D activities

F3. Development and Application of a Management System Model, PAUL B. HENDERSON, JR., *Assistant for Management Research and Development Division, Navy Bureau of Ordnance, 18th Street and Constitution Avenue, Washington 25, D C*

The paper describes the development of a general management system model and the application of the model in systems analysis and synthesis It includes the theory and structure of the model (Management Matric), techniques of analysis and synthesis of data systems, management controls and organization, and determination of measures of inefficiency (complexity, repetition, redundancy and discontinuity)

The experiences and results to date of two applications now underway are described, with a brief summary of the use of punched-card equipment and digital computers in sorting and summarizing the data and in computing inefficiencies The first is an analysis of the entire management data system of the Bureau of Ordnance and its decentralized field activities, the second, a report on the use of the model in the synthesis of a Research and Development Management System

F4. Use of a Simulation Laboratory to Study the Organization and Effectiveness of Air Force Logistics, STEPHEN ENKE, *Chief, Logistics Department, The RAND Corporation, 1700 Main Street, Santa Monica, California*

Since October 1956 RAND has conducted a Logistics simulation laboratory, employing from 50 to 100 people, to study the organization and effectiveness of Air Force logistics The first large-scale exercise will be completed by October 1957 This simulation compares two different sets of policies and procedures for procuring and distributing spare parts among bases in support of Air Defense Command interceptors It includes bases, supply activities, parts repair depots, IRAN depots, fabricating plants, and various Air Force Commands, the interactions of these organizations being observed and altered to increase support effectiveness By various means, time is compressed so that a quarter of a year is represented by two days of operations on the laboratory floor The design of the exercise provides for both mechanical (IBM 704) and human simulation, the latter emphasizing organizational problems that cannot be programmed for a computer Alerts and wartime attacks are simulated also

F5. The Optimal Structure of an Organizational Hierarchy, MARTIN L. LEIBOWITZ, *Operations Analysis Group, Convair, San Diego 12, California*

A mathematical model is developed which relates the work output of an organization to the manpower and the structure of the organization's hierarchy The basic assumption is that the work output of a group is a function of 1) the work output of the group that controls it, 2) the size of the group, and 3) the effectiveness of communication within the group Numerical results are given for an example in which these functional relationships are of a mathematically simple nature Once these functions are known, the optimal structure can be found by minimizing the manpower cost to do a fixed amount of work per unit working period The resulting equation also shows the dependence of an organization's optimal structure on the type of work which is to be performed

SESSION G—GENERAL

G1. A Programming Model of the National Economy, JOHN DeWITT NORTON, *Director, Study of Economic Planning, National Planning Association, 1606 New Hampshire Avenue, N W , Washington 9, D C*

The application of large scale models to emergency planning for the national economy and for the formulation of business expectations by industrial sector is discussed The paper is divided into the following topics 1) The 190 sector model developed in 1952 by the U S government interindustry economics research project, 2) Its use under the circumstances of a classical industrial mobilization (i e World War II or the Korean War) is examined with respect to four levels of decision making which have counterparts in business planning strategic—long range, budgetary—intermediate range, procurement—short range, and materials allocation—immediate, 3) The shortcomings of the existing Federal statistical system for the statistical implementation and appraisal of such models, 4) The types of stipulation of final demand which could be made for future applications and the difficulty faced outside the Government of making a satisfactory specification in total, granted the present scale of military procurement, 5) The suitability of square, triangular and linear programming models for economic programming

G2. Inventory Control in a Multiple Warehouse System, PETER R. WINTERS, *Assistant Professor of Industrial Administration, Graduate School of Industrial Administration, Carnegie Institute of Technology, Pittsburgh 13, Pa*

A factory-warehouse system operates as follows A lot of a particular item is made at the factory, this lot is divided into several parts, and is shipped to several warehouses A multiple trigger rule has been developed to decide when to place orders with the factory This trigger considers jointly the inventory positions and sales forecasts for each warehouse where the item is held (not just the total inventory of the item) In conjunction with the trigger rule, a lot-size rule prescribes the total lot to be run at the factory, and how this lot should be divided among warehouses

The rules are derived by minimizing expected costs, including inventory holding cost, fixed costs of ordering and making a lot at the factory, and depletion costs related to amount out and length of time out

A method is described for modifying the rules to conform to aggregate decisions on inventory and production, and it is shown how the method can be extended to include an intervening factory-warehouse

G3. The Analysis of a Quadratic Inventory and Production Model with Inequality Restraints on Inventory Levels and Production Rates, ROBERT M. OLIVER, *Broadview Research Corporation, 1127 Chula Vista Avenue, Burlingame, California* **and DONALD ROELLKE,** *Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge 39, Massachusetts*

In this paper the authors analyze an inventory and production scheduling model which includes linear and quadratic costs of storing and producing, inequality restrictions on the inventory levels and production rates and a forecast of sales T periods ahead The problem of minimizing the cost rate of storing and producing is formulated first as a calculus of variations problem and then as a dynamic programming problem Analytical and numerical solutions of the mathematical model without inequality restrictions are shown first for comparison purposes As inequalities are introduced and the width or range of the inequalities are reduced, the effect on a) the optimal solutions for inventory levels and production rates and on b) the computer solution times is shown Computations have been carried out on the M I T Whirlwind I computer for constant sales forecasts and sinusoidal sales forecasts Emphasis is also placed on the effect of changing the relative cost of producing to storing upon the optimum solutions

G4. Monte Carlo Applied to a Problem in Yield, DONALD L. FREYBERGER and PAUL E. GREEN, *Operations Research, Lukens Steel Company, Coatesville, Pa*

The function of "provision" in the steel industry is to determine the amount of steel in ingot or slab form which when rolled and finished will yield the desired dimensions to meet the customer's order without incurring "too much" scrap Providing tightly reduces scrap incidence but increases the chance of rejects for failure to meet pattern while loose providing reduces the probability of rejects through failure to meet pattern but generates more scrap The problem is to determine what allowances the provider should add to the customer order dimensions so as to minimize, over the long run, the sum of these two groups of cost

Monte Carlo was employed in the solution of this problem by simulating the performance of alternate "providing" methods on the long run incidence of order rejections through failure to meet pattern Customer "good will" was imputed by ascertaining the cost of scrap produced with alternate providing allowances vs the change in reject incidence Study findings resulted in a change in prevailing providing methods and a resultant payoff of some consequence

G5. Optimal Strategies in the Allocation of Advertising Expenditures, LAWRENCE FRIEDMAN, *Nowland and Company, King Street, Greenwich, Connecticut*

The allocation of advertising expenditures by area and by media is a problem faced by all national marketing organizations The problem when formulated correctly can be treated with some of the techniques of game theory and allocation theory In this paper several mathematical models will be described along with

their solutions The models are theoretical and are based on various assumptions about the effect of advertising on sales The validity of these assumptions as well as the possible application of these models is discussed

G6. The r-th Best Path Through a Network, FREDERICK BOCK, HAROLD KANTNER, and JOHN HAYNES, *Armour Research Foundation, Technology Center, Chicago 16, Illinois*

Given a network consisting of a finite number of nodes together with a set of directed links of known value, each link connecting two of the nodes, to find the r-th best path (the path of rank r) running from a node designated as origin to a node designated as destination The value of a path is defined as the sum of the value of the links, the best path (r = 1) is the path of least value, the second best path (r = 2) is the path whose value is next larger, and so on This problem arises, for example, in the assignment of trip demand to a highway network where it is known that drivers having the same origin and destination will distribute themselves over the available routes The best path can be found by the method of tree construction and trace-back (G B Dantzig, "The Shortest Route Problem", *Opns Res* 5 270 (1957), E F Moore, "The Shortest Path Through a Maze", International Symposium on the Theory of Switching, held at Harvard University (1957)) Methods for solving the general problem, by means of digital computation, are discussed

G7. Some Problems of Research on Hospital Operations, DANIEL HOWLAND, *Supervisor, Operations Research Group, Ohio State University, Columbus 10, Ohio*

The rapidly increasing cost of and demand for hospital services poses some challenging problems for operations research These problems are discussed, with particular reference to the development of criteria for hospital operations, the formulation of an integrated program of interdisciplinary research, and specific study areas Particular emphasis is given to the integration of research methods of operations research and the social sciences