Faculty Working Papers

PRECOGNITIVE SYSTEMS AND COMPUTER-AIDED INFERENCE

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College of Commerce and Business Administration
University of Illinois at Urbana-Champaign

FACULTY WORKING PAPER

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A Sabbatical Study

By Louis J. Rago

## INTRODUCTION

To reconcile the wide discrepancy between academic assumptions and industrial practices, a study on "Precognitive Systems and Computer-Aided Inference" was undertaken during the past academic year. This is a brief summary of the project and the results of the research.

Academic teaching in today's B-Schools is predicated on the assumption that modern business makes extensive use of the computer and in doing so relies heavily on mathematical models. Such models are presumed to be capable of pre-auditing the outcome of alternative contemplated managerial actions and hence, the building of mathematical models appears to be the essence of managerial decision-making and managerial practices. In light of this presumption, I undertook this research project. The "study of precognitive systems, including problem-solving, computer-aided inference, and decision making, which would involve me in the gathering of data, and the evaluation and analysis of empirical studies for theoretical considerations," should enable me to return to campus with a large number of actual industrial applications of operations research and with the proof that the quantitative approach to management has indeed penetrated American as well as foreign industry. Although computers are invariably available in every firm I contacted and visited, the fact was discovered that computers are not used as extensively in decision-making, neither at the highest nor at the lower

managerial endeavors, as the academic community has apparently assumed. Unless information systems, which involve very little mathematical modeling and analysis, can be considered as an integral part of this study, my report tends to show a decreasing rather than an increasing tendency as far as mathematical models in managerial decision-making are concerned, but an increasing trend toward a systematic and quick retrieval of collected information (information systems). What the implications of this discovery may be for academic teaching, may become relevant from the report itself.*

In prefacing my research results, let me say at the outset that the validity of this research is assured by a "valid and representative sample" of firms. Although my original list was somewhat altered, essentially the 30 firms comprising the Dow Jones Industrial Average were visited and their executives, from president (occasionally the board chairman) down to executives and computer or operations research experts, were interviewed. The change of the list was necessitated by the unfavorable geographical locations of some of these firms; if changed, a company in the same line of business was placed into the list selected primarily because it had a better geographical location. Corporate headquarters are widely scattered throughout the United States and I had to select corporations more or less in certain segments of the country. The European firms were selected in a similar fashion. However, to avoid the language barrier I went to countries where I could communicate with the executives (England, France, Germany, Switzerland, Austria, Hungary, Belgium).

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*This fact tends to support Professor H. Hinomoto's sabbatical project, "A Plan for Developing a Program in Information Processing Systems," 1970-1971 (University of Illinois) and the recent report of the ACM on "Curriculum Recommendations for Graduate Professional Programs in Information Systems" (Communications of the ACM - Association for Computing Machinery, Inc., May 1972, Vol. 15, No. 5).

In Europe, the automobile, oil, electrical appliances and machinery, steel and similar large scale operations were studied, whereas in the United States the managerial practices of firms engaged in food and meat processing, canning and can making, steel, automobile, farm and electrical machinery, machinery and tool making, paper, oil, aircraft and aerospace, aluminum, chemicals, cement and other building materials, soap and detergents, leisure-time products, etc. were studied. In addition some public utilities were added to the list to round out the variety of industrial corporations.

In addition to interviewing executives of corporations, I also visited with some academic colleagues and exchanged information on the subject with them. In some instances we had agreements, in other instances we had to iron out the differences in our research results precipitated primarily by different interpretation of "quantitative analysis." Some individuals speak of operations research, yet they mean data processing and related programming rather than modelbuilding and problem solving per se. Industry in particular uses the term operation research interchangeably with information systems, yet they mean a form of sophisticated record keeping in scheduling and inventory control or in some other functional field.

Prior to visiting the corporate headquarters of said industrial firms, correspondence was exchanged between top executives and myself. Before I actually went to see these firms, I made it clear to them that I am not interested in the clerical operations - a usual domain of computers - but mainly in the use of the computer in decision-making (see Exhibit I).

Since these companies knew in advance the subject I was interested in, they prepared for me an itinerary and arranged interviews with a large number of appropriate corporate executives, including operations research experts and computer specialists. In most companies I also spent some time with the company president and occasionally I also met the chairman of the board. Executives were very cooperative and felt gratified that academia comes to them for advice. They were particularly pleased that this inquiry was via personal interviews rather than via lengthy questionnaires. They felt that direct mail tends to give misleading information* and leads to academic assumptions not necessarily matching the true state of affairs. The "word" quantitative analysis and the use of the term decision-making means different things to different people in industry and questionnaires do not always answer the "real questions" the academic community is interested in. It appears therefore that some of the misinformation circulating in academic communities about the "extensive" use of computer-aided decision-making can largely be attributed to the fact that most research projects of this kind are based not on the interview technique. As a rule I spent a whole day with corporate executives and at times I returned to the company a second time to meet those I could not see the first time I visited the city.

In addition to the questions I raised in my initial correspondence with corporate

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*Professor William Vatter: "The Use of Operations Research in American Companies", The Accounting Review, October 1967.

executives, need arose for additional questions and answers. I asked thus the following additional questions:

1. Are the operations research specialists on "corporate budget" or are management science (operations research) activities financed from fees charged by the operations research group?
2. Is the operations research function dispersed throughout the organization or is it practiced only by a specific group or department?
3. Is there now or has there ever been an operations research group employed in the company in question?
4. How do the operations research experts view their own academic training and what suggestions can they give to the academic community?
5. To what extent are line executives familiar with the work of the operations research staff and what service do they expect of managements scientists?

The importance of the above questions will become apparent from this report.

Above introduction implies that my research was an attempt to establish some kind of a coordination between the schools that train business students and the business that employ them. Such coordination is deemed essential if academic teaching, and particularly my own teaching, is to remain relevant to the realities of business life. This brings me to the ultimate purpose for which I decided to undertake this study (i.e. how my own field of production management is affected).

The teaching of production has undergone significant changes over the past ten to fifteen years. Particularly the decision-making aspects of production management changed in view of the fact that the computer made it possible to sharpen managerial judgment or at least to narrow the area where judgment is needed. Better planning and implementation of work tend to reflect in higher productivity. I raised the question whether or not the tremendous efforts expended by business schools in recent years were successful and wanted to see the extent to which the operations research approach to production management as well as management per se has indeed penetrated American and foreign industry.

RESEARCH RESULTS

This study either supports or contradicts some studies which were made in this area in recent years (see Appendix 1 and 2). To some extent it supports studies in this area of Professors A. C. Wallace (Education in Business Administration, Summer 1972), the ACM and Hinomoto, and contradicts a study by Professor Vatter made back in 1966. Let me clarify, however. It may be quite true that in the 1960s operations research was flourishing in industry, but in 1972 an apparent disappointment among corporations set in which forced most operations research groups out of business. In the early 1960s almost every corporation I visited, including foreign corporations, established operations research departments or groups with the purpose in mind to apply new scientific knowledge to the solution of real problems. These groups were at the time financed from "corporate budgets." This has changed in recent years. Corporations apparently refused to support "research staffs" which continued to operate in industry somewhat like "pure research" so characteristic of

university research . Hence, budgets were cut off with the result that (a) operations research groups or departments were either dissolved or (b) converted to an internal consulting staff. In the latter instance, an in-house consulting company was created which will charge fees for the services rendered, just like any other outside consulting house would do. Although many companies dissolved the operations research group altogether, the people who worked there were actually rehired in a somewhat "more productive capacity." Accordingly, the current study reveals two kinds of operations research experts still operating in the typical American and foreign corporation:

1. operations research staff (operates via solicitation of research work from various corporate departments within the organization and bills them in the same way as outside consultants; the internal consultants actively seek business also from the outside in order to keep busy and to achieve a better distribution of the fixed costs);
2. operations researchers work in various productive capacities, such as financial analysts, computer programmers, data processing supervisors, production controllers, accountants, market researchers, inventory and budget experts, etc. and tend to work on different model building projects only on a part-time basis. Their salaries come from the "productive" jobs they hold, but some time is always provided by the employing department to permit quantitative analysis if that work pays sufficient dividend to warrant the activity in question;
3. full fledged operations research departments still exist (paid from corporate budgets) primarily in European companies, but this

may be attributed to the fact that the Europeans always lag 4-5 years behind their American counterparts.

Where operations research departments disappeared, the executives rationalized by saying: "Operations researchers promised far more than they could deliver." Of course, the various interviews revealed that this is only partly so. The fact is that to do an adequate modeling work, theory is not enough. The operations researcher is able to model the relationship between factors which are involved in any decision, but what he is not always able to find is the "data." Thus, the operations researcher was not always able to obtain the data so important to plug into his model and provide the computer with "input". In other words, industry is not yet adequately provided with "data banks" and hence, the management scientist is not yet in the position to make use of his models. The apparent consequence of this is that he works not only in the classroom, but also in industry with assumed data. And if the corporate management was disappointed with the "advice" of operations researchers, this can be attributed primarily to the fact that the operations researcher was not provided with data and had to "assume" too many things. It goes without saying that computer answers based on such assumptions are not any better than those based on seasoned judgment. Thus, what seems to be lacking today is the data bank. Industrial enterprises are unable to build up the required information systems fast enough to make adequate use of operations researchers. This raises the question whether or not our educational system misplaced its priorities and trained the wrong kind of "experts." It seems apparent to this observer that we now have many canned programs (i.e., useful models, including the computer program), but we cannot find situations where we can make good use of these models. And here primarily the input data are

missing. Had industry been capable of collecting "information" with which to solve problems stated in mathematical terms (in mathematical models), the operations researchers would not have to fail in industry. In some of the companies visited the operations researchers were extremely successful. The reason being that the company had adequate information with which the computer and operations research experts could work (e.g., oil and can making industries, steel companies, food processors, etc).

In addition to lack of availability of data, the operations researchers were frequently not successful simply because they were not well enough versed in the "specific area" they were supposed to solve problems. The theoretically trained operations researcher was simply unable to convert theoretical knowledge and symbolic thinking into practical applications. However, some of these mathematically trained individuals were able to stay long enough on the job to learn enough about the production, marketing or financial problems of the company so that they could acquire intimate functional skill and the necessary operational know-how so essential to convert theoretical knowledge into practical applications. Those who already passed the sound barrier and are successful in industry were suggesting to me that universities should sacrifice a little theory* and supplement academic teaching with adequate functional knowledge and know-how to enable graduates to make better use of acquired theory. They suggested that some "case work" which includes data of real problems should be used in the class room in order to make the theoretical knowledge more relevant to the realities of industrial life.

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*not this reporter's words, but commonly used by executives

From the organizational point of view the tentative conclusion is that operations research is not considered in most of the companies visited as an integral part of the organization, merely as an appendix or resource which may be tapped if it appears useful. The reason for the operations research group being more or less an appendix to rather than a part of the organization is that the operations research group has apparently promised the heaven, but could not deliver it. As a result - almost invariably - the original operations research group was disbanded or has been rehired in a somewhat different job classification. If the operations research group was not disbanded, then the group became an "internal consulting firm" charging a fee for services rendered. If the group was retained, then it began to function "from within" in functional departments. The third is employed primarily by those firms which began with the operations research group just a few years ago (3 to 5 years ago). Here the operations research group is still financed from corporate budget (overhead charges).

That operations research is not more successful in industry than it is, may also be due to the relative position of the group in the corporate organization. Apparently neither the academic community nor industry paid enough attention to the organizational aspect of the "operations research staff." Corporations could for instance place the operations research expert in such a juxta or strategic position that his effectiveness would be assured by the very level of the organizational structure. A staff position can and does have an important impact if it is placed into the organization in such a way that it not only generates heat, but also light. Some kind of "power" could make operations research specialists considerably more useful to the organization than currently

is the case. It appears, in light of following paragraph, that in many respects, management science would have a logical place in the area of long-range planning.

Operations researchers tend to think in "long-run" objectives and design accordingly models to measure and forecast long-run situations the fruition of which may be so far away that the process of project completion may outlast the executive in charge (the executive whom the research results are supposed to serve). As executives are promoted, transferred or quit, the project already underway is in jeopardy. Thus, no matter how knowledgeable the operations researcher and how sound his ideas are, some projects become shelved in mid-stream. For practical reasons industrial enterprises cannot wait until a project comes to fruition 5 or 10 years hence. Apparently, operations researchers failed to consider this dollar and cents aspect of the realities of industrial life - they were attempting to solve problems not of today, but ten years hence. A large number of executives explained that the operations researchers in their companies failed because they could not gear their plans to the solution of today's problems (where the results would have been immediately visible). By presenting solutions to long-range problems so far away that the company needed five generations of executives until finally the project in question came to fruition, management support was lost. The human element was thus neglected and since the second or third executive coming into the position did not have the same enthusiasm for the idea as his predecessor/predecessors, many projects died due to lack of interest. While the new executive has often recognized the soundness of such long-range plans, he had to

break up the total project into pieces; into such pieces which would show immediate results. Thus, the suggestion was made that the teaching community makes it clear to graduates that any new idea which they come up with must be geared more to the realities of life than to some abstract future.

The operations research group is not necessarily the same group as the systems analysis group which tends to function, more or less, as a "service department" rendering clerical services (for which the computer is eminently suitable). Here a charge for the service is, of course, warranted, because the department provides the necessary payroll or whatever information producing function it serves.

## CONCLUSION

The rivalry between the empiricists and the theoreticians in business administration shifted in recent years toward the theoreticians and curricula in B-Schools tend to reflect this shift. Emphasis on quantitative eloquence - an essential characteristic of theory - has created a research atmosphere in which relevance became secondary to rigor. Looking at the university from the outside in (as American and foreign industry looks at us in the academic community), this development has not been too satisfactory. Industry hired, in the early sixties and late fifties, operations research experts in the belief that they will be able to improve the profitability of business, but these experts with notable exceptions, could not always translate theoretical knowledge into solutions of practical value. True, this is not necessarily the fault of the experts; experts need the necessary data to be pluged into

the models. Nevertheless, training in quantitative analysis has apparently bypassed functional areas. Hence, the functional application of these managerial tools to problems the graduating senior or the M.B.A. will encounter in industry, needs conside ably greater emphasis.

As an adjunct to above, it appears that the academic community has neglected to develop the area of information systems -- systematic gathering and evaluation of business data. Because so little emphasis has been placed on data gathering and system development, operation research theory has apparently outran its applicability. In this context, the study of "information systems" should conceivably precede, or be taught concurrently with "management science."

Most of the operations research experts I spoke with during my sabbatical were Ph.D.'s themselves trained in mathematics and/or operations research. In looking back at their own careers in industry, they felt that their own training was theoretical to the point that they needed an unusually long apprenticeship in industry before they could become "productive members" of the corporation.

In sum then it appears necessary to look upon the curricula of B-schools, including the College of Commerce and Business Administration of the University of Illinois, with critical eyes. Further study may be undertaken by other faculty members and further correspondence may be exchanged with corporate executives to check whether or not the study I have undertaken and the conclusions I have reached indeed reflect their own views.

If the results are substantially the same, I believe that applied empirical studies which have largely been neglected in most textbooks and teaching material, including Ph.D. research, would warrant serious academic attention.

Particularly the computer science area, as is used in the College of Commerce and Business Administration, appears to be functioning well. Industry feels that not many graduates they hire can make an adequate use of the computer and hence, the industrial community feels that universities should do better in this area. Basing my opinion on my own experiences in the College of Commerce and Business Administration at the University of Illinois, we are certainly not among those schools which neglect this area. Most of our courses are so structured that students get a working knowledge of the computer and the use management can make of EDP.

How my remarks apply to the Ph.D. level and research I could not tell. Industry is concerned primarily with graduating seniors and M.B.A.'s and whatever information I collected and whatever conclusions I have reached applied primarily to students who graduate and end up working for an industrial concern rather than continue doing theoretical or empirical research in academia.

EXHIBIT I.

Dr. Louis J. Rago
Department of Business Administration
COLLEGE OF COMMERCE & BUSINESS ADMINISTRATION
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
URBANA, ILLINOIS 61801

February 23, 1972

Dear Mr.

Be assured that your prompt reply of February 10, 1972, was highly appreciated. I am in the process of developing my itinerary, and you will hear from me as soon as my traveling plans are finalized.

You may be interested in the fact that I am visiting 30 very carefully selected companies located in different parts of the country. In the meantime, I would like to provide you with information so that you have a clear picture about the exact purpose of my visit.

Academic teaching is focused today on quantitative analysis and computers. Yet very little solid evidence is available to the academic community as to what industry needs in the area of operations research and computer applications. Thus, I hope to find out (1) What kind of production, marketing, and financial decisions are being made in your company via computers and to what extent management actually follows the computer's "advice"? (2) What mathematical models are being used and what kind of data are substituted into these mathematical formulas (programs)? (3) How does management find the "numbers" which constitute the input data other than the program itself (cost data, capacity or time study, sales figures or forecasted sales, profit figures or other decisional criteria)? (4) Who interprets the computer output and how are decisions implemented and turned into corporate action (decision)?

It goes without saying that any information I receive from you will be held strictly confidential. Thank you very much for your cooperation and I remain

Sincerely yours,

Louis J. Rago

Prof. Louis J. Rago

LJR:emk

Method of Financing OR Activities (in %)

| | 1962 | 1972 |
|---|---|---|
| 1. Corporate Budget | 80% | 7% |
| 2. Miscellaneous departmental budgets | 10% | 35% |
| 3. Consulting fees | 10% | 58% |

The Existence of a Department dealing with Information Systems* in

| 1960 | 1965 | 1970 | 1972 |
|---|---|---|---|
| 5% | 15% | 70% | 90% |

*based on the sample companies

The Future of Quantitative Analysis in Industry *

| | 1975 | 1980 |
|---|---|---|
| Operations Research | decline | decline |
| Information System | increase | increase |
| OR and Information System | same as now | increase |

* based on opinion of those who were interviewed

Departments where OR is carried out in industry *

| | Europe | | United States | |
|---|---|---|---|---|
| | 1962 | 1972 | 1962 | 1972 |
| In-House Consult. | 0% | 10% | 10% | 58% |
| OR Department | 5% | 75% | 80% | 7% |
| Part-time Activity | 9% | 15% | 10% | 35% |
| Not employed | 86% | 0% | 0% | 0% |

*it was impossible to distinguish between OR and information systems as described by those interviewed (there is a confusion between data processing, operations research or programming and information systems)

## Type of Problems Handled with Quantitative Techniques

| | |
|---|---|
| Bidding (Network Analysis) | 17% |
| Resources Allocation and Capital Budgeting (Linear Programming) | 40% |
| Simulation (various techniques) | 60% |
| Sales Forecasting | 75% |
| Miscellaneous problems (closing down plants, modernization) with break-even techniques, opportunity cost analysis etc. | 35% |

## Departments where OR work is done on a part-time basis

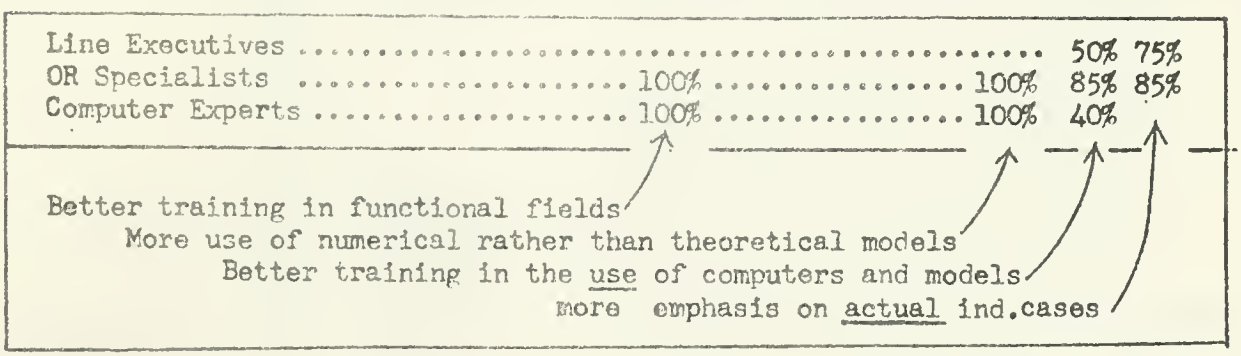
| | |
|---|---|
| Computer Services | 12% |
| Information Systems | 4% |
| Accounting and Finance | 10% |
| Sales Forecasting | 5% |
| Production and Inventory Control | 4% |

## Existence of a Formally recognized Operations Research Department in Europe United States *

| | 1962 | 1972 | 1962 | 1972 |
|---|---|---|---|---|
| | 5% | 75% | 80% | 7% |

*Since only the largest European companies were visited (in Hungary only government owned enterprises), the percentage indicates the extent to which large companies recognize the operations research function.

## SUGGESTIONS MADE BY INDUSTRY REPRESENTATIVES TO UNIVERSITIES



APPENDIX II.
(Vatter Report
made in 1962)



WHERE OR WORK IS DONE—ACCOUNTING, PRODUCTION, ENGINEERING, OR OTHER DEPTS.
(Formal Recognition of OR Functions)

| *Location or Combination* | *No. of Firms* | *% of Total* | *% of Users* |
|---|---|---|---|
| Accounting (Finance) only | 48 | 13 | 20 |
| Accounting, Production, Engineering | 25 | 7 | 11 |
| All Departments | 23 | 6 | 10 |
| Data Processing, Information System | 20 | 6 | 8 |
| Accounting, Engineering | 19 | 5 | 8 |
| Miscellaneous Departments Only | 15 | 4 | 6 |
| Accounting and Production | 13 | 4 | 5 |
| Engineering Only | 11 | 3 | 5 |
| Industrial Engineering | 10 | 3 | 4 |
| Centralized OR Department | 9 | 3 | 4 |
| Accounting and Miscellaneous | 9 | 3 | 4 |
| Production and Engineering | 6 | 2 | 3 |
| Engineering and Miscellaneous | 6 | 2 | 3 |
| Production, Engineering, and Miscellaneous | 6 | 2 | 3 |
| Production Department Only | 5 | 1 | 2 |
| Accounting, Production, and Misc. Depts. | 5 | 1 | 2 |
| Accounting, Engineering, and Misc. Depts. | 5 | 1 | 2 |
| Production and Miscellaneous Depts. | 2 | | |
| Total with formal departments | 237 | 66% | 100% |
| OR used informally | 50 | 14% | |
| OR not used | 73 | 20% | |
| Total | 360 | 100% | 100% |

RELATIVE USE OF TECHNIQUES, BY SIZE OF FIRM (REVENUES)

| *Revenue Class* (Millions) | *No. of Firms* | *Percentage of companies using indicated number of OR tools* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Five or more* | *Four* | *Three* | *Two* | *One* | *None* |
| $ 1,000 | 30 | 97 | — | — | 3 | — | — |
| 500-999 | 37 | 65 | 14 | 11 | 5 | 5 | — |
| 100-499 | 122 | 50 | 15 | 9 | 9 | 7 | 10 |
| 50- 99 | 45 | 13 | 11 | 30 | 13 | 11 | 22 |
| 25- 49 | 49 | 16 | 12 | 28 | 10 | 14 | 20 |
| 1- 24 | 64 | 6 | 13 | 9 | 19 | 20 | 33 |
| ? mil. | 13 | 15 | 15 | 15 | 15 | 15 | 25 |
| All | 360 | 37 | 12 | 14 | 11 | 10 | 16 |

RELATIVE USE OF GIVEN TECHNIQUES IN INDUSTRY GROUPS (% OF FIRMS IN INDUSTRY GROUP)

| *Industry* | *LP* | *CP* | *Q* | *I* | *S* | *F* | *R* | *X* | |
|---|---|---|---|---|---|---|---|---|---|
| Heavy and Light Manufacturing | 37% | 56% | 8% | 52% | 44% | 10% | 32% | 43% | |
| Utilities and Transportation | 60 | 71 | 40 | 49 | 69 | 18 | 73 | 87 | |
| Services | 20 | 46 | 13 | 37 | 40 | 7 | 20 | 47 | |
| "Scientific" | 75 | 82 | 37 | 73 | 66 | 32 | 68 | 66 | |
| Consumer Goods | 50 | 68 | 16 | 57 | 43 | 9 | 45 | 55 | |
| Financial Institutions | 36 | 55 | 34 | 14 | 39 | 18 | 48 | 59 | |
| Wholesale, Retail (trading) | 38 | 54 | 8 | 62 | 46 | 15 | 54 | 54 | |
| Construction and Materials | 37 | 59 | 19 | 41 | 52 | 7 | 22 | 37 | |
| All Companies (360) | 46% | 63% | 22% | 52% | 50% | 15% | 46% | 56% | (Others) 13% |

LP = Linear Programming
CP = Critical Path Methods
Q = Queueing Models
I = Inventory Models
S = Simulations
F = Factor Analysis
R = Regression Analysis
X = Statistical Sampling

DISTRIBUTION OF RESPONDENTS BY SIZE (GROSS REVENUE)

| *Amount of Annual Revenue* | *Number of Firms* | *%* |
|---|---|---|
| Less than $1 million | 13 | 4 |
| $1- $24.9 million | 64 | 18 |
| $25- $49.9 million | 49 | 14 |
| $50- $99.9 million | 45 | 12 |
| $100-$499.9 million | 122 | 34 |
| $500-$999.9 million | 37 | 10 |
| Over 1 billion | 30 | 8 |
| Total | 360 | 100% |

DISTRIBUTION OF RESPONDENTS BY INDUSTRY CLASSIFICATION

| | *Number of Firms* | *%* |
|---|---|---|
| Heavy Manufacturing | 56 | 15 |
| Light Manufacturing | 38 | 11 |
| Utilities, Transportation | 45 | 13 |
| Services | 30 | 8 |
| "Scientific" | 59 | 16 |
| Consumer Products | 44 | 12 |
| Financing | 44 | 12 |
| Wholesale, Retail, Trading | 13 | 4 |
| Construction and Materials | 27 | 7 |
| Public Authorities | 2 | 1 |
| Unidentified | 2 | 1 |
| Totals | 360 | 100% |

DATA PROCESSING METHODS (MENTIONS)

| | | | |
|---|---|---|---|
| Computers, | Tape | 260 | (Because of duplicate responses, these will add to more than 360.) |
| | Disc | 202 | |
| | Other | 62 | |
| Punch cards | (EAM) | 243 | (Only 24 firms do not use a computer.) |
| Other means | | 27 | (Only 3 firms use neither punched cards nor computers.) |

EXTENT OF USE OF OPERATIONS RESEARCH TECHNIQUES (360 FIRMS)

| | Number | % |
|---|---|---|
| No use whatever | 56 | 16 |
| Use of one technique | 37 | 10 |
| ... Two | 39 | 11 |
| Three | 49 | 14 |
| Four | 44 | 12 |
| Five | 34 | 9 |
| Six | 39 | 11 |
| Seven | 38 | 11 |
| Eight | 18 | 5 |
| Nine or more | 6 | 1 |
| | 360 | 100% |

HOW LONG, IF AT ALL, HAS YOUR COMPANY RECOGNIZED OPERATIONS RESEARCH AS A SPECIFIC RESPONSIBILITY OR FUNCTION, SOMEWHERE IN THE ORGANIZATION?

| *Number of Years* | *Number of Firms* |
|---|---|
| 9 or more | 36 |
| 8 | 8 |
| 7 | 5 |
| 6 | 11 |
| 5 | 25 |
| 4 | 14 |
| 3 | 23 |
| 2 | 32 |
| 1 | 24 |
| Less than 1 year | 59 |
| Total formal users | 237 |
| Informal users | 50 |
| Non-users | 73 |
| Total | 360 |

Weighted average period of use 3.6 years.

USERS AND NON-USERS BY SIZE OF FIRM (GROSS REVENUES)

| *Revenue Class* | *Users* | | *Non-Users* | | *Total* | |
|---|---|---|---|---|---|---|
| | *Number* | *%* | *Number* | *%* | *Number* | *%* |
| Over 1 billion | 30 | 100 | — | — | 30 | 100 |
| $500-999.9 million | 35 | 90 | 2 | 5 | 37 | 100 |
| $100-499.9 million | 111 | 91 | 11 | 9 | 122 | 100 |
| $50- 99.9 million | 33 | 73 | 12 | 27 | 45 | 100 |
| $25- 49.9 million | 36 | 73 | 13 | 27 | 49 | 100 |
| $1-$24.9 million | 33 | 52 | 31 | 48 | 64 | 100 |
| Less than $1.0 million | 9 | 69 | 4 | 31 | 13 | 100 |
| Totals | 287 | 80 | 73 | 20 | 360 | 100 |

NUMBER OF FIRMS USING SPECIFIED OPERATIONS RESEARCH TECHNIQUES

| Use | | | Technique | Results | | | |
|---|---|---|---|---|---|---|---|
| *None* | *Some* | *Often* | | *Poor* | *Fair* | *Good* | *Uncertain* |
| 194 | 113 | 53 | Linear or Other Mathematical Programming | 8 | 46 | 86 | 26 |
| 134 | 163 | 63 | Critical Path Scheduling (PERT) | 10 | 68 | 122 | 26 |
| 279 | 68 | 13 | Queueing (waiting-line) Models | 3 | 28 | 34 | 16 |
| 173 | 115 | 72 | Economic order-size or Other Inventory Models | 9 | 63 | 88 | 27 |
| 179 | 121 | 60 | Simulations | 5 | 44 | 112 | 20 |
| 305 | 44 | 11 | Factor Analysis | 8 | 14 | 25 | 8 |
| 195 | 99 | 66 | Regression Analysis | 7 | 46 | 93 | 19 |
| 159 | 127 | 74 | Statistical Sampling | 2 | 41 | 136 | 22 |
| 313 | 25 | 21 | Other | 0 | 11 | 32 | 3 |

PATTERNS OF ACTIVITY WHEN OPERATIONS RESEARCH IS USED INFORMALLY

| *Combination* | *% of firms* | |
|---|---|---|
| Accounting department alone | 14% | |
| Accounting and some other department(s) | 21 | |
| One or more other departments (not acctg.) | 24 | |
| Almost any or all departments (incl. acctg.) | 2 | 61% |
| Audit Firm alone | 3 | |
| Audit firm and accounting department | 3 | |
| Audit firm and some non-acctg. department(s) | 1 | |
| Audit firm, accounting and some other dept(s) | 1 | 8% |
| Consultants alone | 10 | |
| Consultants and accounting department | 6 | |
| Consultants and some non-acctg department(s) | 8 | |
| Consultants, accounting and some other dept(s) | 7 | 31% |
| Total (166 firms) | | 100% |

RESPONSES TO REQUESTS FOR UNUSUAL INFORMATION

| | | |
|---|---|---|
| Requests met completely without much delay | 41% | |
| Requests met in part, or by substitution | 33 | |
| Total inquiries met in some fashion | | 74% |
| Requests not met because cost prohibitive | 10% | |
| Requests not met because system cannot produce such information | 16 | |
| Total inquiries not met | | 26% |
| | | 100% |

(These are averages based on replies from 242 firms.)

REASONS GIVEN FOR NON-USE OF OPERATIONS RESEARCH

| | |
|---|---|
| Inadequate access to appropriate equipment | 31 |
| Lack of sufficiently competent personnel | 103 |
| Lack of interest among operating managers | 91 |
| Not applicable to this business at all | 8 |

REQUESTS FOR SPECIAL DATA NOT ORDINARILY SUPPLIED

| | |
|---|---|
| Requests of this kind are seldom received | 88 |
| There are requests of this kind sometimes | 154 |
| Requests of this nature are made frequently | 110 |
| No answer | 8 |
| | 360 |

THE FUTURE OF OPERATIONS RESEARCH

(How much do you think operations research techniques will increase from their present level in your company?)

| | *No opinion* | *Not at all* | *A little* | *Considerably* | *Very much* |
|---|---|---|---|---|---|
| (a) Within the next five years | 7 | 19 | 120 | 180 | 34 |
| (b) Between five and ten years | 62 | 4 | 52 | 141 | 101 |
| (c) After ten years | 93 | 6 | 47 | 95 | 119 |