



Working Paper



INDIAN CONTRIBUTIONS TO O.R.
LITERATURE

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INDIAN CONTRIBUTIONS TO O.R. LITERATURE

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ABSTRACT

O.R. researchers in India have been making contributions to O.R. literature from its early days of development. They have published hundreds of original research papers in well-known journals. This review focuses on the contributions made by Indian researchers to the published O.R. literature in last 25 years (1961-85). This paper reports major findings of the review.

1. INTRODUCTION

O.R. researchers in India have been making contributions to O.R. literature from its early days of development. It is believed that O.R. originated in India during the last phase of World War II. Even in India, the first application of O.R. was in defence. Soon, O.R. was used for national planning. In 1957, the Operational Research Society of India (ORSI) came into existence and was soon affiliated to IFORS (International Federation of Operational Research Societies). The ORSI started publishing a journal with the name Opsearch in 1964. The Society also started organizing annual conferences from 1968. From sixties onwards many universities and academic institutions started including O.R. in their curricula.

O.R. has also been a subject of research of many Indian scientists from its early days. The major purpose of this paper is to study the research work done by

Indian researchers in last 25 years, i.e. from 1961 to 1985. There must have been contributions before 1961, but it was felt that such contributions were few in numbers and were difficult to locate. Besides their relevance to modern user would be so limited that the search effort involved in locating them would not be justified.

2. METHODOLOGY

O.R. researchers, like researchers in other fields, make contributions in many forms. Research works appear in form of reports, theses, working papers, book chapters, monographs, published research papers, etc. The work published in the form of reports, theses, working papers, monographs, etc. is also called "grey-literature", and is not easily traceable and obtainable. Moreover a good amount of such work often ends up as published research literature. We therefore limited our review to research work which has been published in journals.

As it has been rightly observed by Gray [1] and Hall & Hess [2] O.R. has become too pervasive as one sees O.R. research work appearing in more than one hundred journals all over the world. If we review only a limited number of journals, it is possible that we may miss many important contributions. The operations research societies representing 35 countries and 5

kindred societies are united in the International Federation of Operational Research Societies (IFORS). IFORS sponsors the abstracts journal "International Abstracts in Operations Research (IAOR)". IAOR [3] covers 33 primary journals. These journals are considered to be of interest to operational researchers "by definition, so every paper in each of these journals is cited by IAOR." Moreover, IAOR regularly screens 70 "supplementary journals" for papers which would be of interest to operations researchers. There are, in addition, 70 other "specialist" journals which are also regularly screened for papers of potential interest to some operations researchers. Since the abstracting of IAOR is fairly exhaustive, we limited our search of Indian contributions to the contents of IAOR. It is possible that we might have not included those papers in our review which have not been abstracted in IAOR.

Since we were interested in contributions made by Indians, we included every article abstracted in IAOR and published during 1961-1985 which had at least one coauthor with affiliation to an Institution in India. We are aware of the fact that several Indian researchers have published enormously, while they have been on assignments abroad, with foreign affiliations. Such articles, however, are not included in our review. Our review will no doubt underestimate Indian contributions to that extent. Till 1970, IAOR did not publish the

author affiliations, and therefore each abstract was carefully examined to see if any of the coauthors was likely to be an Indian! The original journals were then cross-checked to verify the affiliations. From 1971, IAOR started providing affiliation of the first author, but the same were not provided for other coauthors. Here again if any of the authors appeared to be Indian, the original journal was cross-checked for affiliation.

3. RESULTS

Our study shows that Indians have published 858 research papers in 85 different journals during the period 1961-85. Appendix 1 gives a list of journals along with the number of articles in which Indian contributions have appeared. We have divided the study duration of 25 years in five five-year periods: 1961-65, 1966-70, 1971-75, 1976-80, and 1981-85. The frequency distribution is given in Table 1.

TABLE 1

Period	No. of Papers	Percentage
1961-65	124	14.5
1966-70	175	20.4
1971-75	127	14.8
1976-80	194	22.6
1981-85	238	27.7

As it is evident from Table 1, the contributions have generally increased over the years except for the period of 1971-75. The number of contributions in the period 1981-85 are almost double than 1961-65. In

fact there were only 19 articles published in 1961 and increased to 49 in 1985.

Though contributions have appeared in 85 journals, there were only 20 journals which have at least 8 articles (1% of the total contribution) each in these 25 years. These 20 journals are marked with asterisk in Appendix 1. Out of these 20 journals only 5 had at least twenty-five papers in 25 years. Table 2 gives a breakdown of this data.

TABLE 2

Journal	No. of Papers	Percentage
CCERO	103	12.0%
Journal of O.R. Society	28	3.3%
Management Science	29	3.4%
Opsearch	242	28.2%
Operations Research	41	4.8%
Others	415	48.4%

As it can be seen CCERO, Journal of O.R. Society, Management Science, Opsearch, and Operations Research account for more than half of the publications. Among these five journals Opsearch is the most preferred journal followed by CCERO. We have further investigated the trend of journal preference over these years, and divided the number of publications in five time periods. Table 3 gives the relevent data.

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TABLE 3

Journal	1961-65	1966-70	1971-75	1976-80	1981-85	Total
CCERO	1 (1%)	25 (14%)	29 (23%)	24 (12%)	24 (10%)	103 (12%)
Journal of O.R. Society	3 (2%)	2 (1%)	1 (1%)	12 (6%)	10 (4%)	28 (3%)
Management Science	2 (2%)	10 (6%)	7 (6%)	6 (3%)	4 (2%)	29 (3%)
Opsearch	31 (25%)	73 (42%)	39 (31%)	43 (22%)	56 (24%)	242 (28%)
Operations Research	17 (14%)	12 (7%)	9 (7%)	1 (1%)	2 (1%)	41 (5%)
Others	70 (56%)	53 (31%)	42 (33%)	108 (56%)	142 (60%)	415 (49%)
Total	124	175	127	194	238	858

It is clear from Table 3 that Indians continue to contribute to Opsearch in a manner similar to the past. Their preference to other journals such as CCERO, Management Science, and Operations Research seems to be reducing in favour of other foreign journals. The share of other journals in 1981-85 is almost 60% of the total contribution. Therefore, it appears that Indians are broadening their publication base in foreign journals while retaining 25% to 35% contribution to Opsearch.

IAOR classifies research papers in four categories: Process Oriented, Application Oriented, Technique Oriented, and Professionally Oriented. The Process Oriented category consists of papers with emphasis on

the modelling of operations, functions, or activities common to various enterprises. The Application Oriented category covers papers with emphasis on certain arenas and models which are specialised to an arena. Technique Oriented category covers papers on mathematical models, methods, topics, techniques, and solutions. The last category of Professionally Oriented covers papers with emphasis on the practice and development of O.R. itself. Further details on these categories can be seen in [3] from page 12-13. We have analyzed data to identify major research interest areas of Indian researchers. Table 4 gives a summary of breakdown of research contributions in these four categories.

TABLE 4

Category	No. of Papers	Percentage
Process Oriented	302	35.2%
Application Oriented	104	12.1%
Technique Oriented	434	50.6%
Professionally Oriented	18	2.1%

From Table 4 it is clear that Indian contributions have been primarily in the theory of O.R. Even the contributions classified as Process Oriented are mainly contributions to the O.R. theory. The actual application papers are barely 12% of total contributions. We have further analyzed data to see whether there have been any

shifts over time. Table 5 gives a breakup of four categories over five time periods.

TABLE 5

Category	1961-65	1966-70	1971-75	1976-80	1981-85	Total
Process Oriented	40 (32%)	65 (37%)	47 (37%)	66 (34%)	84 (35%)	302 (35%)
Application Oriented	21 (17%)	25 (14%)	12 (9%)	21 (11%)	25 (11%)	104 (12%)
Technique Oriented	62 (50%)	76 (43%)	64 (50%)	104 (54%)	128 (54%)	434 (51%)
Professionally Oriented	1 (1%)	9 (5%)	4 (3%)	3 (2%)	1 (0%)	18 (2%)
Total	124	175	127	194	238	858

From Table 5 it does not appear that there have been any major shifts over the years in terms of research interests in these four categories. Since the researchers have mainly contributed in Process Oriented and Technique Oriented categories, we have further analysed them. Tables 6 and 7 give summaries of research contributions in Process and Technique Oriented categories, respectively.

TABLE 6

Process	No. of Papers	Percentage
Inventory	59	19.5%
Production	32	10.6%
Reliability	73	24.2%
Scheduling	55	18.2%
Others	83	27.5%

TABLE 7

Technique	No. of Papers	Percentage
Graphs and Networks	35	8.1%
Math. Programming	162	37.3%
Queues	104	24.0%
Statistics	15	3.5%
Others	118	27.2%

Mathematical Programming is the most favoured research area in Technique Oriented contributions followed by Queues. We have further subdivided Mathematical Programming and results are shown in Table 8.

TABLE 8

Technique	No. of papers	Percentage
Fractional Prog.	42	25.9%
Integer Prog.	11	6.8%
Linear Prog.	11	6.8%
Nonlinear Prog.	27	16.7%
Quadratic Prog.	19	11.7%
Transportation Prog.	25	15.4%
Others	27	16.7%

It may come as a surprise that among the Mathematical Programming techniques, Fractional Programming has attracted maximum papers. The traditional areas such as Linear Programming, Integer Programming, etc. do not appear to be favourites of Indian O.R. researchers.

4. CONCLUSIONS

In this paper we have reviewed Indian contributions to O.R. literature in last twenty-five years from 1961 to 1985. During this period Indians have published 858

research papers in 85 journals all over the world. It has been found that except for the time period 1971-75 Indian contributions have been increasing over the years. About 80% of contributions have appeared in 20 journals. The national journal Opsearch has attracted 28% of the total papers followed by CCERO with 12% contributions. Over the years the share of Opsearch has remained steady but the other major journals such as CCERO, Management Science, and Operations Research have been losing their share to other foreign journals.

About half of the contributions have been in the techniques of O.R. Though 35% papers have been in the Process Oriented category, most of them have theoretical emphasis. Only 12% papers have been with emphasis on applications of O.R. This trend has been consistent over the years and has not changed much during last 25 years. In the Process Oriented category the key areas of interest have been: Inventory, Reliability, Scheduling, and Production. In the Technique Oriented category the major areas of interest have been in Mathematical Programming and Queues. In Mathematical Programming, Fractional Programming has attracted largest contributions followed by contributions in Nonlinear Programming. Surprisingly traditional area, such as Linear and Integer Programming have not attracted much attention.

5. ACKNOWLEDGEMENTS

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2. Hall, J. and Hess, S.. "DR/MS Dead or Dying? RX for Survival." Interfaces, Vol. 8, No. 3, 1978, pp. 42-44.
3. International Abstracts in Operations Research, Vol. 37, No. 1, August 1988.

- 1 Ablauf und Planungsforschung
- 2 Agricultural Systems
- 3 Annals of the Institute of Statistical Mathematics
- 4 Artha Vijnana
- 5 Australian Journal of Applied Science
- 6 Australian Journal of Statistics
- 7 Biometrics
- *8 Cahiers du Centre d'Etudes de Recherche Operationnelle [CCERO]
- 9 Computers and Mathematics with Applications
- 10 Computers and Operations Research
- 11 Computing
- 12 Control & Cybernetics
- 13 Decision Sciences
- *14 Defence Science Journal
- 15 Discrete Applied Mathematics
- *16 Discrete Mathematics
- 17 Econometrica
- 18 Economic Computation and Economic Cybernetics Studies and Research
- 19 Ekonomicko-matematicky Obzor
- *20 Engineering Optimization
- *21 European Journal of Operational Research [EJOR]
- 22 IEEE Transactions on Systems Science and Cybernetics
- *23 Information Network and File Organisation [INFOR]
- 24 Illinois Journal of Mathematics
- 25 Indian Journal of Public Health
- 26 Indian Journal of Tuberculosis
- 27 Industrial Engineering Journal
- 28 IEEE Transactions on Engineering Management
- 29 IIE Transactions

- 30 Interfaces
- 31 International Journal of Operations & Production Management [IJOPM]
- 32 International Journal of Physical Distribution & Materials Management [IJDMM]
- *33 International Journal of Production Research [IJPR]
- 34 Journal of Agricultural Engineering
- 35 Journal of the American Statistical Association
- 36 Journal of Computational & Applied Mathematics
- 37 Journal of Information & Optimization Sciences [JIOS]
- 38 Journal of Mathematical Analysis and Applications
- 39 Journal of National Productivity Council
- 40 Journal of Water Resources Planning & Management
- 41 Journal of the Australia Mathematical Society
- 42 Journal of the Korean Operations Research Society [JKORS]
- *43 Journal of the Operational Research Society [JORS]
- 44 Journal of the Operations Research Society of Japan [JORSJ]
- 45 Journal of the Royal Naval Scientific Service
- 46 Journal of the Royal Statistical Society
- 47 Large Scale Systems
- 48 Maintenance Management International
- *49 Management Science
- 50 Mathematical Programming
- 51 Mathematics and Computers in Simulation
- 52 Mathematics of Operations Research
- 53 Mathematische Operations forschung und Statistik Series Optimization
- *54 Metrika
- *55 Naval Research Logistics Quarterly [NRLQ]
- 56 Networks
- *57 New Zealand Operational Research [NZOR]

- 58 Omega
- *59 Operations Research
- 60 Operations Research Letters
- 61 Operations Research-Spektrum
- *62 Opsearch
- *63 Optimization
- 64 R & D Management
- *65 Revue Belge de Statistique d'Informatique et de Recherche Operationnelle (RBSTARO)
- 66 Revue Francaise d'Automatique Informatique et de Recherche Operationnelle [REAIRO]
- 67 Revue d'Automatique d'Informatique et de Recherche Operationnelle [RAIRO]
- 68 SIAM Journal on Computing
- 69 SIAM Journal on Control & Optimization
- *70 Sankhya
- 71 SIAM Journal on Applied Mathematics
- 72 Statistica Neerlandica
- 73 Stochastic Processes & their Applications
- 74 Technological Forecasting & Social Change
- 75 Technometrics
- 76 The Annals of Mathematical Statistics
- 77 The Indian Journal of Mathematics
- 78 The Journal of Industrial Engineering
- 79 The Journal of Mathematical Sciences
- 80 The Railway Gazette
- *81 Trabajos de Estadistica e Investigacion Operativa
- 82 Transportation Research
- 83 Transportation Science
- *84 Unternehmensforschung
- *85 Zeitschrift fur Operations Research [ZOR]

* Denotes journals with at least 1% contribution