Bibliometric Indicators for Publication Productivity Analysis of an Individual Scientist

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Recently, lot of Bibliometric, Scientometric, and Informetric Studies, all over the world, have focused attention on evaluation of contributions of an individual scientist or his/her research group. Present paper attempts to bring together the productivity indicators for analysis of one of the most famous Indian Scientists. So that such studies will emerge as guidelines for evaluation of contributions of contemporary scientists, which may help in identification of present talent in the country, so that it can be nurtured further and latent potentials can be harnessed.

This case study analyses Dr Vikram Ambalal Sarabhai's publications by year, domain, collaboration pattern, channels of communications used, and distribution of articles among channels, and keyword frequencies appeared in the titles of publications. He had 160 publications in the domains *Cosmic Rays* (89), *Science Policy and National Development* (57), and *Management* (14) to his credit. His highest collaboration coefficient was 1.00 during 1947-53, 1955-56, and 1961. His productivity coefficient was 0.58 indicating his consistent publication activity through-out his scientific career. His most prominent collaborators in number of papers were; G Subramanian (14), G L Pai (11) and K N Nair (11).

Core journals, with papers to which he had contributed were : *Physical Review* (8), *Proceedings of Indian Academy of Sciences* (8), and *Nature* (6). Bradford multiplier was 2.44. Publication density was 1.30, and publication concentration was 2.86. His high frequency keywords in the titles of the articles were : *Anisotropy* (18), *Daily Variations* (18), *Cosmic rays* (14), *Galactic cosmic rays* (14), *Geomagnetic field* (14), and *National development* (11).

The results indicate that the temporal publication productivity and the nature of the research activities were such that he is eminently qualified to be taken as a *role model* for the younger generation to emulate.

1. Introduction

Vikram Ambalal Sarabhai was born on August 12, 1919 at Ahmedabad. He had his early education at a private school at Ahmedabad. He then went to Cambridge and obtained his tripos in 1939. He worked in the area of cosmic rays under the guidance of Sir C V Raman, the Nobel Laureate in Physics for 1930 at Indian Institute of Science, Bangalore.

His craze for physics was formed early and remained intense as ever throughout his life.

He worked at the Meteorological Department, Poona as early as 1942.

He was awarded the Doctorate for his thesis *Cosmic ray investigations in tropical latitudes* by the Cambridge University in 1947.

Sarabhai was responsible for the establishment of Physical Research Laboratory (PRL) in Ahmedabad in 1947 and personally directed till 1971, and founded the Ahmedabad Textile Industry's Association (ATIRA) in 1947 and was an Honorary Director till 1965. Sarabhai also founded Indian Institute of Management (IIM) in Ahmedabad in 1962 in order to cater to the

demands for professional management skills of high order in India and was its Honorary Director till 1965.

He was a pioneer in space research in India and was responsible for taking up major steps like setting up of the Space Science and Technology Centre (SSTC) near Thumba and the establishment of an Experimental Satellite Communication Earth Station (ESCES) at Ahmedabad. Sarabhai's major achievement with which he was closely associated is the famous Satellite Instructional Television Experiment (SITE).

Sarabhai's pioneering efforts could enable India to launch its first Scientific Satellite Aryabhatta named after a great Indian Astronomer and Mathematician into space by Soviet rocket carrier only after three and half years of his untimely death in 1971.

He had several positions in different capacities and received many honours and awards in recognition to his contributions in the fields of space research and Atomic energy.

(a) Professor of Cosmic Rays Physics (1947-65).

(b) President, Indian Science Congress Physics Section (1962).

(c) Chairman, Indian National Committee for Space Research (INCOSPAR) (1962).

(d) Bhatnagar Medal (1962).

(e) Fellow of the National Science Academy (1963).

(f) Director, Physical Research Laboratory (PRL) (1965-71).

(g) Secretary, Department of Atomic Energy (1966-1971).

(h) Chairman, Atomic Energy Commission (1966-1971).

(i) Padma Bhushan (1966).

(j) Member, International Council of Scientific Unions (1966).

(k) Chairman, Panel of Experts and Scientific Chairman of the UN Conference on the *Exploration and Peaceful Uses of Outer Space* (1968).

(l) President, 14th General Conference of the International Atomic Energy Agency (1970).

(m) President, Indian Geophysical Union (1970-71).

(n) Vice-President, Fourth UN Conference on Peaceful Uses of Atomic Energy (1971).

(o) Padma Vibhushan (Posthumously) (1972).

In 1966, after tragic death of Homi Jehangir Bhabha, Sarabhai was asked to take up the Chairmanship of the Atomic Energy Commission. He threw himself whole-heartedly in to the work with boundless energy and Space Research Organisation (ISRO) into even closer contact.

Vikram Sarabhai put India on the space map of the world. He was inducted into the International Space Hall of Fame at the Space Centre, Alamogorodo, New Mexico, at an impressive ceremony on October 2, 1993. He is the first Indian Scientist to be honoured by the Americans in recognition of his contribution to the Indian Space Programme and in applying space technology for the welfare of people. His work has been well documented [1-8].

2. Objectives

Objectives of the present study were to highlight quantitative aspects of research publications of Vikram Sarabhai such as authorship, pattern, domainwise contribution, author productivity, core channels of communications used, distribution of articles among channels, documentation of keywords from titles of publications, Bradford multiplier etc.

3. Methodology

Scientometric analysis is usually based on the utilization of several independent data like publications, citations, experts opinions, content analysis, etc. which together permit to enlight various sides of the development of a definite science field.

Publication and citation counting techniques have been used in the assessment of scientific activity for atleast fifty years. During the half-century of this activity the main thrust of interest seems to flow along two connected parallel paths : the bibliometric path of publication and citation counts as tools for the librarian, and an evaluative path using these same tools to illuminate the mosaic of scientific activity [9].

Evaluative bibliometrics shows that there are

large differences in influence among scientific journals; few scientists would deny this. Evaluative bibliometrics shows that our great scientific institutions are in fact publishing large numbers of highly cited papers in highly influential journals; few scientists would dispute this. Evaluative biblometrics shows that scientific activity is related to Gross National Product (GNP), and that, as the economic might of the United States and the Soviet Union have grown over the last 50 years, so have their measured positions in the scientific world; few would question this. Clear evidence emerges that the productivity of individuals varies widely, and that the truly creative scientists publish often, are heavily cited, and contribute to the progress of science in an amount which is many times that of the average scientist. Few would object to this observation [9].

The choice of unit of analysis and of the initial set has a strong influence on the measures and results of any bibliometric study. Generally speaking authors are used when the study focuses on the influence of individuals, articles are used to study the particular idea as embodied in the article, key terms are used to follow an idea over time as it crosses disciplines and journals when the study focuses on the institutional embodiment of a discipline [10].

Bibliographic details of all publications of Vikram Sarabhai were documented on cards and sorting was done as per requirement to extract various data.

Normal count procedure [11] was followed. Full credit was given to each author regardless of whether he happens to be the first or the last author. It is widely recognised that scientists all over the world look at their own papers exclusively in that way. Similarly titles of the articles were analysed and one score was alloted for each key word, subject, journal etc.

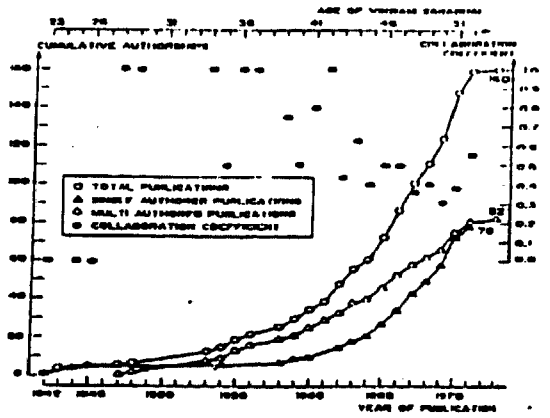


Figure 1. Yearwise Publication Output of Vikram Sarabhai.

The degree of collaboration [12] in a discipline was defined as the ratio of the number of collaborative research papers to the total number of research papers published in the discipline during a certain period of time.

Vinkler [13] defined Publication Density as the ratio of the total number of papers published to the total number of journals in which the papers were published, and Publication Concentration as the ratio in percentage of the journals containing half of the papers published to the total number of journals in which those papers were published during the period under study.

Sen and Gan [14] defined Productivity Coefficient as the ratio of 50 percentile age to the total productivity age.

Frequency of keywords from the titles of the articles were recorded. Data obtained from above study were presented in tables and figures.

4. Results And Discussions

During 1942-1973 Vikram Sarabhai had published 160 publications in the domains *Cosmic Rays* (89), *Science Policy and National Development* (57), and *Management* (14).

Yearwise publication output of Vikram Sarabhai is shown in Figure 1. His highest Collaboration Coefficient was 1.00 during 1947-53, 1955-56, and 1961.

His productivity coefficient was 0.58 which is clear indication of his consistent publication productivity behaviour throughout his research publication career.

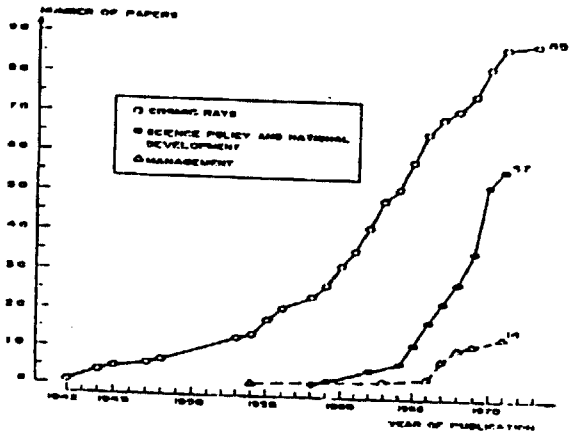
Vikram Sarabhai had 78 single author publications and 82 multi-author publications to his credit. He was first author in 46 multi-author papers.

His first paper was published in 1942 in *Proceedings of Indian Academy of Sciences* at the age of 23.

Vikram Sarabhai had single authored papers in various domains as *Cosmic Rays* (15), *Science Policy and National Development* (52), and *Management* (13).

His domainwise cumulative number of publications is depicted in figure 2.

Table 1 shows author productivity and distribution of author in various domains. The research group of Vikram Sarabhai has the credits of number of authorships in various domains : *Cosmic Rays* (194), *Science Policy and National Development* (75), and *Management* (15). Total number of authors in the research group were 39. Researchers and their authorships in collaboration with Vikram Sarabhai in chronological order of their association (in first publication with Sarabhai) are depicted in Figure 3. Most active researchers and their contributions with Sarabhai were G Subramanian (14), G L Pai and K N Nair (11) each. Other active collaborators with Sarabhai were U R Rao (7), U D Desai, R P Kane and D Patel (6) each. Other collaborators having four papers each were four, three papers each were four, two papers each were four and single papers each were 17. P D Bhavasar, E V Chitnis had collaborated with Sarabhai in the domains *Cosmic Rays* and *Science Policy and National Development* whereas K Choudhary had collaborated only in the domain *Management*.



Figre 2. Domainwise Growth of Publications of Vikram Sarabhai

Domainwise collaboration of Vikram Sarabhai with his 38 collaborators and their status of authorship in various domains is provided in Table 2.

Table 1. Author Productivity and Distribution of Authors in Various Domains

No. of authors	Domainwise Authorships			No. of authors	Total authorships	Prominent Collaborators
	A	B	C			
1	6	10	1	17	17	
2	6	2	-	4	8	
3	6	6	-	4	12	
4	16	-	-	4	16	
5	10	-	-	2	10	Nerurkar, N. W. and Pathank, P. N.
6	18	-	-	3	18	Desai, U. D.; Kane, R. P. and Patel, D.
7	7	-	-	1	7	Rao, U. R.
11	22	-	-	2	22	Pai, G. L. and Nair, K. N.
14	14	-	-	1	14	Subramanian, G.
160	89	57	14	1	160	Sarabhai, V.
Total	194	75	15	39	284	

A = Cosmic Rays B = Science Policy and National Development C = Management

Communication channelwise scattering of publi-cations of Vikram Sarabhai is provided in Table 3. He has published eight papers each in *Proceedings of Indian Academy of Sciences* and *Physical Review*, six papers in *Nature*, four papers each in *Indian and Foreign Review*, *Journal of Geophysical Society of Japan*, and *Planetary and Space Science*, and three papers in *Proceedings of Royal Society*.

In addition to 69 publications in 32 periodicals,

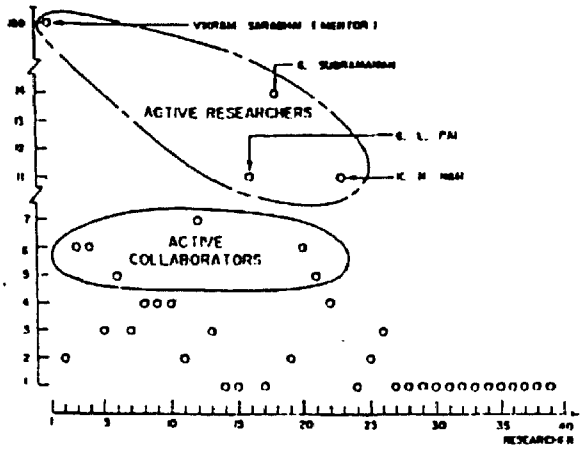


Figure 3. Researchers Association in Chronological Order and Authorships

he had 91 papers to his credit in various conferences, symposia etc.

Average Bradford multiplier was 2.44 publication density was 1.30 and publication concentration was 2.86.

The channelwise frequency and cumulative number of papers published is depicted in Figure 4.

The keyword frequencies in the title of the papers were provided in Tables 4 and 5. High frequency keywords were *Anisotropy* (18), *Daily variations* (18), *Cosmic ray intensity* (14), *Cosmis rays* (14), *Galactic Cosmic rays* (14), *Geomagnetic field* (14), and *National Development* (11).

These keywords indicate his wide spectrum of interest, materials, methods, instruments used and subjects addressed to in the course of his 24 years of research papers publishing life span.

Table 3. Channelwise Scattering of Publications of Vikram Sarabhai

Sl. No.	Journal	No. of papers	Percentage	Cumulative percentage	SCI JCR 1992		Period of journal usage		
					IF	II	FPY - LPY		Total
1.	Physical Review	8	5.000	5.000	-	-	1944	1960	17
2.	Proc. Ind. Acad. Sci	8	5.000	10.000	-	-	1942	1962	28
3.	Nature	6	3.750	13.750	22.139	5.224	1953	1970	18
4.	Indian & Foreign Review	4	2.500	16.250	-	-	1968	1970	3
5.	J. Geophys. Soc. Jap.	4	2.500	18.750	-	-	1962	1962	1
6.	Planetary and Space Sci.	4	2.500	21.250	1.075	0.259	1964	1970	7
7.	Proc. Roy. Soc.	3	1.880	23.130	-	-	1961	1961	1
8.	Astrophysics J.	2	1.250	24.380	2.931	0.152	1966	1967	2
9.	Ind. J. Person. Adm.	2	1.250	25.630	-	-	1968	1969	2
10.	J. Geophys. Res.	2	1.250	26.880	2.100	0.900	1963	1970	8
11.	J. Sci. Ind. Res.	2	1.250	28.130	0.062	0.033	1962	1971	10
12.	Science and Culture	2	1.250	29.380	-	-	1970	1970	1
13.	Science Today	2	1.250	30.630	-	-	1969	1970	2
14.	Yojana	2	1.250	31.880	-	-	1966	1967	2
15.	Acta Physics	1	0.625	32.505	-	-	1970	1970	1
16.	Ann. Rev. Nucl. Sci.	1	0.625	33.130	4.034	0.400	1956	1956	1
17.	Astrophys. and Space Sci.	1	0.625	33.755	0.325	0.155	1973	1973	1
18.	Can. J. Phys.	1	0.625	34.380	0.461	0.099	1968	1968	1
19.	Cosmic Electrodynamic	1	0.625	35.005	-	-	1971	1971	1
20.	COSPAR Information Bull.	1	0.625	35.630	-	-	1962	1962	1
21.	Gandhi Marg	1	0.625	36.255	-	-	1969	1969	1
22.	IAGA Bull.	1	0.625	36.880	-	-	1969	1969	1
23.	J. Geomag. Geoelec.	1	0.625	37.505	0.333	0.529	1966	1966	1
24.	Link	1	0.625	38.130	-	-	1970	1970	1

25.	Nuovo Cimento	1	0.625	38.755	-	-	1958	1958	1
26.	Opsearch	1	0.625	39.380	-	-	1970	1970	1
27.	Physical Review Letters	1	0.625	40.005	3.375	1.449	1967	1967	1
28.	Proc. Phys. Soc.	1	0.625	40.630	-	-	1948	1948	1
29.	Science & Technology Series	1	0.625	41.255	-	-	1960	1960	1
30.	Space Research	1	0.625	41.880	-	-	1965	1965	1
31.	Space Science	1	0.625	42.505	-	-	1970	1970	1
32.	Times of India	1	0.625	43.130	-	-	1970	1970	1
33. to 123	Conference Proceedings etc.	91	56.870	100.000	-	-			
	Total	160							

SCI JCR = Science Citation Index Journal Citation Reports, IF = Impact Factor, II = Immediacy Index, FPY = First Paper Published Year, LPY = Last Paper Published Year.

So far a very few scientometric studies have been carried out on individual scientist [15-47]. This is an interesting interdisciplinary domain which reveals characteristics of the School of Scientific Excellence, formed around a creative scientist, that results in Synergetic effect of progress in Science and Technology. Hence needs further research so as to get insight into the system of harnessing effectively the potentials in human resources. There is a need to assess the performance on a continuous basis. There are individual scientists doing good work. If we can project image of such scientists, it may be possible to attract talents of younger generation. It is the human intelligence and imagination that is going to build 21st century.

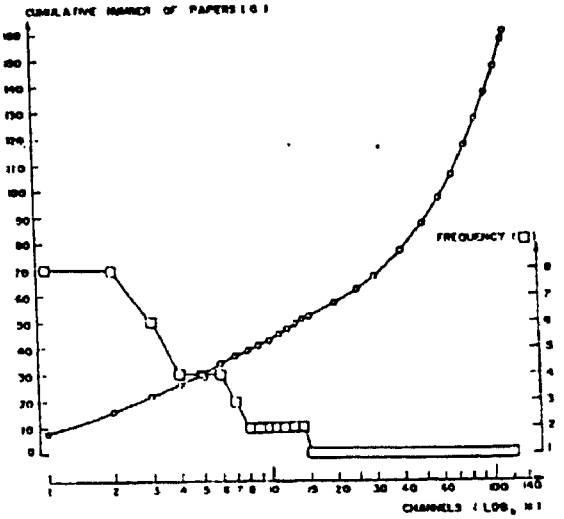


Figure 4. Bibliograph on Publication of Vikram Sarabai

Table 4. Keyword Frequencies in the Titles by Vikram Sarabhai

Keyword	Frequency	Keyword	Frequency
Anisotropy	18	Scientific research	3
Daily variations	18	Solar activity	3
Cosmic ray intensity	14	Solar cosmic rays	3
Cosmic rays	14	Solar wind velocity	3
Galactic cosmic rays	14	Television	3
Geomagnetic field	14	Asymmetry	2
National development	11	Atomic power station	2
Fluctuations	7	Cosmic ray storms	2
India	7	Electro magnetic state	2
Low latitudes	7	Employment	2
Meson intensity	7	Energy	2
Cosmic radiation	6	Extra terrestrial	2

Interplanetary space	6	Galectic cosmic ray density	2
Solar system	6	Geomagnetic equator	2
Time variations	6	Interplanetary plasma	2
Developing countries	5	Leadership	2
Interplanetary magnetic field	5	Mesons	2
Science	5	National goals	2
Magnetosphere	4	Nonviolence	2
Modulation	4	Organization	2
Education	3	Plasma wind	2
Green revolution	3	Security	2
Magnetic storms	3	Semidiurnal anisotropy	2
Nuclear Power	3	Semidiurnal variations	2
		Telecommunication electronics	2

Table 5. Keywords Used Only Once in the Titles of Papers by Vikram Sarabhai

Air showers	Government	Science & Industry
Arms control	Green coronal emission	Sector structure
Asymmetric interactions	Human function	Satellite
ATIRA (Ahmedabad Textile Industries Research Association)	Human values	Short period fluctuations
Atomic energy	Innovation	Shower anticoincedences
Atomic Energy Commission	INSAT-A	Social environment
Control & Management	Management	Solar and terresterial relationship
Coronal intensity	Meteorological	Solar anisotrypy
Cosmic ray effects	Meson component	Solar Cycle
Cosmic ray fluctuations	Mu mesons	Solar equatorial plane
Density of Solar Wind	Music	Solar flare
imiliterasation of space	Narrow angle telescope	Solar influence
Dip equator	Noise	Solar maximum activity
Disarmament	Non Uniformity	Solar minimum activity
Electromagnetic conditions	Nuclear Centre for Agriculture	Solar plasma
Energy spectrum	Nuclear Medicine	Solar wind effects
Environment	Operational research	Space
Equatorial sky	Outer space	Space exploration
Gangetic plain	Planning	Space research
Geomagntic disturbance	Polar cap absorption	Temperature effect
Geomagnetic effects	Pollution	Three dimensional dynamotheory
Geomagnetic fields	Public sector enterprises	Time distribution
Geomagnetic plasmas	Public sector management	Trivendram
Geomagnetic variations	Remote sensing	Unemployment
	Reorganisation	

5. Conclusion

Publication productivity analysis of the successful scientist Vikram Sarabhai, carried out here has thrown light on his pivotal contributions to science and technology. He can be considered as a *role model* for younger researchers to follow. Knowledge is valuable for its own sake and research has cultural values. Desire of being creative is built in our genes. Who knows this effort may switch on genes for creativity in some of those

who happen to read this article. Narrating success stories always has an encouraging effect. It is also important to recognise that excellence in science is not just a matter of a few individual successes, what is required is a wide base of high quality, which would enable peaks to come up more frequently and on a more definite basis. New ways to motivate scientists seem as important to contest outcome as new sources of funds. Science policy makers interested to know about functioning of active research teams as centres of excellence and factors responsible for optimizing, maximising and enhancing outputs may find further interest in scientometrics. As per Indian Scientific Policy Resolution 1958, which our scientists regard as their charter, *to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity* all must work together with holistic approach.

There is no dearth of ideal role model scientists in India, what we lack is the systematic and continuous studies on such scientists. Hence, the comment *Most of the developing countries lack role models to motivate other scientists* [48] does not hold good at least for India.

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