RESEARCH UNDERTAKEN IN PHYSICAL RESEARCH LABORATORY (PRL) : A BIBLIOMETRIC STUDY

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BY

NISHTHA ANILKUMAR

RESEARCH GUIDE

DR. SHYAMA RAJARAM

DEPARTMENT OF LIBRARY AND INFORMATION SCIENCE
FACULTY OF ARTS
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA
VADODARA -390002
GUJARAT, INDIA

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DECLARATION

I hereby declare that the research work presented in this thesis is prepared and carried out by me. The descriptions and narrations found therein are entirely original. I also declare that such material as has been obtained from other sources has been duly acknowledged.

Date : 19 August 2011 (Ms. Nishtha Anilkumar)

Place : Vadodara Candidate

CERTIFICATE

This is to certify that the research titled, “Research undertaken in Physical Research Laboratory (PRL): A Bibliometric Study”, incorporates the results of an independent study carried out by Ms. Nishtha Anilkumar under the guidance of Dr. Shyama Rajaram for the degree of Doctor of Philosophy in Library and Information Science. The contents presented herein have not been submitted for the award of any other Degree or Diploma of this or any other university.

(Ms. Nishtha Anilkumar) (Dr. Shyama Rajaram)

Candidate Research Guide

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Nishtha Anilkumar

Candidate

PREFACE

Science and Technology (S & T) research is not limited to few countries these days, rather it is becoming an increasingly international endeavor. Governments around the world acknowledge the role of science and technology in generating new jobs, economic prosperity and advantage in global competition. As huge amount of money is being spent on S & T research, there is a rising need to know and monitor the value of investment amongst the policy makers and research funding agencies. The knowledge and processing of research results regarding any scientific area are a basic input to the evaluation of the research activities. Universities and research institutes are adopting the procedures for regular monitoring of research activities. Research evaluation in the form of papers published and cited in journals has almost become mandatory. Scientists also welcome the use of metrics to measure and assess scientific performance because of the potential for clarity and objectivity.

Bibliometrics is very often being used as a tool for a critical assessment of research output. Bibliometric analysis, constructed upon publication and citation data, enables one to obtain an interesting overview of scientific research. Studies over long periods of time are especially relevant to understand the dynamics of research and to identify the emerging and declining topics of research. Thus the use of bibliometric studies is on the rise in most of the countries. It not only evaluates research productivity of individuals and institutes, but rather encompasses the countries and subject disciplines all over the world.

As no bibliometric study of PRL has been carried out till now, the researcher thought it appropriate to undertake the present study for her doctoral research. Research output of PRL is mainly available in two forms – research publications of the scientists and doctoral theses of the Ph. D. students. The researcher has studied both these forms of scholarly communication for the period 1997 to 2006. The findings of the study will help in identifying the future direction of research. The improved understanding will help in consolidating lines of research, exploring new approaches or beginning collaboration on a national or international scale. It will also reveal preferences and gaps in collection development and management of information resources.

LIST OF ABBREVIATIONS

AAD	– Astronomy & Astrophysics Division
B	– Book
CB	- Chapter of a Book
CI	– International Collaboration
CN	– National Collaboration
CP	- PRL Collaboration
CPI	– International Conference Proceeding
CPN	– National Conference Proceeding
D	– Double authored paper
Ep	– E-print
GSDN	– Geosciences Division
JI	– International Journal
JN	– National Journal
M	– Multiple authored paper
NSJ	– Non Subscribed Journal
CP	– PRL Collaboration
PLANEX	– Planetary Exploration
P	– Proceedings
PSDN	- Planetary Science Division
R	– Report
S	– Single authored paper
SJ	- Subscribed Journal
SO-PH	– Solar Physics Division
SOXS	- Solar X-ray Spectrometer
SPA-SC	- Space & Atmospheric Science Division
St	- Standard
Th	- Thesis
THE-PH	– Theoretical Physics Division
TI	– International Invited Talk
TN	– National Invited Talk

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CHAPTER 1

INTRODUCTION

If you can measure that of which you speak, and can express it by a number, you know something of your subject but if you cannot measure it, your knowledge is meager and unsatisfactory

- Lord Kelvin

Measurement is the main tool of science. Methods of measurement were perhaps invented as civilizations developed. In the beginning, measurement was related mainly to length, breadth, weight and volume. As civilization progressed, need was felt to measure number of other phenomena. For a long time measurement was the field of study of physical scientists and mathematicians alone. Gradually, other areas of science and social science also started adopting it. Interdisciplinary subjects like econometrics and sociometrics have come into existence wherein mathematics and statistics have been applied to study the problems in the respective fields of economics and sociology. However, in recent times, measurement has started being used to measure science itself as the volume of scientific research has expanded exponentially. Science research is now such a large enterprise and so specialized and complex that personal knowledge and experience are no longer sufficient for understanding trends or for making decisions. On the other hand there is a need to highlight the promising areas of research and to manage better investments in science.

The fund allocation in government, industry and education has not grown as fast as 'Science'. Those in industry, government offices, laboratories and universities are being told to justify what should be supported and what should not, which research projects should receive more support than others. Achievements in industry can be measured by number of patents or sales revenue – the commercial success of discoveries as they move

from the laboratory to the marketplace. But the achievements and trends in science are not so easily counted. And so until recently peer review has been the main route by which science policy makers and research funders have coped with decisions to set the path of progress.

Growing demand to quantify the research output from public funding has compelled funding agencies and employers to treat numerical indices of research output more seriously. Thus increasingly, quantitative methods are being used to supplement the standard approach of peer review to evaluate research (Kelly, 2006).

One such method is bibliometrics. Etymologically bibliometrics is composed of two distinct parts - biblio and metrics. The prefix biblio is a Greek word meaning books and metrics means measurement. So 'bibliometrics' connotes the science of measurement pertaining to books or documents. Gradually it started being used to measure research itself. At the most basic level, quantitative approach to research evaluation is simply counting. The complexity is in the analysis and use of numbers, for, the data obtained can be understood as indicators of achievement or lack of it. There are many activities and outcomes of research that can be counted. The most basic and common is number of publications and citations received by them. Citations, the references researchers append to their papers to show explicitly earlier works which they have used or referred in their present study, indicate how a work is used in subsequent research. The citations thus act as signboards on the highway which lead the researchers to the destination. Citation Analysis is one of the main tools used to measure the research output. Following the citations and understanding their trends is a key to evaluating the influence of research.

Historical Development

Roots of bibliometrics can be traced back to 1917 wherein Cole & Eales analyzed publications in comparative anatomy published between 1543 and 1860 by simply counting number of titles, both books and journal articles and grouping them by country. In 1923

Hulme published an analysis of the international catalogue of scientific literature for the year 1901 through 1913. Subsequently, Lotka (1926) analyzed the frequency distribution of scientific productivity and his work led to the development of Lotka's Law. This law assesses the patterns in author productivity. Following the above works, Gross & Gross (1927) took the next step in the analysis of literature when they tabulated citations for the Journal of Chemical Society. This study aimed to identify journals with a high impact in their own field – Chemistry. Another pioneering study was carried out by Bradford (1934), who considered the frequency distribution of papers across journals. This work also led to formulation of Bradford's law, which is now very widely used in bibliometrics. This was followed by a study made by Zipf (1935). He studied the frequency of words in a text. Bibliometrics took a quantum jump through the works of Garfield (1955) and Price (1963). However, it was not until 1969 that the term bibliometrics first appeared in print (Pritchard, 1969). Pritchard defined it as "application of mathematical and statistical methods to books and other media of communication".

Gradually, the practical value of bibliometric studies started attracting many researchers' attention. More and more people started taking up such studies which resulted in more publications in this area. In 1980s the interest in bibliometrics took a nose dive due to lack of availability of documents, the manual collection of data and the license fee charged for obtaining documents. The breakthrough came as a result of new technological developments during 1990s in the form of availability of online data regarding publications (Glanzel, 2003).

Citation Index

As mentioned earlier, a citation is a reference to a published or unpublished source. Citations are formal, explicit linkages between papers that have particular points in common. A citation index is built around these linkages (citations). It lists publications that have been cited and identifies the sources of the citations. Anyone conducting a

literature search can find additional papers on a subject just by knowing one that has been cited.

A citation database for science was first described in 1955 by Eugene Garfield, the founder and chairman emeritus of ISI (Institute of Scientific Information, Philadelphia) in the journal 'Science'. He realized his vision a few years later with the production of the 1961 Science Citation Index (SCI). The main purpose of Garfield's citation database is improved or expanded information retrieval. By recording not only bibliographic information of the journal articles, but also the cited references in these journal articles, Garfield offered researchers a way to find articles relevant to their work that they would not otherwise turn up searching author names, title words or subject headings alone. Garfield was aware that such a database could serve other purposes as well, such as monitoring and analyzing the structure and growth of science. Others too saw this possibility. Among them two prominent ones are Derek J de Solla Price, author of the 1963 classic 'Little Science Big Science' and Francis Narin of CHI Research, USA who was pioneer in using the citation data to analyze science, particularly through his influential 'Evaluative Bibliometrics' of 1976. The combination of an ever growing corpus of publication and citation data compiled by ISI over the 1960s and 1970s and the simultaneous increase in computing power and software applications, especially those developed in the 1980s and 1990s, has made bibliometrics a very useful pursuit (Pendlebury, 2008) .

The advent of SCI and electronic access to the ISI's massive datasets has had a catalytic effect on the popularity, scope and ambition of bibliometric research. SCI grew out of specialty index to the literature of genetics and was inspired by Shephard's legal citation index which was created almost a century earlier (Cronin, 2001). However, Weinberg (1997) was of the opinion that true conceptual origins of citation indexing are to be found in the fourteenth century Hebrew literature.

Scientometrics and Informetrics

Statistical analysis when applied to a field of activity generates a new field derived out of fusion, e.g., when it is applied to information systems and services, it becomes Informetrics. The organization of science and its productivity analysis gives rise to Scientometrics. All these techniques give rise to statistical models in a particular context. Such models help in utilization of information in a productive manner and also help in identifying areas of further research.

Since Vassily V. Nalimov coined the term 'Scientometrics' in the 1960s, this term has grown in popularity and is used to describe the study of science: growth, structure, productivity and inter-relationships. Scientometrics is related to and has overlapping areas with bibliometrics and informetrics. All the three terms refer to component fields related to the study of the dynamics of disciplines as reflected in the production of their literature. Hood & Wilson (2001) carried out a study pertaining to the literature of bibliometrics, scientometrics and informetrics. Studying the frequency distribution of the metric terms, they found 7750 bibliometric documents followed by 1878 scientometric documents and 615 informetric documents. Thus, over time, the popularity of the terms has changed, with the older term – bibliometrics, fairly stable and newer terms – scientometrics and informetrics gaining in usage.

A study was carried out by Chubin (1987) wherein he has divided the evolution of bibliometrics as a subject specialty into two generations. The first generation marked by Garfield's founding of the Science Citation Index and Price's visionary thought and experimentation, explored the feasibility of understanding science through its literature alone instead of through one's participatory role in its creation. The second generation sought to develop and exploit publication and citation data as a tool for informing decision makers, especially in federal agencies and universities. This generation thus has all the features of an institutionalized scientific specialty – multidisciplinary journals and practitioners, a clientele (both consumers and patrons) and its increasing use as a policy tool. The paper assesses the most promising approaches and methods that have been

employed and suggests how quantitative data and model could be refined to augment decision making processes in science.

Types of Bibliometric studies

Depending on the use, Lancaster (1991) has classified the bibliometric studies into descriptive and evaluative studies. Descriptive bibliometric studies include the study of the number of publications in a given field, or productivity of literature in the field for the purpose of comparing the amount of research in different countries, the amount of literature produced during different time periods or the amount produced in different subdivisions of the field. This kind of study is made by count of the papers, books and other works in the field, or often by a count of those writings which have been abstracted in a specialized abstracting journal. Evaluative studies measure the literature usage by means of citations or references cited by the researchers in their papers or other documents like theses, reports, etc.

Barre (1997) carried out a descriptive bibliometric study on the European perspective on Science & Technology indicators which highlighted the outputs of various countries in Europe, the diversity of institutional settings and the growing potentials.

Bibliometric studies are also used to determine the research collaboration as it increases the research output by decreasing the redundancy of research efforts. To compare the extent of collaboration in two fields or to show the trend toward multiple authorships in a discipline, Collaborative Index or Degree of Collaboration is being used. Sangam (2001) investigated the type of collaborated research carried out in India in Psychology. He concludes that there is high degree of collaboration in Psychology in India. In another study, Rey-Rocha and Martin-Sempere (2004) studied the patterns of the foreign contributions published in six scientific journals in Earth Sciences published in different countries. The effect of geopolitical, cultural, economic and linguistic bonds amongst countries on publication and collaboration patterns have been studied.

Bibliometric Indicators

The introduction of Journal Citation Reports (JCR) as a companion volume to SCI has extended the use of citation analysis to examine relationships among journals. The journal citation data in JCR are compiled by counting the different article-to-article links. These are further used to construct journal measures (indicators) such as Impact Factor (IF), Immediacy Index (II), References per Paper (R/P), Half Life (HL), etc. Journal citation indicators are commonly used as general measures for various journal characteristics and research impact by different participants in the publication, dissemination and evaluation process of scientific knowledge. Todrov & Glanzel (1988) tried to review and comment on some citation based measures for scientific journals which are available and applied as evaluative indicators.

Impact Factor (IF)

The *JCR* provides quantitative tools for ranking, evaluating, categorizing, and comparing journals. The impact factor is one of these; it is a measure of the frequency with which the "average article" in a journal has been cited in a particular year or period. The annual *JCR* impact factor is a ratio between citations and recent citable items published. Thus, the impact factor of a journal is calculated by dividing the number of current year citations to the source items published in that journal during the previous two years. The impact factor for a journal is calculated based on a three-year period, and can be considered to be the average number of times published papers are cited up to two years after publication.

For example, the impact factor 2011 for a journal would be calculated as follows:
A = the number of times articles published in 2008-2009 were cited in indexed journals during 2010
B = the number of articles, reviews, proceedings or notes published in 2008-2009
Impact factor 2010 = A/B

Immediacy Index

This calculation, published in the JCR, is one developed by ISI as an indicator of the speed with which citations to a specific journal appear in the published literature. Such information is useful in determining which journals are publishing in emerging areas of research

Immediacy index is the average number of times that an article published in a specific year within a specific journal is cited over the course of that same year.

Cited half-life

ISI developed this calculation to provide an indicator as to the long-term value of source items in a single journal publication. The cited half life calculation appears only in the JCR.

Cited half-life is a measurement used to estimate the impact of a journal. It is the number of years, going back from the current year, that account for 50% of the total citations received by the cited journal in the current year. Say for example, Geochimica Cosmochimica et Acta (GCA) received 1000 citations in itself up till now. Number of years it took to get cited 500 times is the cited half life of GCA.

Citing half-life

ISI developed this calculation to provide an indicator of the subtle changes in scope of a publication over the course of time. Evaluation of this factor can provide information on the cross-disciplinary nature of research in a specific field of interest.
It is measured by the number of journal publication years, going back from the current year, that account for 50% of the total citations given by the citing journal in the current year. In other words, suppose Nature cites GCA 100 times up till now, then number of

years it took, going back from current year to reach 50 citations of GCA in Nature is the citing half life of GCA.

H-index

The h-index is a relatively recent bibliometric indicator for assessing the research output of scientists, based on the publications and the corresponding citations. The index was suggested by J E Hirsch, a physicist, as a tool for determining the researcher's impact (Wikipedia, 2011). Hirsch has defined h index as "A scientist has index h if h of his/her Np papers have at least h citations each and the remaining papers (Np-h) papers have <= citations each i.e. if a scientist has 30 papers to his credit and 20 of his papers have 20 or more citations, then his h-index is 20 (and remaining 10 papers will have less than 20 citations each). Thus, this index is based on the set of the scientist's most cited papers and the number of citations that they have received in other people's publications. Due to easy calculation and immediate intuitive meaning, this indicator has become very popular in the scientific community. It attempts to measure both the productivity and impact of the published work of a scientist or scholar. It gives an estimate of the importance, significance, and broad impact of a scientist's cumulative research contributions. This index may provide a useful yardstick with which to compare, in an unbiased way, different individuals competing for the same resource when an important evaluation criterion is scientific achievement. The index can also be applied to the productivity and impact of a group of scientists, such as a department or university or country (Hirsch, 2005).

A new journal indicator (SNIP - Source-Normalized Impact per Paper) of a scientific scholarly journal has been proposed by Moed (2010). It is based on a journal's subject field and takes into account the frequency and immediacy of citation and database coverage in a subject field. It is important to take into account differences in communication and citation practices between various subject fields as this affects the journal impact.

In recent years, the demand and supply of research indicators have very quickly developed both in quantitative as well as qualitative terms. These indicators are based on variety of research functions, capabilities and outcomes. In fact, nowadays, almost every research assessment decision (accepting research projects, contracting researchers, awarding scientific papers, sanctioning a grant and so on) depends to a great extent upon the scientific merits of the involved researchers.

Using these indicators, research measurement of a country or a subject field is a complex process. A number of studies have been carried out to find out India's research output in many subject fields. Next chapter on review of literature gives an overview of a few of them.

Statement of the Problem

There is a growing need to measure the impact of the research undertaken in most of the countries as lot of resources are being allocated to S & T research but the results are not tractable. The pressure is building up for research managers in the universities and research institutes to justify the money spent on research. Though it is not very easy to measure the research output of any institute, the results of bibliometric studies have proved to be a boon for the policy makers and fund managers.

The quantifying methods employed in a bibliometric study yield a fairly good idea about an institute's contribution in the national scientific output. Therefore, universities and institutes where a lot of funds are being allocated to the research activities are keen to assess the research output of their scientists. Physical Research Laboratory (henceforth mentioned as PRL) is an institute of national repute and is being funded by Department of Space (Government of India). However, a bibliometric study measuring its research output has not been carried out yet.

The present research titled "Research Undertaken in Physical Research Laboratory (PRL) : A Bibliometric study" is a step in that direction and as the title indicates is a bibliometric study of PRL which tries to find the publication pattern and thrust areas of research carried out in the institute. Physical Research Laboratory, established by Dr Vikram Sarabhai way back in 1947, is the cradle of Space Sciences in India. As a unit of the Department of Space, it carries out fundamental research in Astronomy & Astrophysics, Geosciences, Planetary Sciences, Solar Physics, Space Sciences and Theoretical Physics. A more detailed profile of PRL is given in Chapter 3.

The present study will also help in determining the usage of library collection. This quantitative study will benefit the policy makers of the institute by supplementing their qualitative tools of research evaluation.

Objectives of the study

Several investigators have conducted bibliometric analysis of research productivity of different countries in the world. Comparisons between research outputs in different subject fields are limited because of the different methodologies used and the impact of geographic and population characteristics on the research output. A few studies have also been carried out to assess the productivity and impact of a single institute. As no bibliometric study on PRL has been done before, the researcher thought it appropriate to carry out the above study for her doctoral research with the following objectives:

1. To study the publication pattern of PRL research publications
2. To study the research trends in PRL
3. To determine the usage of library collection
4. To find the usage of electronic vs. print resources in the theses of the Ph. D. students
5. To find out how far research carried out at PRL is being cited by its Ph. D. students

Significance of the study

More than ever before, governments around the world are acknowledging the role of Science and Technology (S & T) in generating new jobs, economic prosperity, response to national issues and global challenges and global competitiveness. There has been a steady increase in the country's S & T budget from the first five year plan to the twelfth five year plan. The S & T activities in India are undertaken by institutions, units and government departments – central as well as state. Other stakeholders are public sector industry, private sector industry, non-profit institutions and associations. In these sectors, the extent of Research & Development (R & D) efforts vary according to the resources deployed and types of activities undertaken. A study was carried out by Chetal & Raj (1998) to determine the trends in country's R & D domain. From the viewpoint of S & T management in the country, sponsored R & D has remained the least understood area. In spite of the extensive flow of funds from the central S & T sector to the benefiting institutes, not much is known about the basic issues like the nature of distribution of R & D funding among various institutes, short-term and long-term impact of R & D in terms of development of research capabilities of the institutions, generation of Ph. Ds, generation of patents, generation of technologies and its usage, etc. One of the major findings of this study was that the percentage of projects resulting in published research papers was the highest for CSIR followed by ICAR, DoE, DST and ISRO.

The knowledge and processing of research results regarding any scientific area are a basic input to the evaluation of the research activities. Increasingly universities and research institutes are adopting the procedures for regular monitoring of research activities. Not only the government policymakers but scientists themselves are users of such kind of studies with which they assess their own research output. Using the Science Citation Index, Virk (2004) has surveyed the scientific research in India viz-a-viz global trends. This study reveals that during the 1980s, India occupied the 8^{th} position among top 20 nations of the world, in scientific research and during the 1990s, India came down in rank to the 12^{th} position, after Italy, Holland, Spain and Australia with only one tenth of the scientific manpower available to them compared to that in India. It clearly shows that our

per capita productivity is much lower compared with that of Europeans, not to mention that of Americans and Japanese who are far ahead. With continuing decline in scientific research, India is now out of top 20 nations. Compared to India, scientific productivity of China and South Korea has increased immensely.

Another study was carried out by Dhavan & Gupta (2007) which examined the broad characteristics of India's publication output in Physics, its subject areas of strength and also the extent to which the research pursuits have technological orientation. The study finds that India's physics related contribution is significantly high (86 per cent) in SCI covered journals of which 26.4 percent were in high impact journals (IF = 1.5). Its contributions in condensed matter physics and materials science are significantly strong. R & D sector exceeds all other sectors in publications output per institute.

China and India are seen as emerging world leaders, so a lot of curiosity exists as regards what happens in the area of S & T in these two countries. Madhan, et al (2010) have analyzed research papers published by Chinese and Indian researchers during 1998-2007 which were cited at least 100 times by end of 2009. The authors have identified prominent authors and institutions, journals used and fields of research. They found that Chinese authors have been able to place their papers in high impact journals such as Nature and Science far more often than Indian authors. The Indian Institute of Science, Bangalore, Tata Institute of Fundamental Research, Mumbai and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore are the prominent Indian institutions.

The above studies clearly suggest that bibliometrics is increasingly being used as a tool for a critical assessment of research output. All significant compilations of research indicators depend heavily on publication and citation statistics. Other aspects normally considered for research evaluation are patents, organization of meetings and lectures, teaching assignments, conference participation, awards and editorial activities.

As no bibliometric study of PRL has been carried out till now, the researcher thought it appropriate to undertake the present study for her doctoral research. Research output of PRL is mainly available in two forms – research publications of the scientists and doctoral

theses of the Ph. D. students. The record of papers - published in journals and conference proceedings - and invited talks delivered will be used to study the publication pattern. Content analysis of papers published in journals will be done to identify the active areas of research. Bibliographies of theses submitted by doctoral students of PRL will be studied to determine the citing pattern which throws light on the use of the library resources. The findings of the study will help in identifying the future direction of research. It will be useful and relevant to the S & T policy makers in general and PRL Management in particular. The improved understanding will help in consolidating lines of research, exploring new approaches or beginning collaboration on a national or international scale. It will also reveal preferences and gaps in collection development and management of information resources.

This thesis report is organized into seven chapters as mentioned below.

Present chapter (Chapter 1) elaborates different aspects of bibliometric studies, its genesis and historical development, objectives and significance of the present study. Chapter 2 presents a review of selected literature where studies are briefly summarised to get an overview of what kind of bibliometric studies have been carried out by other researchers.

Chapter 3 on 'Research Methods and Techniques Used in the Study' presents the scope, operational definitions, data collection, techniques used for analysis and limitations of the study. Chapter 4 on 'Publication Pattern in PRL' covers the authorship pattern, collaboration pattern, number of publications in international journals, and conference proceedings, Invited talks delivered – national and international and most preferred journals for publication.

Chapter 5 on 'Research Trends at PRL' throws light on division wise output, thrust areas of research under broad subject headings and most prolific authors. It helps to identify those areas of research, which are very active and the ones, which are not. All the articles published in journals during the study period are analysed to give keywords. Physics and Astronomy Classification Scheme (PACS) devised by American Institute of Physics (AIP) is used to arrive at the subject headings.

Chapter 6 is on 'Citation Pattern of theses submitted to PRL'. It gives the usage of library collection like the type of documents preferred i.e. books, journals, reports, proceedings, etc., print vs. electronic resources used and subscribed vs. non-subscribed journals referred by the students. It helps in identifying how far Ph D students cite the research carried out in PRL. Most used journals have also been identified using the same data. Chapter 7 concludes the present study with major conclusions and suggestions for future research.

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CHAPTER 2

REVIEW OF RELATED LITERATURE

Any study to be undertaken requires a survey of the literature published in that subject area as a prerequisite so as to give insights into the research which has been carried out in the past and also to give a perspective to the researcher as regards the different methodologies employed, results found and conclusions drawn thereof. Hence the review of the literature was carried out for the present study too.

Since 1955, many bibliometric studies were undertaken which resulted in a flood of publications in this area. During 1980s, the interest in these kinds of studies dwindled due to lack of availability of documents, the manual collection of data and the license fees charged for obtaining documents. However, the emergence of online databases in 1990s proved to be blessing for such studies (Glanzel, 2003).

For the present study, preliminary literature survey of these studies was done using LISA database. Full-text on-line databases of Springer-link, Sage Journals, Emerald Publishing and ScienceDirect were also searched using the keywords – bibliometric analysis, bibliometric studies, scientometric analysis, scientometric studies, research performance and research evaluation.

The survey of literature yielded many interesting studies, collected from various sources. A few of them were evaluating a subject field, a few were limited to journals' impact in a subject field and some of them studied the research output of countries. For ease of comprehension, the researcher thought it appropriate to group the studies in different categories. An overview of 35 studies is presented in the ensuing pages grouped under six categories mentioned below. Within the categories, the studies are placed in chronological order.

A Studies pertaining to a specific subject field (7)

B Studies pertaining to particular journal/s of a subject field (7)

C Studies evaluating a country's output in a particular field (6)

D Studies evaluating India's output in a particular field (6)

E Studies evaluating a particular institute (4)

F Studies pertaining to the bibliographies of theses/dissertations (5)

A Studies pertaining to a specific subject field

1. Sujit Bhattacharya, S. P. Singh and P. Sudhakar (1997)

This paper attempts to monitor the changes in research priorities in physics by analyzing the research profile of thirty-three countries in major fields of physics as classified under PACS (Physics & Astronomy Classification Scheme). Data is taken from INSPEC (CD-ROM version) under two different time periods – 1990 and 1995. Priority Index (PI) is used to understand the priorities of countries in major fields and shifts in their priorities during these two time periods. Correspondence analysis is applied to the matrices of research priorities to understand the multivariate relationships between countries and fields and reveal the dynamics of changes taking place in two time periods.

The publication profile of a country can be visualized as an indicator of its research priorities. Tracking changes in the publication profile of a country can lead to identification of thrusts and areas of weakness in different macro-fields and micro-fields of research.

The study found that general physics, classical phenomenology, condensed matter I & II and cross-disciplinary physics account for more than two third of total output in each time

period (73.11 % in 1990 and 76.34% in 1995). All these fields have more number of research papers in 1995 than in 1990.

The paper gives graphical representation of subject fields for all the countries in the two time frames. The data reveals that South Korea has shown a remarkable increase in rank. Spain, Mexico, Finland, Italy and Greece have also improved their ranks by more than one. Netherlands, Poland, Hungary and Czech Republic had a steep decline in their ranks. India and Denmark have lost their position by more than one. USA, Japan, China, Argentina, Egypt and New Zealand have remained in the same position.

The top five countries in respect to the physics output are USA, Japan, Russia, Germany and UK in 1990. In 1995, this order changes in the third position i.e. Germany is in third and Russia is in fourth position. France jumps by one position and comes at fifth position.

2. Sujit Bhattacharya, Chandra Pal and Jagdish Arora (2000)

In this study, the authors have attempted to reveal the active research topics/themes within the frontier areas of physics during 1990 and 1995.

The active research topics are classified as frontier topics. Countries active in these frontier topics are distinguished in each time period. Association among countries and frontier topics are observed using the multi-variate technique of correspondence analysis. Dynamics are observed by analyzing the changes in the profiles of the countries in the two time periods.

Earlier study had identified the high activity areas (macro-fields), while actual research is conducted in micro-fields. Hence the present study was undertaken.

The same timeframe is used to arrive at precise findings. The total research contribution in 1990 and 1995 were collected in the 20 frontier areas using the PACS. This classification has a hierarchical structure, with a maximum of five digits. The first two digits classify the

area and first four digits together indicate a topic/theme of the article. In some cases an additional alphabetic character is used to classify a sub-topic.

A threshold of 200% increase in the research output in 1995 within the frontier areas was taken as significant. A high threshold was chosen to ensure that this increase cannot be attributed to chance.

Data was collected for fifteen countries in topics which were identified as frontier topics. These frontier topics were divided into two groups – topics which appeared in 1995 only (A) and topics which had significant presence in 1995 in comparison to 1990 (B). 33 topics were in group A and 29 topics in group B. Thus under 20 main frontier areas there were 62 frontier topics. Maximum numbers of topics were found in Physical Chemistry (82). USA was the lead country followed by Japan, Germany & U K.

This type of study provides the decision-maker a method for keeping abreast of scientific developments in a field. However, it can only act as a supplement to the decision-making in a research field and should not be used singularly for research assessment or resource funding.

3. Ed J. Rinia, et. al. (2002)

In this paper the researchers report the results of an exploratory study of knowledge exchange between disciplines and subfields of science, based on bibliometric methods. First the knowledge exchange between disciplines at a global level is considered by analyzing cross-disciplinary citations in journal articles, based on the world publication output in 1999. Second topic is a discussion of measures which may be used to quantify the rate of knowledge transfer between fields and the importance of work in a given field or for other disciplines. Two measures are applied which appear to be proper indicators of impact of research on other fields. These indicators of interdisciplinary impact may be applied at other institutional levels too. The results show that Basic Life Sciences have the

maximum impact within the Life Sciences and Physics diffuses maximum into the Exact Sciences.

4. Basu, A. and Lewison, G. (2005)

Performance evaluation of scientific units (from university departments to nations) requires analysis of research outputs in a given subject. For an evaluation of national performance, reliance is usually placed on an analysis of papers selected from large database like SCI as it covers all scientific fields and includes all authors' addresses.

This paper sought to characterize world astronomy research by an analysis of papers in the SCI identified with a special filter and to study Indian output in order to identify the leading institutions and authors. Lists of specialist journals and title words of papers were selected to create a filter giving high precision and recall for astronomy papers.

The filter developed by the authors was designed to capture ASTRO papers (including ones on the solar system) and was calibrated through partnership between a subject expert and a bibliometrician. The sample of the study thus comprised of 95186 papers, of which 73019 appeared in ASTRO journals. The outputs of 16 countries accounted for 99% of ASTRO papers in 1994-2003. Leading countries are US, UK and Germany. The highest growth rates were achieved by China and Spain. Countries with less ASTRO research effort were Japan and Sweden. Countries where the relative research effort in astronomy increased were Italy, The Netherlands, UK and Switzerland.

5. B. S. Kademani, Vijai Kumar, Anil Sagar, Anil Kumar (2006)

This paper attempts to highlight quantitatively the growth and development of world literature on thorium in terms of publication output as per SCI (1982-2004). During this period a total of 3987 papers were published by the scientists in the field 'thorium'. The

average number of publications published per year was 173. Highest number of papers (249) was published in 2001. The spurt in the literature output was reported during 1991-2004. There were 94 countries involved in the research in this field. USA is the most prolific country with 1000 authorships followed by India with 498 authorships. Intensive collaboration was found during 1990-2004. There were 586 international collaborative papers. BARC topped the list with 153 authorships, followed by Los Almos National Laboratory (LANL), USA with 105 authorships. The most preferred journal was Journal of Radioanalytical Nuclear Chemistry.

6. Gian Singh, Rekha Mittal & Moin Ahmad (2007)

The study has been undertaken with the purpose of finding out the growth and characteristics of digital library literature. Over 1,000 articles for the period 1998-2004 were collected from LISA Plus and were analyzed to study authorship patterns, authors' productivity and prominent contributors, language-wise and year-wise distribution of articles, country-wise distribution of journals, core journals in the subject area, and indexing term frequency. Some of the important findings are that most articles (61 percent) are single-authored; author productivity is not in agreement with Lotka's Law, except in one case where number of articles is three; the maximum number of articles were published in 2003 with English being the most productive language; maximum articles were published in the journal D-lib Magazine; distribution of articles nearly follows Bradford's Law; and USA is ranked first for maximum number of journals. The paper is relevant to those interested in bibliometrics and provides a comprehensive overview of authorship in the library and information science community.

7. Jayant M Modak and Giridhar Madras (2008)

The objectives of this study was to compare the number of journal publications and analysis of the citations to measure the quality of research in chemical engineering and its impact, published by various countries and institutions.

The publication record in terms of quantitative aspects of the number of publications from China has increased exponentially over the last decade and has overtaken USA. However, the citation analysis indicates that there is ample scope for improvement. Analysis of the output of selected Indian universities/organizations against that of the top universities in the world indicated that these are not comparable to the best universities in USA but are comparable to the best in Asia and are significantly better than the best universities in China.

The number of publications in the field of chemical engineering has increased by a ratio of 2.08 between the time periods 1990-94 and 2000-04. During these time periods USA has maintained its top position. During the same period South Korea and China have significantly increased their number of publications. India has nearly doubled its number of publications during these time periods. Among the institutes in India, IISc tops the list followed by IIT M and IIT K.

In the ranking of top 100 universities, the first four slots are occupied by the Chinese universities. However top 20 had only three Asian universities in 1990-94 which increased to nine in 2000-04.

It was also found from the citation analysis of the papers published, that average citations per paper published from USA is nearly twice that of China or India. The publication from India though smaller in number had higher number of citations per paper compared to China. However the h-index of China is higher than that of India. The number of publications in top journals as well as citation analysis indicates the clear dominance of USA.

B Studies pertaining to particular journal/s of a subject field

8. Arthur Lifshin (1993)

Geochemical publications have been found in a wide range of journals. Although primarily geological in nature, a wide range of geochemical data and information may be found in the chemistry and physics literature. In 1923, the field generated it's first and for 37 years its only journal – Chemie der Erde. In 1950, the journal Geochimica et Cosmochimica Acta began publication and rapidly became an important journal in the field of geochemistry.

The present study analyzes the first ten years of GCA (Vols. 1-21), 1951-1960. This decade represents the field on expansion due to new techniques. Data was collected for all articles in 21 volumes covering that period with the exception of 8 articles that were bibliographies. Data was collected for each volume and later grouped by year. Total number of articles was 515 with 10852 references. Data was then sorted and analyzed by journal title, book title, continuation title, dates, etc.

This study also confirmed the earlier studies about the journal articles being cited the most (78.3%) followed by books (11.3%), continuations (7.7%), theses (1.3%) and personal communication (1.6%). Over the years there is decrease in German language citations and increase in English language citations. An examination of the rank order listing of journals shows that American Journal of Science, American Mineralogist, Journal of Geology, Nature and Physical Review are cited at least 10 times every year. The inclusion of Physical Review in this list is due to the material on meteorites and element abundances.

Distribution of journal citations as a function of dates shows that due to the nature of the field of earth sciences, there are citations from 1800s present in almost all the years. The breakdown of citations by discipline shows that there is a significant increase in geology citations and decrease in general citations.

9. Blaise Cronin, Elisabeth Davenport and Anna Martinson (1997)

The authors have explored the social structure of the field of *Women Studies* by analyzing bibliometrically all scholarly articles and acknowledgements appearing in three pioneering journals over a twenty year period. They have analyzed the authors and the acknowledgments in terms of gender. They have also conducted content analysis of all the editorial statements published by the journals. The results demonstrated the highly gendered nature of the field and the incompatibility of its publicly stated objectives.

The journal literature of a field can furnish valuable insights into not only substantive issues addressed by a community of more or less like minded scholars but also into social relations that define a particular domain. Specifically bibliometric techniques can be used to expose the underlying social structure of a field by describing patterns of publication, co-authorship, citation and acknowledgment.

The sample of this study consisted of leading scholarly journals to analyze in detail authorship, acknowledgment and editorial patterns and practices over time. For inclusion, a journal had to meet three criteria longevity, impact and centrality. The three journals which met the criteria were Feminist Studies, Signs: Journal of Women in Culture & Society and Frontiers : A Journal of Women's Studies.

The bibliometric analysis of contributions to these three leading *Women's Studies* journals over twenty years revealed several notable patterns: a high level of sole authorship, a preponderance of female over male authors and intensive acknowledgment with higher number of credits accruing to women than men. A content analysis of editorials in the sample revealed an affirmative action agenda to give more women a voice in publications which conform to academic production protocols.

10. Sharon J Lenon, Kim K P Johnson, Ji-Hye Park (2001)

The authors of this paper thought that the end of a millennium is a good time to assess research trends in a discipline. It helps to reflect on past accomplishments, analyze the current state of research and strategize for the future.

The aim of this study was to assess trends in research, research strategies, data analysis techniques, funding sources, affiliations and the use of theoretical frameworks in *Textiles and Clothing Research*. Empirical research focused on *Textiles and Clothing* and published in three home economics related journals from 1980-1999 has been content analyzed. The three journals are – Journal of Family and Consumer Sciences, Family and Consumer Science Research Journal and Clothing & Textiles Research Journal.

The sample of the study consisted of 586 articles published in the above three journals. During the study the authors faced difficulties with coding of information and suggested researchers should strive to include research purpose, hypotheses, theoretical framework, analysis procedures used, statement of research strategy used and source of funding.

The authors found that survey method and experimentation were the first and second most used research strategies in all except one 5 year period. Data analysis techniques were primarily quantitative with increase in the use of some advanced statistical techniques. However, qualitative treatment of data had also increased during the period covered.

In addition to having familiarity with other research methods, students need knowledge of statistical tools and techniques. The authors' findings suggest that knowledge of statistics beyond basic levels will continue to be required in the future.

11. Ming-Yueh Tsay & Yi-Ling Chen (2005)

The purpose of this study is to analyze and compare journal citation data, of General & Internal Medicine and Surgery. The source items and five kinds of citation data i.e. citation counts, impact factor, immediacy index, citing half life and cited half life are examined.

The results of this work reveal that frequently published journals are cited more frequently and also have high impact factor and immediacy index. In addition they are usually accompanied with short citing half-life i.e. they usually cite current literature. A significant correlation also exists between impact factor and immediacy index. However, there is no correlation between cited half life and other citation data, except citing half life.

One obvious criterion for the evaluation of journals is that of productivity, which can be expressed as number of papers published by a journal in a specific subject field during a particular period of time.

12. John D Lee, Andrea Cassano-Pinche and Kim J Vincente (2005)

The paper here gives the result of a bibliometric analysis of 1682 papers and 2413 authors published in *Human Factors* from 1970-2000. The ISI Web of Science electronic database was used to compile the citation history of papers published in *Human Factors.* The analysis shows that Human *Factors* has substantial influence on the scientific progress in the field of human factors and ergonomics as measured by impact, immediacy and half-life.

A trend toward a greater number of authors per paper in *Human Factors* parallels that in many fields and may reflect a general trend toward increased emphasis on multidisciplinary analysis of complex systems. In other fields, the number of co-authors is associated with greater impact, and this may be the explanation for steady increase in the impact of *Human Factors*. Although, the growing number of co-authors may lead to papers with greater impact, bibliometric analysis suggest more direct ways to enhance the impact of *Human Factors.* Making the full-text of all papers available online would likely increase the

impact, immediacy and half life of the journal. A journal web site with more content tends to be more visible, as measured by the incoming links. A highly visible web site would likely increase the use of *Human Factors* by students and practitioners and might also encourage the researchers to choose it as publication venue.

This study also found that relatively few papers account for the majority of the journal's impact. And highly productive authors tend to be highly cited primarily because they write more papers, not because individual papers are cited more often.

13. Tove Faber Frandsen (2005)

Citation analysis is widely used as an evaluation method within sciences. Researchers, politicians and publishers often use citation analysis as the basis for statements on research quality or impact. The paper has not tried to argue against the strong position taken by citation analysis but rather discussed the possibilities for strengthening these analyses by ensuring a large degree of reliability and validity. This has been done by pointing out some apparent weaknesses of the simple citation analyses. These weaknesses can be partly dealt with by finding hidden structures of the science under evaluation.

The paper has investigated whether an analysis of the interaction of economics journals, where different characteristics of the journals are taken into account, can contribute to a larger insight into the science of economics and thus be used to qualify citation analyses.

The analysis indicates several underlying factors within citation patterns in economics that should be accounted for when doing citation analysis for evaluation purposes. A journal is to a large extent self-supplying with citation but when this is extracted from the data, journals are dependent on similar journals – with respect to sub-discipline, geography and journal impact factor – to supply citations. In an evaluation that takes place across a wide range of sciences, an analysis of both cited and citing journals may help to determine which factors should be taken into account for evaluation. This paper includes only a sub-set of

the journals in economics. Other sciences may exhibit other patterns and thus other underlying factors.

14. Anil Kumar, E R Prakasan, V L Kalyane & Vijai Kumar (2008)

The authors felt that as Pramana is a prominent Indian journal in physics with a current impact factor of 0.417, its evaluation in detail will give a fairly good idea about the state of physics output in terms of collaboration, organizational affiliation and preferred sub-field of physics research in the country.

The study found that during 1982-2006, Pramana has published 3976 articles with a yearly average of 159 articles. The increasing number of articles over the years shows its increasing popularity among physicists. Articles written in collaboration by two authors are found to be predominant, followed by single authors, collaboration with three authors and four authors. Among the institutes, Department of Physics, Delhi University contributes the maximum number of articles to this journal, followed by BARC and PRL. A total of 73 countries occurred in the affiliations of authors. Around three fourths of total affiliations were from India. Keyword analysis was done to examine the nature of contents of the articles. The focus areas were found to be cosmology, super symmetry, chaos, quantum chromodynamics, phase transition and quark-gluon plasma. There are 84847 references in 3976 articles of Pramana making an average of 21.34 references per article.

C Studies evaluating a country's output in a particular subject field

15. Subbiah Arunachalam, M. K. Dhirendra Rao and Praveen K. Shrivastava (1984)

The authors have tried to find the impact of physics research carried out in Israel on the international literature from the data of publication and citation counts. Authors have considered all papers published from Israel and covered under five of the ten major

sections of INSPEC's Physics abstracts – Jan-Jun 1977. These sections are *Condensed Matter Physics, Nuclear & Particle Physics, Atomic & Molecular physics, Biophysics and Physical Chemistry.* Citations to these papers as seen from five annual editions of Science Citation Index, 1977-198 were also part of source data.

In the major subject groups chosen by the authors, there were 25,593 papers world wide, out of which Israel's share was 251, amounting to a little over 0.94%. These 251 papers received 1530 citations in the five year period of 1977-1981. From this sample, 40 papers were cited between 6-10 times, 16 papers were cited more than 25 times each, out of which 3 papers received more than 85 citations each.

The journal titled 'Journal of Chemical Physics' which accounted for 14 papers received the maximum number of citations (212). Out of the eight Israeli institutes, Weizman Institute, Rehovot tops the list followed by Tel Aviv University. Israel appears to be more productive in *Nuclear Physics* and *Atomic & Molecular Physics*, areas in which her share exceeds 1.3% of the world's literature as against 0.89% in all of physics as seen from SCI 1973. There are at least 41 articles published in journals which have the words 'chemical physics' in their titles. About 35 papers were published in journals whose titles contain the 'nuclear'. These are indicative of Israel's thrust in physics research. Israel because of its close political and economic ties with the west has certain advantages. Not only does it receive all the economic benefits that such ties ensure, but its scientists get ample opportunities to collaborate with fellow researchers in very well equipped laboratories in the US and Western Europe.

16. Daisy Jacobs and Peter Ingwersen (2000)

Although many bibliometric studies have been carried out all over the world, except for a few scattered case studies in South Africa, no comprehensive study has been undertaken to understand the publication pattern of scientific research in South Africa. Hence the authors undertook the present study covering a 16 year period to analyze the publication pattern in

four science disciplines – Physics (including Mathematics & Astrophysics), Chemistry, Plant & Animal Sciences and Biochemistry (Microbiology).

The authors observed a distinct growth up to 1987-91. From then there is a gradual decrease. They also found a correlation between the research output and the status of the survey respondents. Analyses of data clearly indicate that professors published the most, followed by Associate Professors, Lecturers and Senior Lecturers in that order. Senior lecturers demonstrate a surprisingly low research activity. One of the reasons for this can be attributed to a lack of expectations for promotion in the immediate future.

This study therefore agrees with earlier similar studies which suggest that promotion was the driving force behind faculty research publications.

17. Subbiah Arunachalam and Jayshree Balaji (2001)

In this study, the authors have compared Fish & Aquaculture research in the People's Republic of China over the six years 1994-1999 with that of India, using data from six databases – three abstracting services and three citation indexes.

The authors found that during this six year period, China published 2035 papers (roughly 4.5-5 % of the world output) and India published 2454 papers. More than 95% of China's papers are journal articles compared to 82.8% of Indian papers. About 78% of China's journal paper output has appeared in 143 domestic journals compared to 70% from India in 113 Indian journals. Less than a dozen papers from each of these countries have appeared in journals of impact factor greater than 3.0. Fish research institutes and fishery colleges are the major contributors of the Chinese research output in this area. In India academic institutions are the leading contributors (61%) followed by Central Government institutions (>25%).

Although China's research output and its citation impact are less than those of India, China's fish production and export earnings are far more than those of India. Probably China is better at bridging the gap between know-how (research) and do-how (technology).

18. Mee-Jean Kim (2001)

Until the 1980s, limited R & D resources prevented Korea from promoting Big Science projects which ultimately play an important role in the development of the country. In the 1990s, the need for advanced technology development triggered a Science & Technology policy that emphasized basic research and ushered Korea towards the scientific mainstream. As evaluation of research performance in terms of research publications and the citations' impact is coming to be considered an integral part of science, the scientific community of Korea cannot avoid such scrutiny. This paper has carried out such an evaluation.

For the study, the sample comprised of 4665 papers published by the researchers affiliated with physics departments or physics associated laboratories at Korean Universities and indexed by SCI during the five year period 1994-1998. Out of 4665 papers 1488 papers were a result of collaboration with researchers from other countries. Collaboration with US researchers in 96 papers yielded the highest citation rate, an average of 15.9 citations per paper. These 4665 papers were published in 224 scientific journals from 19 countries. US and Korean journals predominated, followed by Dutch, UK and German journals. Among the 96 Korean academic institutes the top 15 each published more than 100 articles and contributed 4031 papers (86.4%) of the total number of publications. Seoul National University (SNU) took first place with 813 papers followed by Korea Advanced Institute of Science & Technology and Korea University in second and third place respectively.

19. Mario Coccia (2005)

The debate on the reform of the research sector in many European countries has recently become more important, both due to the reduction in public funding and due to the domination of US and Japan in the field of new technology. Nowadays universities and public sector research organizations account for most of the technological developments and innovations which are necessary for the competitive industrial system in a fast growing knowledge society.

In this scenario, a new model is devised by the author covering 108 public research institutes belonging to the Italian National Research Council using the data from 2003 and displays the laboratories with high flow performance. The results are substantially stronger and quicker to obtain than those calculated by using conventional indicators. This model supports the policy makers, who must decide about the level and direction of public funding for research and technology transfer.

This research confirms the concern that Italian national system of innovation is not working satisfactorily and that financial resources are insufficient to strengthen the Italian scientific network in terms of production and diffusion of scientific researches and technology in the economic system. The author suggests that one way to increase the research performance could be the relocation of researchers so that they can choose in which laboratory to work according to their scientific preference. Also, introduction of more incentives for researchers will surely improve the scientific research output of Italy.

20. Eva Isakson (2007)

The author got interested to carry out this study when at the latest research assessment evaluation done at the University of Helsinki in 2005, the panel of experts asked for citation count data for the first time. She then decided to carry out a bibliometric study of

Astronomy in Finland. The author used both ADS and ISI databases in order to find out how they compare.

The sample of the study consisted refereed papers of four institutes doing astronomical research in Finland for the period 1995-2004. The 910 papers had 1,998 authors out of which 162 were listed with affiliations from one of the four Finnish astronomy institutes. Of the most productive 50 authors (with more than 12 published papers) eight were identified as women.

Other interesting finding was that majority of the papers were stand alone in the sense that only one of the four institutes was involved in its publishing. There was not even one paper with all of the institutes co-operating. All the collaborations are directed abroad instead of with other Finnish Astronomy institutes.

D India's output in various subject fields

21. I. K. Ravichandra Rao and P. Suma (1999)

In recent years several projects were sponsored by NISSAT of the Government of India to map Indian Science. As a part of it a database in engineering field was analyzed.

For the purpose of this study COMPENDEX database for the periods 1990 and 1994 was used as source data. It was found that 3520 and 4829 articles were the research output in engineering for the years 1990 and 1994 respectively. Engineers too preferred journals for communicating their research results (88% of the total). This was followed by 11.5% in conference proceedings. Monographs and reports constituted only 0.5% of the total.

Research output in Applied Physics, Light & Optics, Bioengineering and Information Science are increasing at both levels - world and India. In the area of Energy Technology, Metallurgical Engineering and Food Technology output is decreasing at both levels. In branches of Electrical Engineering & Electronics, Computers & Communications,

Environmental Technology, Marine Engineering and Aeronautical Engineering is decreasing from 1990 to 1994. However, in Civil Engineering, Industrial Engineering and Mechanical Engineering, the world's publications are decreasing, whereas India's contributions are increasing.

The study also found that 1000 institutions contributed a total of 8349 publications for the development of the engineering field. Indian Institute of Science (IISc), Bangalore ranked first with 490 (5.87%) publications followed by IIT, Delhi and IIT, Madras with 4.86% and 4.76% of publications respectively.

State wise distribution of publications indicates that Maharashtra is first with 1283 records (15.38%), West Bengal with 1007 records (12.06 %) and Delhi with 917 records.

Indian researchers have used 900 journals published from 27 countries to publish their research output. 41 % of the literature is published in journals from USA and 12% of journals are from India.

22. Subbiah Arunachalam (2001)

This study quantifies and maps mathematics research in India as reflected by papers indexed in MathSci database for period 1988-1998. *Statistics, Quantum Theory* and *General Topology* are the three sub-fields contributing the most to India's output in Mathematics research, followed by *Special Functions, Economics* and *Operations Research and Relativity and Gravitational Theory*. Indian Statistical Institute and Tata Institute of Fundamental Research are the two leading publishers of research papers.

A total of 17,308 papers were published in 11 years. About 92% of these papers have appeared in 877 journals published from 62 countries. Of the 36 journals that have published at least a hundred papers, 20 are Indian journals, of which only two are indexed in JCR. In the late years, there has been a moderate shift to non-Indian journals.

About 78% of papers have come from universities and colleges and 13% from institutions under science related departments. Almost all papers in high impact journals are physics related and most of them have come from institutions under DAE. Over 15% of the 9760 papers published during 1993-1998 are internationally co-authored. The USA, Canada and Germany are the most preferred countries for collaboration followed by France, Italy, Japan and the UK.

23. K. C. Garg and P. Padhi (2002)

Laser research in India began almost simultaneously after the demonstration of the Ruby Laser in 1960. Since then R & D programmes related to laser research have expanded considerably and today encompasses many of the important areas of laser applications. Since laser has many applications and is an increasingly growing field, authors have attempted to look at laser research in India during 1970-1994 using the publication output abstracted by the journal of Current Laser Abstracts published by Laser Focus, USA and their citations in the international literature during 1970-1999 as seen from Science Citation Index published by the ISI, Philadelphia, USA.

The sample of the study consisted of 952 publications published by Indian scientists during 1970-1994. The analysis indicates that laser research in India picked up during the 1978-1994 and reached its peak in 1980. It was also observed that publication output is concentrated among a few institutions and there is a similarity in the activity profile of highly productive institutions. Amongst the most productive institutes, IIT, Delhi, BARC, Mumbai and Hyderabad University are in the top three positions in that order.

Analysis of local, domestic and international collaboration in the papers indicates that most of the Indian collaborations are in theoretical laser research unlike international collaboration where most of the work is in experimental laser research, followed by application oriented laser research. Out of 952 papers published, only 162 were

collaborative papers. Of these 19 were local, 81 were domestic and 62 were international collaborations.

The study indicates the need to develop both domestic and international linkages. The thrust should be on collaborative programmes focusing on application oriented laser research.

24. S. Mohan, B. M. Gupta and S. M. Dhavan (2003)

This paper aims to identify the major areas, sectors and institutions involved in Indian Materials Science research that have collaborative linkages with developed and developing countries. This helped the authors to understand to what extent the collaborative research is helping to meet the national objectives, conforms to the general international trends, as well as to learn about new technological developments taking place in this area.

Publication data for the study was derived from the CD-ROM version of the Materials Science Citation Index (MSCI), brought out by ISI, Philadelphia, USA for the period of 1995-1999. The database covers around 2000 significant world journals in all fields of S & T, focusing on Materials Science research. The study was restricted to co-authored articles, arising out of India's collaborative research with all major developed and developing countries.

Total number of co-authored papers was 2587 during 1995-1999. Each paper was classified under two broad categories – Particular material (subject) and nature of work done on that material (process). There were 36 subjects in category 1 and 14 processes in category 2. Among the 36 subjects in first category, *General Organic Materials* produced the maximum number of papers (285), followed by *General Metals and Alloys* (235). Polymeric Membranes and Fullerenes, which have great potential in new technologies, are yet to take off significantly in India. Among the 14 processes in 2nd category, *Analysis & Characterization* happens to be the most important aspect of the research.

Among the bilateral collaborative papers, highest number were with European countries, while among the multilateral collaborative papers highest number were with USA followed by Germany and Japan.

A total of 154 institutions, including universities and national laboratories participated in collaborative research, with IISc, Bangalore coming on top with 286 papers followed by TIFR, IIT Bombay and BARC.

25. Swapan Kumar Patra and Partha Bhattacharya (2005)

For the purpose of this study, data has been downloaded from PubMed database using the Endnote software. A total of 6408 records were found. Each record contains English language abstract and bibliographic information.

The study shows that Cancer research is increasing, with a marginal decrease in the year 1991, 1993, 1995, 1997 and 2003. US is the largest producer of cancer related research. PubMed indexes biomedical literature published in different communication media too. Journal literature accounted for 88% of the Indian literature on oncology.

All India Institute of Medical Sciences (AIIMS), Delhi has produced the maximum papers on cancer research followed by Tata Memorial Hospital, Mumbai and Post Graduate Institute of Medical Education & Research, Chandigarh.

26. B. M. Gupta and S. M. Dhawan (2005)

This paper presents the status of Computer Science research in India in terms of publications output, its areas of strength and weakness and the leading institutions and individual scholars involved in Computer Science research in the country. The data source for this paper was INSPEC database which contains over 3500 national and international

journals and some 1500 conference/seminar proceedings and numerous other publications. INSPEC is a product of Institute of Electrical and Electronics Engineers (IEE).

The research output as per INSPEC database revealed that Indian scholars published 4690 papers in Computer Science during 1994-2001. Of these, 3143 papers (67%) had appeared in journals and the rest 1547 (33%) in conference/seminar proceedings. Of the 3143 papers published in journals, 2028 were published in JCR – covered journals and 1115 were covered in non-JCR covered journals.

The most preferred journals to publish the research results were Fuzzy Sets & Systems (93), Microelectronics & Reliability (69) and Computers & Structures (64). Highly productive subject fields were found to be *Systems & Control Theory* (1530 papers) and *Computer Applications* (1082 papers).

Most productive academic institutes were IIT, Madras (396 papers), IISc Bangalore (348 papers) and IIT Bombay (267 papers). Most productive research institutes were Indian Statistical Institute, Calcutta (258 papers), Institute of Mathematical Sciences, Chennai (73 papers) and TIFR, Mumbai (72 papers).

Thus Computer Science research in India is mainly driven by the academic sector as only one fourth contribution is made by research institutes, government institutes and industrial sector and three fourth of the output is contributed by the academic sector.

E Studies evaluating a particular institute

27. Suresh C. Sinha & Anil K. Dhiman, eds. (1994)

This bibliometric study has analyzed the research output of Central Building Research Institute (CIBRI) which is one of the engineering laboratories of CSIR.

822 research papers were published by the scientists of CIBRI during Jan 1980- Mar 1990. Each paper was categorized on the basis of journal in which it appeared and to the division to which it belonged.

Out of the 822 papers published by the scientists of CIBRI, 483 were presented in conference/symposia and 339 were published in 94 journals. The preferred Indian journals were Indian Concrete Journal, Indian Ceramics, and Research & Industry. Out of 339 papers, 278 were published in Indian journals, probably because papers in Indian journals are easily accepted because of weak refereeing system. Preferred foreign journals for publication were Building Research & Practice, Cement & Concrete Research and Durability of Building Materials.

It is observed that Engineering Sciences fare poorly from citation point of view. But it can be improved if the scientists of engineering disciplines publish qualitative work in foreign journals having high Impact Factor and Immediacy Index. It is generally seen that engineers do not cite authors whose works they refer in their own research.

28. V. K. Jeevan and B. M. Gupta (2002)

In this study, research publications in national and international journals over a three year period from 1994-95 to 1996-97 are analyzed for a few departments of IIT Kharagpur. In all, 1172 research papers were published during the three year period by the nine selected departments of IIT, Kharagpur. Of these 757 were published in SCI-covered journals. Around 75% and above of the papers from Department of Chemistry and Rubber Technology are published in SCI covered journals.

The publications of the Chemistry and Physics & Meteorology departments have received the largest impact – 2.761 and 2.058 respectively. Based on the proportion of high quality papers, the highest rank is received by Chemistry Department. It is also believed that those departments which qualitatively perform better also tend to collaborate more, both on the

national as well at the international level. In terms of co-authored papers, the largest percentage is in the Physics Department – 64.21%.

Considering the overall performance measure, departments of Chemistry, Physics and Electronics & Electrical Communication have done better than other departments.

29. Chu Keong Lee (2003)

Lee thought of measuring the research output of Institute of Molecular and Cellular Biology (IMCB) as lot of funds had gone into building up this institute. It was set up in 1987 at the National University of Singapore (NUS).

The study found that the number of research scientists and engineers (RSEs) increased from 116 in 1991 to 179 in 1996 and the recurrent budget increased from S$19.38 million to S$ 36.37 million in the same period.

In its first 10 years, the IMCB produced 395 research papers, 33 book chapters, 24 conference papers and 4 monographs. The research papers were published in journals of increasing impact factor, resulting in increased visibility for the IMCB. The articles received 25 to 35 citations per article. Four of its articles received more than 200 citations. IMCB contributed 46 PhDs and 14 MScs to the research force in Singapore.

30. B. S. Kademani, et al. (2007)

The paper analyses the citations to 1733 publications published during 1970–1999 by the Chemistry Division at Bhabha Atomic Research Centre, using Science Citation Index 1982–2003 as the source data. The extent of citations received, in terms of the number of citations per paper, year wise break up of citations, domain wise citations, self-citations and citations by others, citing authors, citing institutions, highly cited papers, the categories of

citing documents, citing journals and distribution of citations among them etc. are determined.

During 1982–2003 Chemistry Division publications have received a total of 11,041 citations. The average number of citations per year was 501.86. The average number of citations per publication was 6.37. The highest number of citations received was 877 in 2001. The citation rate was highest during 1990–2003 as maximum 9145 (82.82%) citations were received during the period. Total self-citations were 3716 (33.66%) and citations by others were 7325 (66.34%). Citation time lag was zero for 144 (15.52%) papers and one year for 350 (37.72%) papers. Single authored publications (168) have received 456 (4.13%) citations and 1565 multi-authored publications have received 10,585 (95.87%) citations. The core journals citing Chemistry Division publications were also identified as a result of the study.

F Studies evaluating the bibliographies of theses/dissertations

31. Margaret J. Sylvia (1998)

In this study the author collected the bibliographic citations for journals from research papers written by graduates and undergraduates taking classes in the Department of Psychology at St Mary's University from Fall 1994 to Fall 1995 (3 semesters). The sample of the study comprised of 157 bibliographies. For each entry journal title and citation year were recorded. The information was used to check for library holdings of the journal. The current subscription price was used to determine the cost-effectiveness of each journal by dividing the cost of the journal by the average number of times cited per year. For the analysis, total number of journal citations was 1289. The study not only identifies new journals which should be subscribed but also indicates which titles should be canceled using not only the citation data but also the re-shelving data from the stacks. The author cautions that decisions for collection development should be obtained by using convergence of data from all available sources.

32. Angela M. Gooden (2001)

A citation analysis of dissertations accepted in the Department of Chemistry at The Ohio State University between the years 1996-2000 was performed as a way to determine material use. Dissertations from this range (1996-2000) totaled 117. The author extracted 25% of the 117 dissertations to obtain a more controllable yet accurate sample. The random number generation analysis tool in Microsoft Excel created a sample of 30 viable dissertations.

Title pages and reference sections were photocopied from each of the 30 dissertations. Information extracted from each included doctoral student's name, year of graduation, year and location of cited work (SEL, other), number of citations, and total of each cited title broken into three categories: journals, monographs, and other documents. The "other" category consisted of patents, proceedings, technical reports, and unpublished papers (including dissertations and theses).

The 30 dissertations generated a total of 3,704 citations. Journal articles were cited most frequently (85.8%), followed by monographs (8.4%), dissertations, theses and proceedings, newspapers and annual reports (2.2%, referred to as "other"). Dissertations and theses comprised over half of the ‘Other’ category (60%).

These results corroborate past research by other authors. Knowing which resources doctoral students require should enable collection managers to more adequately serve them. The method in this study will help chemistry librarians determine which materials are being used at libraries. Ultimately, it is also assumed that an improved collection for chemistry will better support the research needs of future chemistry doctoral students.

33. Vicki L. Waytowich, et. al. (2006)

The purpose of this study was to investigate the citation error rate and quality of reference list in doctoral dissertation proposals. The study also sought relationship between perfectionism and frequency of citation errors and adherence of the reference list to the fidelity of the chosen citation style among doctoral students. Also of interest was to determine which demographic variables predict citation errors and quality of reference list.

The sample of this study consisted of 64 doctoral students from various disciplines enrolled in a graduate level dissertation preparatory course at a large South Eastern University in the USA.

The findings indicated the graduate students with relatively high levels of self oriented perfectionism tended to commit the most citation errors and construct reference lists that departed the furthest from the citation style stipulations. Every dissertation on an average contained 12 missing or inconsistent citations. This indicated that for every 3 citations included, one of them represented some type of error. Analysis revealed that students with lowest expectation levels tended to commit the highest rate of citation errors. The authors suggest that there is a need for more formal and more deliberate approaches for all instructors to instill in students the importance of avoiding citation errors.

34. R. V. Chikate and S. K. Patil (2008)

In this study authors have used 27 LIS dissertations, submitted to the University of Pune, from 1982 to 2005, as a source of data. A total of 6,257 citations were found in all 27 dissertations. Data compiled includes year of publication of article, journal subject, journal language. Publication status, place of publication and publisher of the journal is taken from the online version of Ulrich's International Periodical Directory. This data was entered in SPSS.

The study found that journal articles comprised of 42.2% of citations followed by 31.2% of citations from books. Other interesting finding was that out of 2,639 journal citations, most cited journal by LIS researchers is College & Research Libraries (141 times), Journal of American Society for Information Science (113 times), Journal of Documentation (99 times) and Aslib Proceedings (82 times).

This study confirmed the Bradford's Law of scattering. The ranked list of 351 journals from 2,639 citations reveals that most of the journals cited are from USA (131) followed by India (88) and UK (71). Nearly all citations are from English documents – 2,485 (94.2%) followed by Marathi documents – 118 (4.5 %). The study also revealed that LIS doctoral students cited journals from a multitude of disciplines including science, medicine, economics, psychology, etc.

35. Núria Vallmitjana and L. G. Sabaté (2008)

A bibliometric study was carried out on the citations within the Chemistry Ph. D. dissertations to ascertain what types of documents are the most frequently used in the research process, the most frequently consulted journals and obsolescence rate of the journals. The analysis covered 46 doctoral theses presented at the Institute Químic de Sarriá (IQS) from 1995 to 2003. The results obtained from the 4,203 citations revealed that the most frequently used documents were scientific papers, which accounted for 79 percent of the total; 33 journals met 50 percent of the informational needs; and the age of 50 percent of the citations was no older than 9 years. Finally, the results can be used as a tool for the collection management of the library.

The literature review of above 35 studies under six categories thus revealed a gap of research output evaluation of an institute in physics. Going through the above studies, the researcher felt that it would be worthwhile to undertake a bibliometirc study of one institute – Physical Research Laboratory as no such study has been carried out till now. The researcher thought of making use of immense amount of information available in the

annual reports of the institute as the base for getting the list of research documents in the form of papers published in journals, conference proceedings, invited talks and theses awarded during the 10 year period of study (1997-98 to 2006-07). This quantitative study will also benefit the policy makers of the institute as the results of the study could be used to supplement the qualitative tools of research evaluation.

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CHAPTER 3

RESEARCH METHODS AND TECHNIQUES USED IN THE STUDY

Last decade has seen increasing demand and supply of research indicators to evaluate the research activities at institutional and national levels in all subject fields. Employers, policy makers, research managers have become very much interested in these indicators so as to get better idea about the return on investment.

All significant compilations of research indicators rely heavily on publication and citation data which is the raw material for bibliometric analysis. This does not mean that this is the only aspect of research output – patents, organization of meetings and lectures, guiding the Ph D students, social recognition, international awards, and editorial activities – related to the productivity of research also play an important role in overall assessment of institutes or individuals. Bibliometric analysis is thus only a partial indication but it points out one of the essential outcomes of research and is therefore worth using.

All over the world, bibliometric indicators are gaining increasing attention in national and international evaluations and research policy discussions. The basis for developing valid indicators is reliable data, good methods and advanced tools for analysis.

To arrive at an appropriate method for the present study, the researcher made a detailed study of the research methods/strategies commonly used.

Robson (2002) has divided the type of research studies by research purpose as well as by methods used. a) Research type by research purpose – Exploratory, Descriptive and Explanatory b) Research type by research method used – Historical, Comparative, Experimental, Case study, Survey and Archival.

It must be emphasized that no research method is inherently superior or inferior to any other. What is most important is not the label of the research method but whether it will enable one to answer a particular question and meet the objectives of the study. Each of the research methods can be used for exploratory, descriptive or explanatory research. It should be remembered that these methods are not mutually exclusive. For example, it is quite possible to use the survey method as a part of a case study.

The present study is a bibliometric study of one organization. Universally accepted definition does not exist for the term bibliometrics. Alan Pritchard (1969) defined bibliometrics as "the application of mathematics and statistical method to books and other media of communication". Bibliometrics is thus a measuring technique by which inter-connected aspects of written communication can be quantified. In the same year Robert A Fairthorne published a classic article "Empirical hyperbolic distributions (Bradford-Zipf-Mandelbrot) for bibliometric description and prediction" in which he used the term' bibliometric' and also acknowledged that Pritchard was the donor of this term.

According to Lancaster (1991) the tools used in bibliometric studies are : i) citation and reference analysis ii) document and content analysis iii) user studies and iv) circulation statistics. The present study uses two of these tools (content analysis and citation analysis) to fulfil its objectives, as mentioned in chapter 1.

Scope of the study

The present bibliometric study aims to measure the productivity of Physical Research Laboratory (PRL) scientists during a 10 year period (1997-2006) using the data of papers published in journals, conference proceedings and invited talks delivered. Thrust areas of research at PRL during this period have been found using content analysis of articles published in journals and allotting keywords to each of them. The study also tries to determine the usage of library collection by employing citation analysis to the bibliographies of the theses submitted by the Ph D students of PRL.

Physical Research Laboratory (PRL)

Known as the *cradle* of Space Sciences in India, the Physical Research Laboratory, Ahmedabad owes its existence to Dr Vikram A Sarabhai due to his deep interest in scientific research, his initiative and his outstanding powers of organization and management. It was founded following an agreement between the Ahmedabad Education Society and the Karmakshetra Educational Foundation in November 1947.

The initial focus was research on cosmic rays and the properties of the upper atmosphere. As a unit of the Department of Space, Government of India, PRL carries out fundamental research in select areas of Experimental and Theoretical Physics, Space and Atmospheric Sciences, Astronomy & Astrophysics and Planetary & Geosciences.

PRL has, from time to time also engaged itself in applied research problems relevant to the country's needs, particularly in the field of Space Science. PRL's vision is to undertake world-class research projects and make a mark for itself as a leading research institution on the global map. In addition to taking up key scientific projects for national development, PRL's mission is also to popularize science amongst the youth. There also exists a strong interaction with the neighboring educational institutions. At the various universities in Gujarat some of the advanced courses in physics have been taught many a times by members of the PRL.

In addition to taking up key scientific projects for national development, human resource development in several areas of above mentioned subject areas is also one of the priorities for PRL. There are about 140 scientists (60 are academic faculty and remaining are technical faculty and Post doctoral fellows) carrying out research in PRL. It has been offering the doctoral programme in various physics related fields since its inception. Accrediting universities with which it has signed the Memorandum of Understanding are Gujarat University, Nirma University, M. S. University of Baroda and Mohanlal Sukhadia University, Udaipur. Up till now 316 doctoral theses have been submitted by the PRL students. Every year about 15 students join for the Ph. D. program.

Period: 1997-2006

The period of study has been taken from 1997-2006. The landscape of scholarly communication witnessed a sea change during this period from print to electronic medium due to the Internet. Developed countries like USA, UK, Japan, and Germany were the first to adopt this change. The internet made it possible to disseminate the latest information to the scientists and students very quickly. Soon, publishers saw a huge opportunity and started offering the secondary databases and the journals in electronic medium. The electronic delivery of journals resulted in elimination of paper, storage and transportation costs and the ability to handle complex data, tables, moving pictures, sound, images and video clips. In addition, unlike sequential design of printed papers, web technology made it possible for the publishers to give interactive hyperlinks to related sources. The growth of the Internet witnessed emergence of several e-journals that were launched only for Internet without a printed counterpart. However, as the technology and popularity of Internet grew, several mainstream journals primarily available for print subscription also started appearing on the web. By 2001-02, the Indian publishers too had started providing the e-access to the print journals.

Keeping in mind this paradigm shift in scholarly communication, the scope of the present study is limited to the period 1997 to 2006. As this period witnessed the maximum flux, the period has been divided into two time slabs: pre-ejournals period (1997-2001) and ejournals period (2002-2006) for citation analysis of bibliographies of thesis submitted by PRL students.

Operational Definitions

Research word is composed of two words ‘re’ and 'search' which means to search again. The concept of research took the shape of social and scientific investigation during the medieval times and developed into a full body of intellectual exercise only in the modern age. Research is a systematic investigation designed to develop or contribute to generalize

the observed phenomenon. Whenever traditional theory is found lacking in explaining the existing phenomena and a novel situation is faced, research originates. Research rejects either old theories or modifies them or suggests new theories. Thus research is a matter of raising a question and then trying to get an answer. Adding new knowledge to the existing corpus is the obvious function of any research. It inculcates scientific and inductive thinking and it promotes the development of rational thought process. It enables finding of solutions to problems and to resolving conflict in society. In this way it promotes progress of the society. Formal definition of the term 'research undertaken' used in the present study, is given below.

The Webster's International Dictionary (1986) defines research as "a careful, critical enquiry or examination in seeking facts or principles, diligent investigation in order to ascertain something."

International Encyclopaedia of Social Sciences (1968) defines research as "the manipulation of things, concepts or symbols for purpose of generalizing to extend, correct or verify knowledge, whether that knowledge aids construction of theory or in the practice of an art".

For the purpose of the present study, the term 'research undertaken' is considered as the research output of PRL comprising of the collection of research articles published in journals and conference proceedings, invited talks delivered and doctoral theses of PRL students. Other research outputs like technical notes, project reports have not been included for the study.

Data Collection for the study

Data for the study (papers published in journals and conference proceedings and invited talks delivered) was collected from the Annual Reports of PRL from 1997-98 to 2006-07. Data collection for the study was done during 2007-2010. For papers in journals, the

record consisted of names of the authors, name of the division, name of the journal, whether it is national or international, whether it has single author, double author or multi authors, whether the collaboration is international, national or domestic and the year of publication. For conference proceedings, data consisted of names of authors, name of the division, whether it has single author, double author or multi author, whether the conference was national or international, whether the collaboration was international, national or domestic and year of the conference. For Invited talks, the record consisted of name of the speaker, location of the talk – India or abroad and the year. Thus, such record was made for all the three components of the research output for all the years. This data was used to find the publication pattern of PRL scientists. To identify the active areas of research content analysis was done of the papers published in journals.

Content Analysis

Content analysis is a method for summarizing any form of content by counting various aspects of the content. This enables a more objective evaluation than comparing content based on the impressions. For example, an impressionistic summary of a TV program is not content analysis. Nor is a book review: it's an evaluation. The results of content analysis are numbers and percentages. Though it may seem crude and simplistic, the counting serves two purposes: to remove much of the subjectivity from summaries and to simplify the detection of trends. Thus content analysis requires extreme thoroughness. The content that is analysed can be in any form to begin with, but is often converted into written words before it is analysed. The original source can be printed publications, broadcast programs, other recordings, the internet, or live situations.

To identify the research trend in PRL during the study period, the researcher has carried out the document and content analysis of the research articles published in journals by providing the keywords to each article. The keywords were then used, to allot a PACS number (Physics and Astronomy Classification Scheme) to each article.

PACS is a hierarchical subject classification scheme designed to classify and categorize the literature of physics and astronomy. PACS provides an essential tool for classification and efficient retrieval of literature in physics and related fields. PACS contains 10 broad subject categories subdivided into narrower categories. PACS also includes detailed schedule for acoustics, geophysics, nanoscale science and technology supplement and an alphabetical topical index with corresponding PACS codes (AIP, 2006).

The PACS codes of all the articles are added up and then grouped. This is done for each year. Data for all the years is added up to arrive at top 25 subject headings put together corresponding to the PACS numbers and are indicated as the thrust areas of research carried out by PRL.

Citation Analysis

Citation analysis is one of the important tools of bibliometric analyses of the scholarly literature for a deeper understanding of scholarly activity and performance. Citation analysis studies the citations provided at the end of any scholarly communication and is generally regarded as a valuable tool for determining the impact of scholarly works. It examines the frequency and patterns of citations in journal articles and books. It uses citations in scholarly works to establish links to other works or other researchers.

In today's world of ever escalating cost of serials, citation analysis is also being used to determine which titles to purchase and which ones to discontinue.

Methods of citation analysis are unobtrusive and can be highly reliable, as it does not require the feedback from the users by way of questionnaire or interview, rather the data is derived from the actual use made as is reflected in the documents already submitted or published.

By examining the resources used (cited), present study aims to better understand and manage the library resources. Citation analysis is used to study the bibliographies of the

doctoral theses submitted by the Ph. D students of PRL during 1997-2006. This was done to find the usage of different types of documents in the library collection, whether there has been increase of use of electronic resources, whether there is increase in the use of non-subscribed journals, how far Ph. D. students cite the research done in PRL and to identify the gaps in journal subscriptions.

Data Analysis for the study

The research output of PRL scientists during the period of 1997-2006 was 2518 units out of which 1318 were papers published in journals, 436 papers in conference proceedings and 764 were the invited talks delivered. These have been used for identifying the publication pattern and research trends in PRL. With in PRL as there are various divisions, an attempt is also made to study division wise output and most prolific researchers in each division.

During the period of study, 68 theses were submitted by the Ph. D. students. These studies yielded a total of 10,864 citations for which citation analysis was done.

Excel software was used to enter the records of each year. Each record consisted of the name of the author/s of the article published, name of the journal, double/multi/single author (D/M/S), international/national journal (JI/JN), international/national/domestic collaboration (CI/CN/CP), division of the author and year of publication. Keywords were given to each article after reading the abstract and introduction of the paper. Then PACS number was allotted to each article.

Each category of this data was counted and sorted in descending order of number of times it appears in each year. Each year's data was then combined and computed in similar manner. As for example, PRL authors published 3, 4, and 2 articles in the Astrophysical Journal Letters in 2004, 2005 and 2006 respectively. So in three years 9 papers were published in this journal. Similarly, the choice of this journal to publish one's research output would be added up for all 10 years of the study. Each category of data – name of

the journal, author, research division, PACS code, collaboration, etc. was counted for each year. This data was then merged for all years to arrive at most preferred journals, most prolific researchers and the thrust areas of research (using the PACS number schedule). The authorship pattern (D/M/S), collaboration pattern (CI/CN/CP), pattern of papers in chapter of a book and international/national journals (CB/JI/JN), international/national conference proceedings (CPI/CPN) and invited talks delivered (TI/TN) were identified by carrying out similar computation.

Similarly, the records have been entered for each bibliography of the collected theses consisting of the name of the journal cited, year of publication and whether the author of the cited article is from PRL. The documents used were then tagged for print or electronic format using the license agreement with the publisher as the reference source. The data was also categorized according to the type of resource – books, journal articles, proceedings of a conference, doctoral theses, etc. (B, J, P, R, Th, St, Ep) cited by the students. The journals cited by the students were tagged as subscribed or non-subscribed (SJ/NSJ) going through the holdings database of the journals of the library for that year. This data is also first computed for one year and then it is merged for all the years to arrive at most cited journals in each subject area.

All this data was collected and analysed to identify which subject areas showed quickest adoption to electronic medium, which type of documents are most cited, which journals are most preferred by doctoral students and to identify the gaps in the library collection by looking through the non-subscribed titles in the cited list of journals.

To simplify the data handling, each data element - double authored paper, division name, international journal, - etc. was coded. These are listed below and have also been provided under the List of Abbreviations on page iv.

I Content analysis of research publications

D	–	Double authored paper
M	–	Multiple authored paper
S	–	Single authored paper
CB	-	Chapter of a book
JI	–	International Journal
JN	–	National Journal
CI	–	International Collaboration
CN	–	National Collaboration
CP	–	PRL Collaboration
CPI	–	International Conference Proceeding
CPN	–	National Conference Proceeding
TI	–	International Invited Talk
TN	–	National Invited Talk

II) Citation analysis of bibliographies of theses

Type of Documents

B	–	Book
Ep	–	E-print
J	-	Journal
M	-	Monograph
P	–	Proceedings
R	–	Report
St	-	Standard
Th	-	Thesis

Type of Journals

SJ	–	Subscribed journal
NSJ	–	Non-subscribed journal

Divisions

AAD	-	Astronomy & Astrophysics Division
GSDN	-	Geosciences Division
PLANEX	-	Planetary Exploration
PSDN	-	Planetary Science Division
SO-PH	-	Solar Physics Division
SOXS	-	Solar X-ray Spectrometer
SPA-SC	-	Space & Atmospheric Science Division
THE-PH	-	Theoretical Physics Division

Limitations of the study

The researcher has not included the number of projects completed and students guided by faculty members during the 10 year period. As it was not possible to get budget data for each year, researcher could not compute the return on investment (ROI) of the research done at PRL. As the researcher does not have access to either of the citation databases – Web of Science or Scopus, researcher could not get the citation data of PRL as a whole institute as well as that of the individual scientists. Not only the productivity, but it would have been possible to determine the impact of PRL as well as of each scientist. This aspect about research measurement remains to be done.

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CHAPTER 4

PUBLICATION PATTERN OF PRL SCIENTISTS

Publishing is one of the formal methods of communication and also the most important means of communication. It allows the scientist / researcher to verify the reliability of information, to assess the relative importance of a contribution and to obtain critical response to the research work done. It is through publication that researcher gets recognition for his/her work especially when it is cited by other colleagues. Scientists, like researchers in other fields, are strongly motivated to get recognition from their peers for having made a significant scientific contribution. There are several factors which put together motivate the scientists to publish their research work such as pleasure of making new discoveries, the urge to create new knowledge, the need to gain visibility for their work, economic gain, reaching the peak of the professional ladder and the institutional pride.

The book was considered the first instrument for publishing ones ideas, the medium through which new ideas, evidence and scientific theories were broadcast to a wide audience. Gradually, original research work started appearing in notebooks where data was noted down and analysed and results obtained. These results were conveyed to other scientists through letters. This method still exists and we often find scientists writing personal letters to each other conveying their result, and it continues to be an important venue for reporting new findings.

The journal came into existence in 1665 and many papers found their way to the scientific journal. The growth of the journal and the development of the scientific societies were simultaneous and the journal became the most convenient vehicle for the transmission of new ideas and research in science. Journals encourage the researchers to publicize their work, offer a forum for the continuous critical examination of hypotheses and theories, and

preserve the material which would otherwise have been dispersed through publication in individual tracts or pamphlets. The journal also helps to establish priority claims in research work. Since, in majority of cases, journal articles are subjected to strict review, the quality of work is much higher than other forms of publishing (Vagiswari, 1997).

Researchers / scientists also communicate the results obtained from data analysis by presenting papers at conferences or symposia before publishing in the journal. This is done for faster communication and wider visibility. Conferences are usually attended by senior researchers who present the papers on their behalf and on that of the younger researcher. Conferences provide an opportunity to meet other researchers working in the same field and to become acquainted with their work and as well discuss their work. Frequently, the rapport developed during the interaction becomes the basis for collaborative work. Very often, senior researchers / scientists are also invited to deliver talks for the plenary session or for keynote address of conferences depending on their high impact scholarly output and recognition amongst the peer group. Thus conferences serve a vital function in the transfer of knowledge.

Sometimes, before the paper is presented at the conference or sent for publication in a primary journal, it may be brought out as a pre-print (nowadays – Eprint). The main aim of the Eprint is to convey the results to the peers in the field much before it is published in the journal which generally takes a few months to one year to process. However, it must be remembered that, since the Eprint does not go through a peer review, there is a chance of its getting rejected by the referees when submitted to a primary journal.

Publication record of a research scientist can adequately reflect his research output (productivity). Consideration of the publication record for output measurements has a distinct advantage over other criteria. Articles published in refereed journals are not only of good quality but are also easy to count. Thus output measurement in terms of papers published in refereed journals is more precise. Several studies have used publication counts and have shown that meaningful and statistically significant positive relationships exist between publication data and progress of science.

Derek de Sola Price (1963) was the first one to discern a pattern in publications and elaborated it in his most influential work 'Little Science Big Science'. This book describes the exponential growth of the scholarly literature and scientific manpower. It covers various aspects of the productivity of scientists like authorship pattern, collaboration pattern, preference of a journal for publishing their results, etc. Narin (1976) surveyed 24 studies in which both bibliometric measures (measures using publication data) and non-literature measures were used and concluded that bibliometric measures are highly recommended for studies in productivity.

As reflected in the publications indexed in international subject databases, India's publications growth rate has been relatively much faster in recent years. As compared to 2.51% annually during 1985-2005, it has almost doubled to 5.4% annually during 1995-2005. India's publications as indexed in Web of Science (WoS) have grown from 14,405 papers in 1990 to 28,603 papers in 2005. The institutional participation in research has broadened from 1,734 institutions in 1985-86 to 3,443 in 2001-02. However, there were only 24 institutions which published 300 or more papers during 1985-86 or 2001-02 (Gupta & Dhavan, 2006).

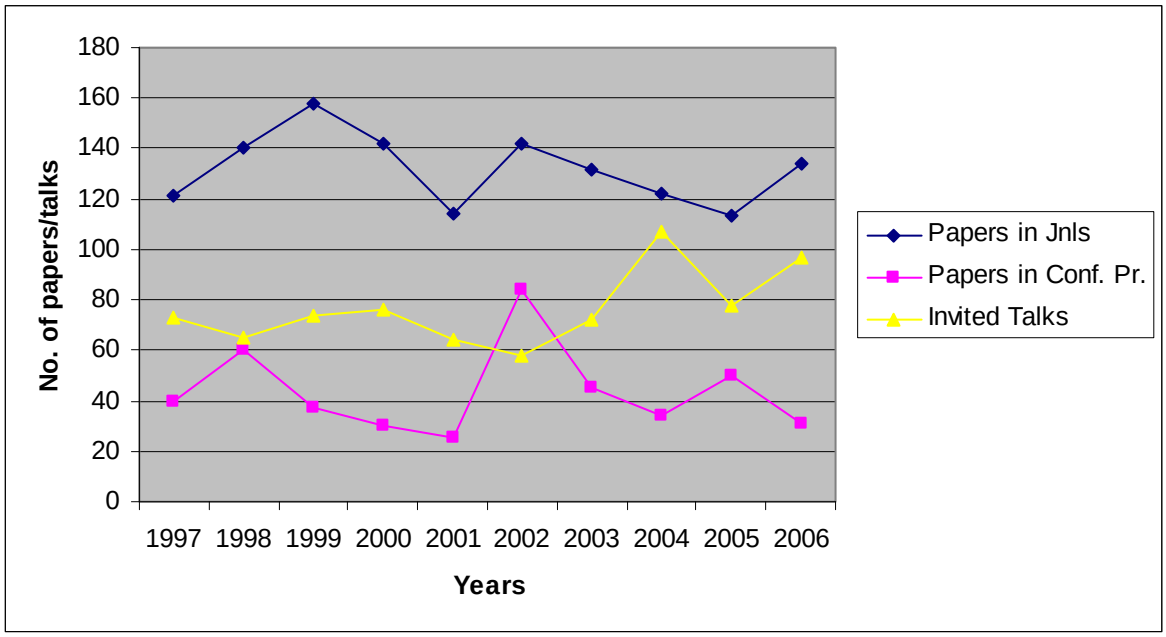
Research output of PRL

The above figures intrigued the researcher so much that she decided to study the research out put of one of the institutes of national importance. The present chapter attempts to identify the publication pattern of one institute – PRL. As mentioned in the previous chapter, the 10 year publication data has been gathered for the years 1997 through 2006. The research output in this period measured in terms of papers published and invited talks delivered consists of 2,518 records out of which 1,318 papers have been published in journals, 436 are published in conference proceedings and 764 are invited talks. This macro data is presented in Table 1.1 and Figure 1.1

Table 1.1 : Research output of PRL during 1997-2006

Year	Papers in Jnls	Papers in Conf. Pr.	Invited Talks	Total
1997	121	40	73	234
1998	140	60	65	265
1999	158	37	74	269
2000	142	30	76	248
2001	114	25	64	203
2002	142	84	58	284
2003	132	45	72	249
2004	122	34	107	263
2005	113	50	78	241
2006	134	31	97	262
Total	1318	436	764	2518

Fig 1.1 : Research output of PRL during 1997-2006



The above macro data is further analysed at micro level to give an idea about the **publication pattern** in terms of indicators such as authorship and collaboration in papers published in journals and conference proceedings, papers published as chapter of a book or in national / international journal, papers contributed in conferences held in India or abroad and invited talks delivered in India or abroad. The chapter concludes with a list of journals preferred by the PRL scientists for publication. For ease of understanding, the total number of publications for each indicator is represented first and then the pattern over 10 years is shown.

Tables 1.2-1.5 cover the authorship in journals and conference proceedings, Tables 1.6-1.9 cover the collaboration in journals and conference proceedings, Tables 1.10-1.15 cover the publication in national / international journals, national / international conference proceedings and national / international invited talks respectively. Last table gives the list of most preferred journals for publication of PRL scientists.

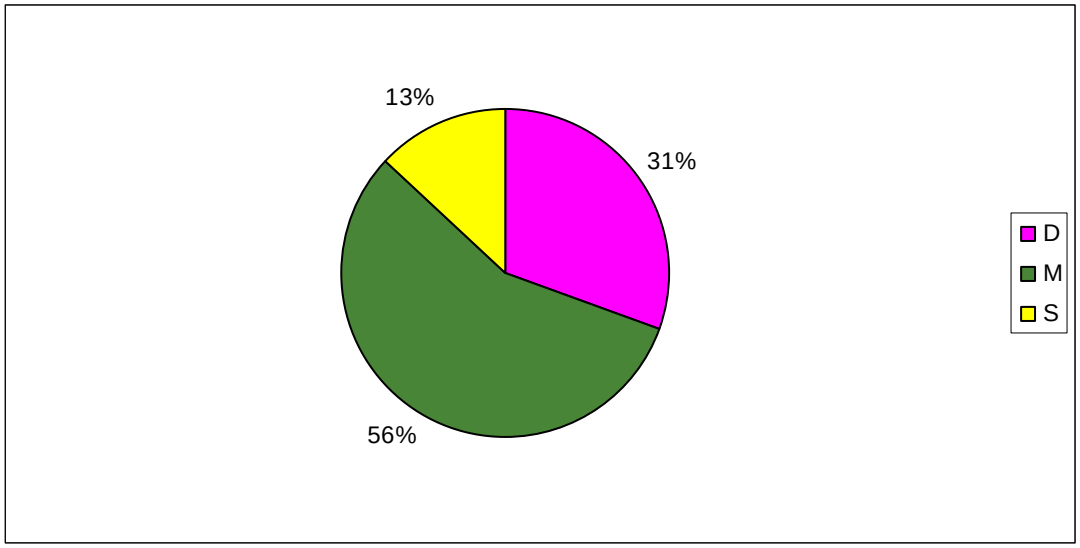
Authorship Pattern

Table 1.2 and Figure 1.2 give the overall picture of authorship during 1997-2006 for the research papers published in journals. It indicates that number of multiple and double authored papers far outweigh the single authored papers. This result is cognizant with the world pattern and confirms many earlier studies. Out of 1318 papers published in journals, 741 (56.22%) papers are multi-authored (M) and 404 (30.65%) are double authored (D) papers and 173 (13.13%) are single authored (S) papers. It can be inferred from this result that team effort in research has become integral part of PRL research.

Table 1.2: Authorship Pattern in Journals during 1997-2006

Authorship	Papers	%
Double authors	404	30.65
Multi authors	741	56.22
Single author	173	13.13
Total	1318	100.00

Fig 1. 2 : Authorship Pattern in Journals during 1997-2006



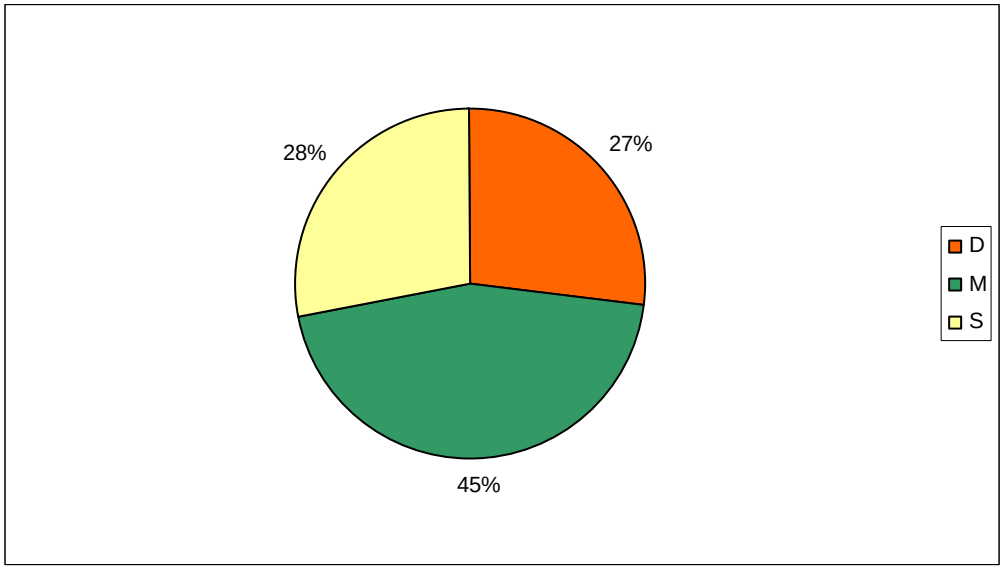
Note : D – Double authored papers, M – Multi authored papers, S–Single author papers

Table 1.3 and Figure 1.3 show the pattern of double authored (D), multi-authored (M) and single authored (S) papers in conference proceedings. Here again, similar scenario emerges, with multi-authored papers far out numbering the double and single authored papers.

Table 1.3 : Authorship Pattern in Conference Proceedings during 1997-2006

Authorship	Papers	%
Double authors	117	26.83
Multi authors	197	45.18
Single author	122	27.98
Total	436	100.00

Fig 1.3 : Authorship Pattern in Conference Proceedings during 1997-2006



Note : D – Double authored papers, M – Multi authored papers, S–Single authored papers

Comparing the data of papers in journals and conference proceedings, overall proportion of multi-authored and double authored papers are more in journals than in conference proceedings, while single authored papers are more in conference proceedings. High percentage of multi-authored and double authored papers in journals is in accordance with

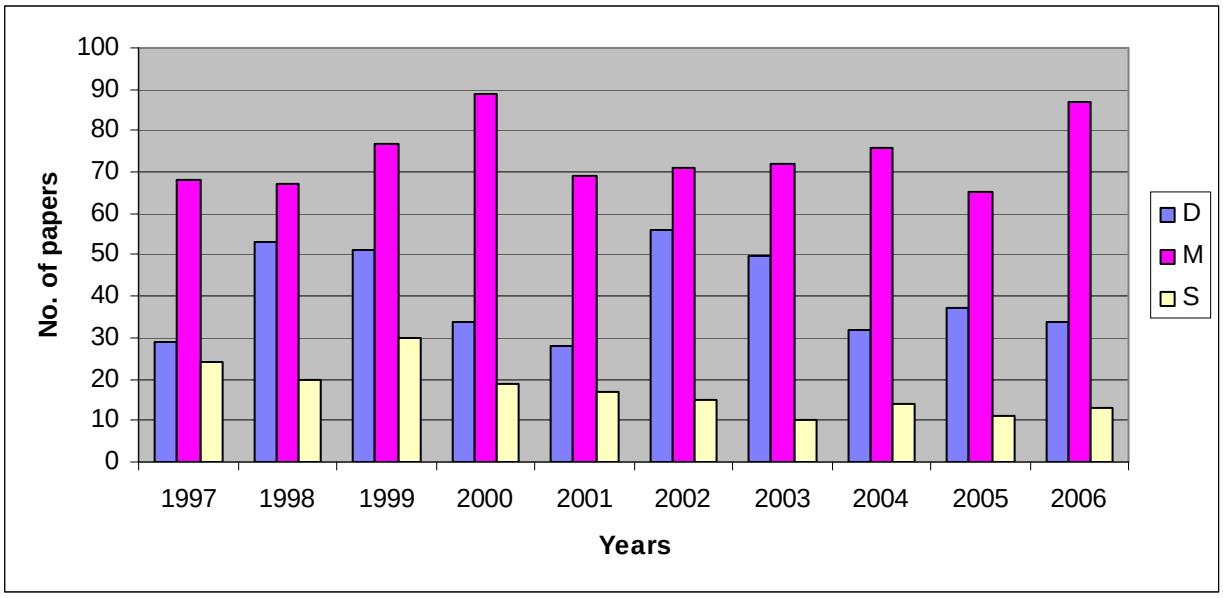
the world pattern and can be attributed to the fact that double and multi-authored papers are generally cited more than single authored papers (Lancaster, 1991).

Table 1.4 and Figure 1.4 give the year wise authorship pattern of papers published in journals through the years 1997 to 2006. Double authored and multi authored papers have increased during the years 1997-2006, on the other hand single authored papers have decreased over the years. Years 2000 and 2006 saw maximum number of multi-authored papers. A sharp decrease is seen in number of single authored papers from 2000 onwards. The reason for this could be that internet and email made it very easy for scientists to share and communicate and make changes in the manuscripts. Geographical location was not a hindrance anymore and hence more number of papers were generated which were either double authored or multi-authored.

Table 1.4 : Year wise Authorship Pattern in Journals from 1997-2006

Year	**D**	**M**	**S**	**Total**
1997	29	68	24	121
1998	53	67	20	140
1999	51	77	30	158
2000	34	89	19	142
2001	28	69	17	114
2002	56	71	15	142
2003	50	72	10	132
2004	32	76	14	122
2005	37	65	11	113
2006	34	87	13	134
Total	404	741	173	1318

Fig 1.4 : Year wise Authorship Patttern in Journals from 1997-2006



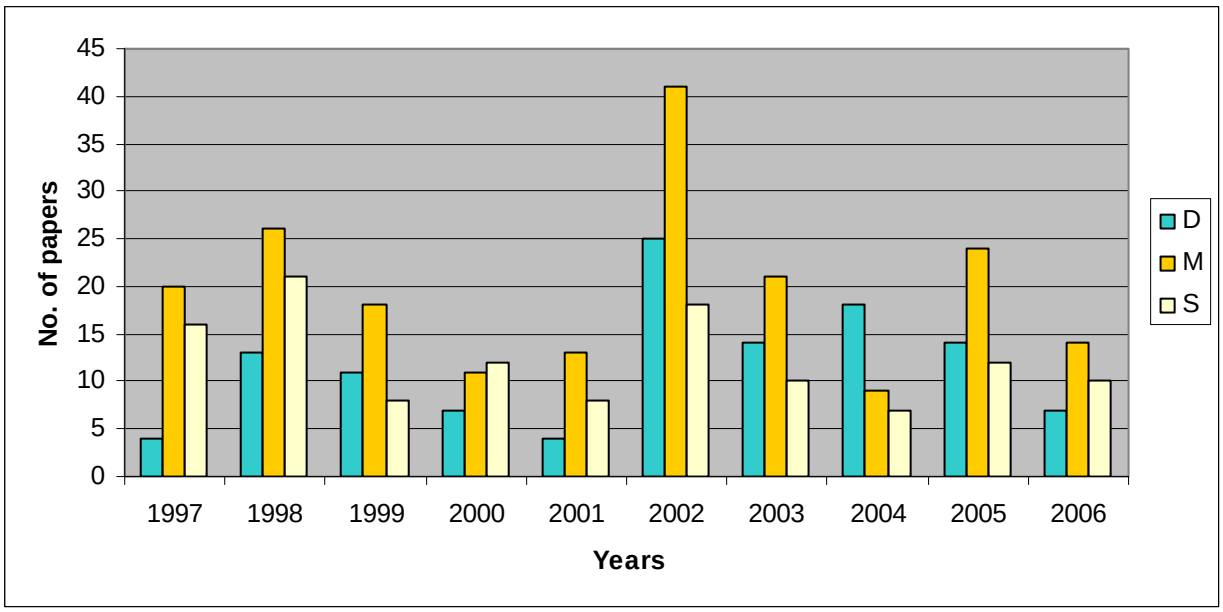
Note : D – Double authored papers, M – Multi authored papers, S–Single author papers

Table 1.5 and Figure 1.5 show the authorship pattern in papers published in conference proceedings from 1997 through 2006. Out of 436 papers, 197 papers are multi-authored papers followed by double authored and single authored papers. The year 2002 saw maximum number of papers in all three categories of papers.

Table 1.5 : Year wise Authorship Pattern in Conference Proceedings from 1997-2006

Year	D	M	S	Total
1997	4	20	16	40
1998	13	26	21	60
1999	11	18	8	37
2000	7	11	12	30
2001	4	13	8	25
2002	25	41	18	84
2003	14	21	10	45
2004	18	9	7	34
2005	14	24	12	50
2006	7	14	10	31
	117	197	122	436

Fig 1.5 : Year wise Authorship Pattern in Conference Proceedings from 1997-2006



Note : D – Double authored papers, M – Multi authored papers, S-Single authored papers

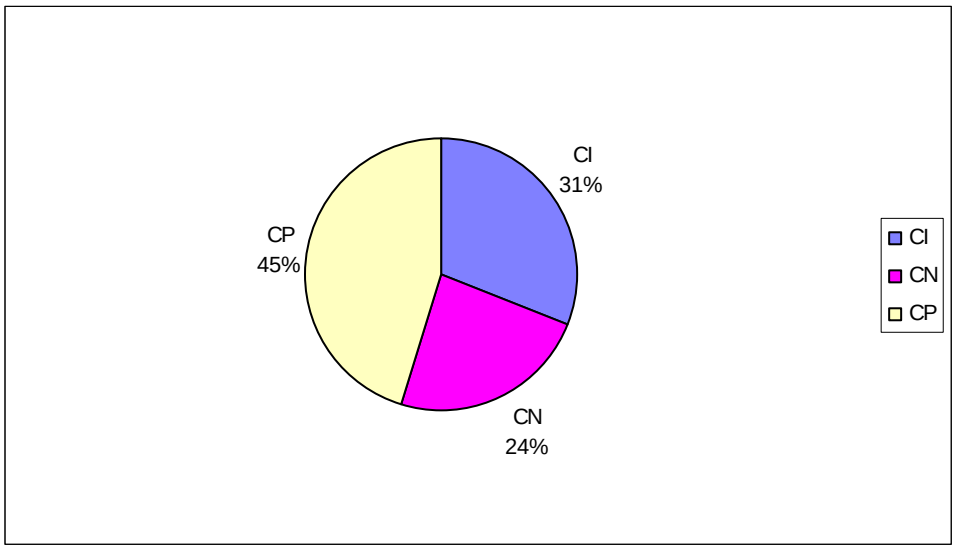
Collaboration Pattern

Table 1.6 and Figure 1.6 below give a graphical representation of the collaborative papers published in journals at PRL during 1997-2006. As seen from the table there are 596 (45.22%) papers with collaboration within PRL (CP) i.e. all the authors of a paper are affiliated to PRL, 411 (31.18%) papers with international collaboration (CI) and 311 (23.60%) papers with national collaboration (CN). The result shows that there is healthy culture of collaboration within PRL.

Table 1.6 : Types of Collaborative Papers in Journals during 1997-2006

Collaboration	Papers	%
CI	411	31.18
CN	311	23.60
CP	596	45.22
Total	1318	100

Fig 1.6 : Types of Collaborative Papers in Journals during 1997-2006



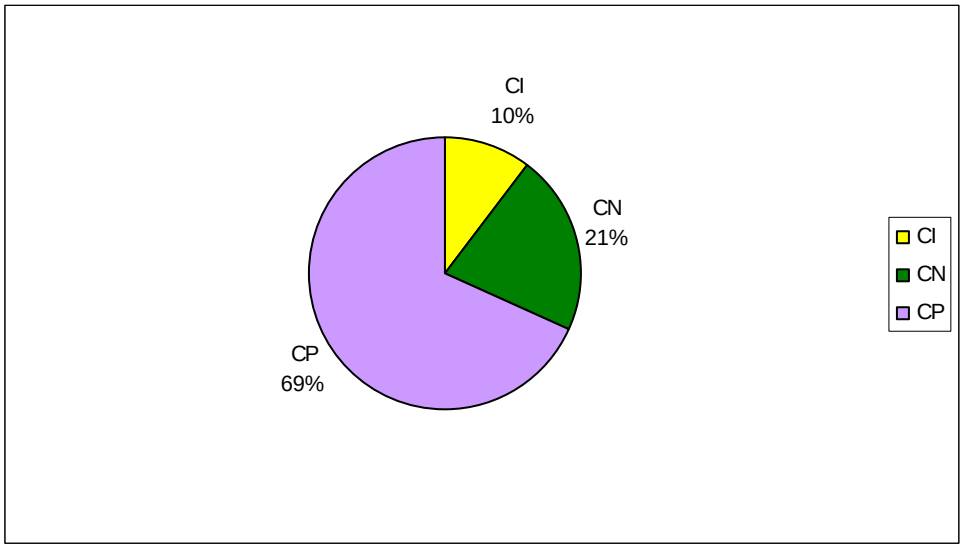
Note : CI - Collaboration International, CN – Collaboration National, CP - Collaboration PRL

Table 1.7 and Figure 1.7 below give an indication of collaborative papers published in conference proceedings. In this case, national collaborative papers (CN) are more than international collaborative (CI) papers. The reason could be that funding is available for national conferences but it is more difficult for international conferences. The domestic collaborative papers (CP) are in much higher proportion (69%) than national or international collaborative papers.

Table 1.7 : Types of Collaborative Papers in Conference Proceedings during 1997-2006

Collaboration	Papers	%
CI	45	10.32
CN	93	21.33
CP	298	68.35
Total	436	100.00

Fig 1.7 : Types of Collaborative Papers in Conference Proceedings during 1997-2006



Note: CI - Collaboration International, CN – Collaboration National, CP - Collaboration PRL

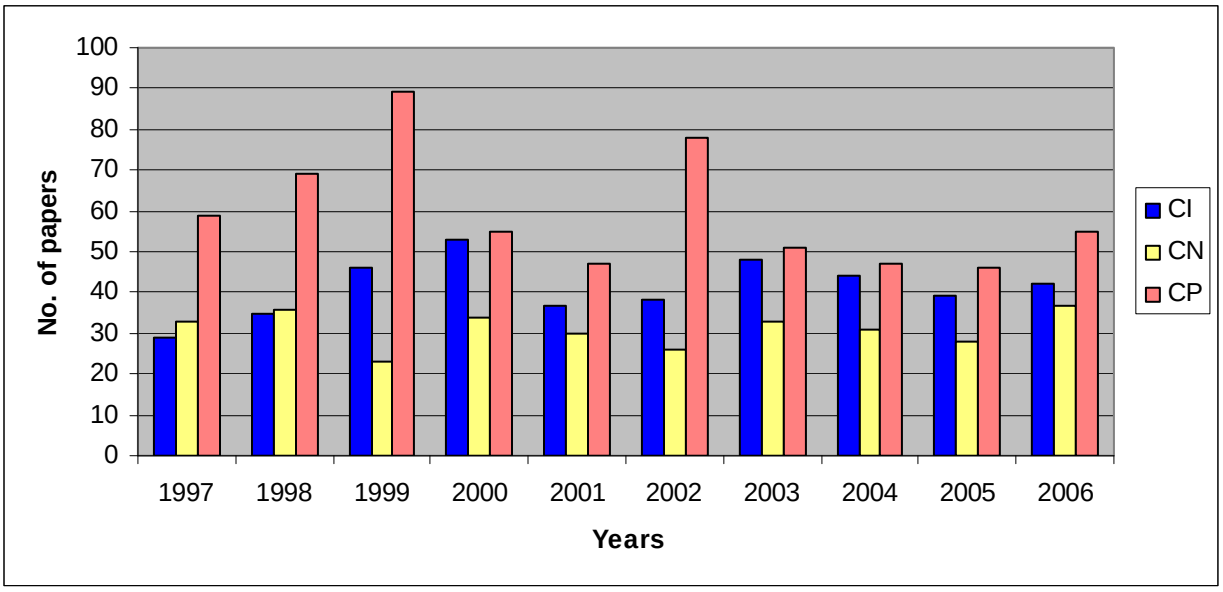
Comparing the data of collaborative papers in journals and conference proceedings, it is seen that international collaboration is higher in journals (31%) than in conference proceedings (10%), national collaboration is almost the same in journals and conference proceedings. Domestic collaboration (CP) is higher in conference proceedings (69%) than in journals (45%).

Table 1.8 and Figure 1.8 give year wise pattern of collaboration in papers published in journals from 1997 through 2006. There has been a general increase in international collaborative papers. National collaboration has increased slightly and domestic collaboration (CP) has decreased slightly over the years. Highest number of international collaborative papers (53) published in journals were in the year 2000. National collaboration was highest (37) in 2006.

Table 1.8 : Year wise Collaboration Pattern in Journals from 1997-2006

Year	**CI**	**CN**	**CP**	**Total**
1997	29	33	59	121
1998	35	36	69	140
1999	46	23	89	158
2000	53	34	55	142
2001	37	30	47	114
2002	38	26	78	142
2003	48	33	51	132
2004	44	31	47	122
2005	39	28	46	113
2006	42	37	55	134
Total	411	311	596	1318

Fig 1.8 : Year wise Collaboration Pattern in Journals from 1997-2006



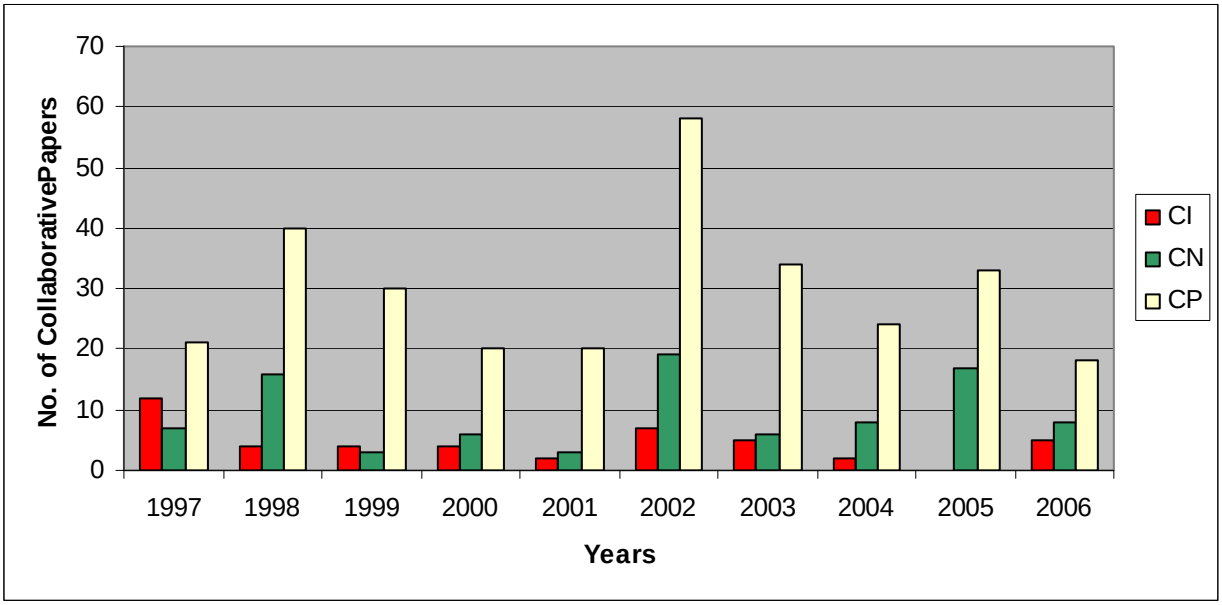
Note : CI - Collaboration International, CN – Collaboration National, CP - Collaboration PRL

Table 1.9 and Figure 1.9 below show the pattern of collaborative papers in conference proceedings during the years 1997-2006. The year 1997 saw highest number of international collaborative papers (12), while national collaborative papers (19) and PRL collaborative papers (58) were highest in 2002.

Table 1.9 : Year wise Collaboration Pattern in Conference Proceedings from 1997-2006

Year	CI	CN	CP	Total
1997	12	7	21	40
1998	4	16	40	60
1999	4	3	30	37
2000	4	6	20	30
2001	2	3	20	25
2002	7	19	58	84
2003	5	6	34	45
2004	2	8	24	34
2005	0	17	33	50
2006	5	8	18	31
	45	93	298	436

Fig 1.9 : Year wise Collaboration Pattern in Conference Proceedings from 1997-2006



Note : CI - Collaboration International, CN – Collaboration National, CP - Collaboration PRL

Also, there has been a decrease in the international collaborative papers over the years i.e. there were 12 papers with international collaboration in 1997 and only five papers with international collaboration in 2006. National collaboration has remained at the same level. In this category too, domestic collaboration has decreased slightly over the years from 21 in 1997 to 18 in 2006.

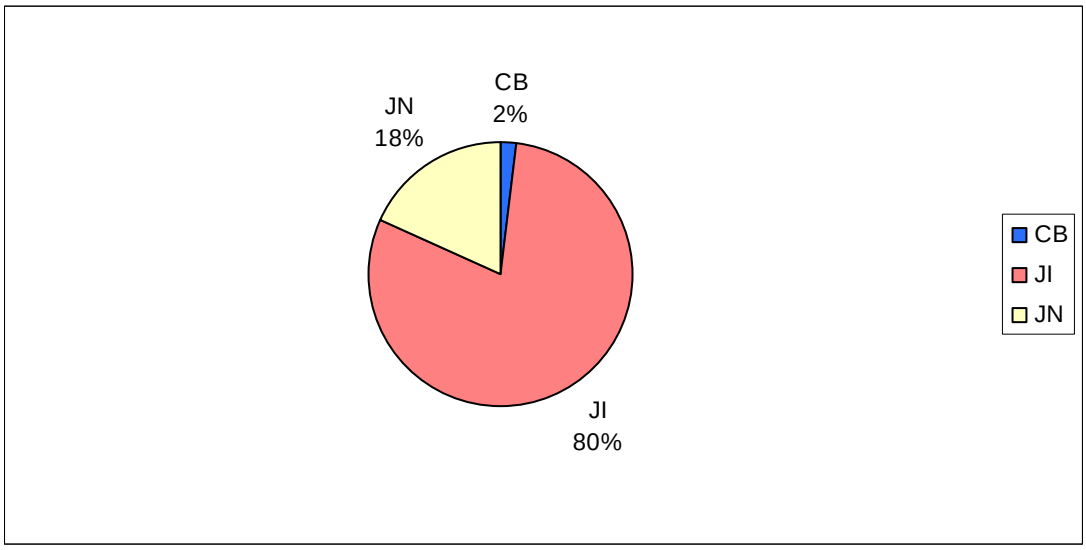
Publication Mode

Table 1.10 and Figure 1.10 give an overview of publication mode preference of researchers with articles published in national and international journals and as chapter of a book. Almost 80% of the papers are published in international journals. It may be noted that researchers at PRL do not seem to prefer to contribute chapters in books.

Table 1.10 : Publication Mode Preference during 1997 - 2006

Publication Mode	Papers	%
CB	27	2.05
JI	1051	79.74
JN	240	18.21
Total	1318	100.00

Fig 1.10 : Publication Mode Preference during 1997 - 2006



Note : CB – Book Chapter, JI – International Journal, JN – National Journal

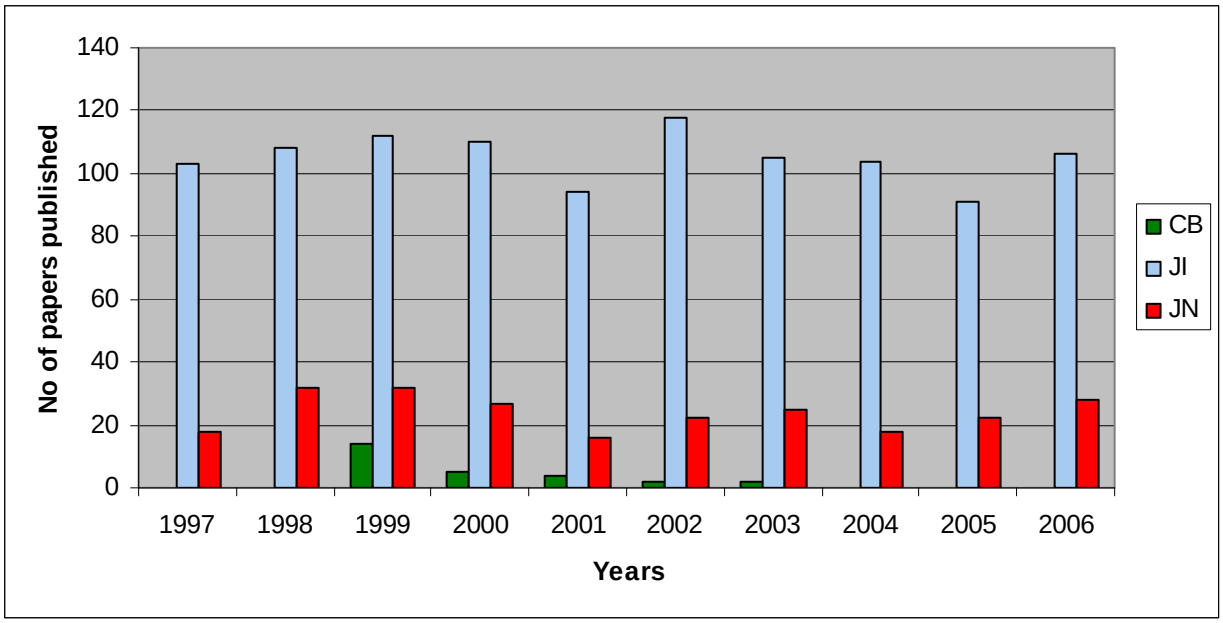
Table 1.11 and Figure 1.11 below give the year wise pattern of publication mode preference from 1997-2006. Out of 1318 papers published, maximum number of papers in international journals were pulished in 2002 (118). However, there has been only a marginal increase in the number of papers in international journals from 103 in 1997 to 106 in 2006. There has been an increase in papers published in national journals – from 18 in 1997 to 28 in 2006.

Jacobs (2001) states that most of the scientists in the developed countries are not aware of the research carried out in third world countries. Probably because of the fact that scientists from some of the third world countries fail to publish the results of their research in reputed international journals. However, the result of the present study is contrary to this, as out of 1318 articles published by PRL scientists, 1051 are in international journals (JI) and only 240 are in national journals (JN) and 27 are chapters of a book (CB). Thus, most preferred mode of publication of PRL scientists is international journal.

Table 1.11 : Year wise Pattern of Publication Mode from 1997-2006

Year	CB	JI	JN	Total
1997	0	103	18	121
1998	0	108	32	140
1999	14	112	32	158
2000	5	110	27	142
2001	4	94	16	114
2002	2	118	22	142
2003	2	105	25	132
2004	0	104	18	122
2005	0	91	22	113
2006	0	106	28	134
Total	27	1051	240	1318

Fig 1.11 : Year wise Pattern of Publication Mode from 1997-2006



Note : CB – Book Chapter, JI – International Journal, JN – National Journal

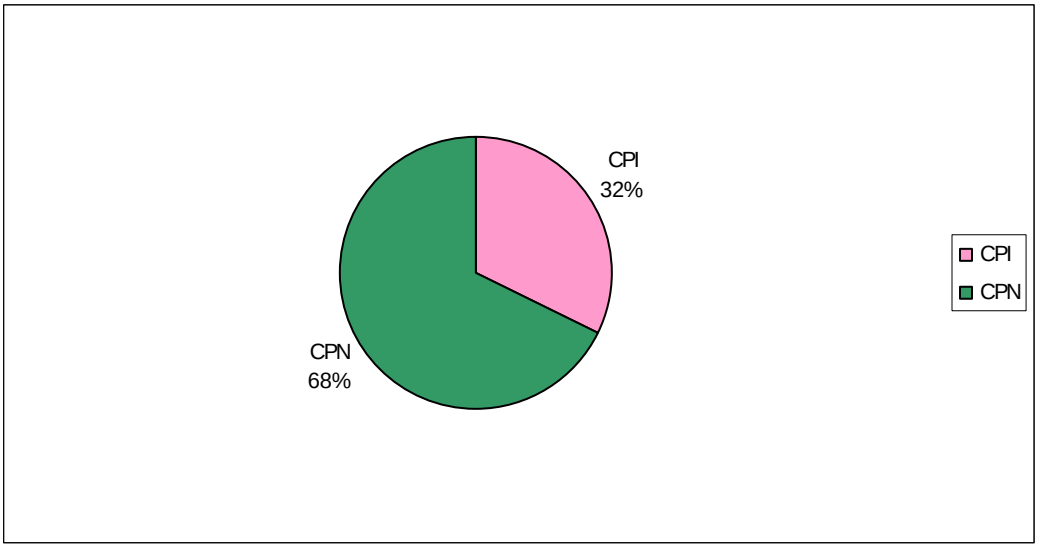
Papers in Conference Proceedings – National / International

Table 1.12 and Figure 1.12 give the proportion of papers published in conference proceedings of international and national conferences. Out of a total of 436 papers published in this period, 295 (67.66%) are in the proceedings of conferences held in India and 141 (32.34%) papers were published in the proceedings of conferences held abroad. Less proportion of papers published in international conference proceeding could be attributed to less number of scientists and students attending the international conferences than the national conferences.

Table 1.12: Papers in Conference Proceedings - National/International during 1997 - 2006

Conference Proceeding	Papers	%
CPI	141	32.34
CPN	295	67.66
Total	436	100.00

Fig 1.12 : Papers in Conference Proceedings – National/International during 1997 - 2006



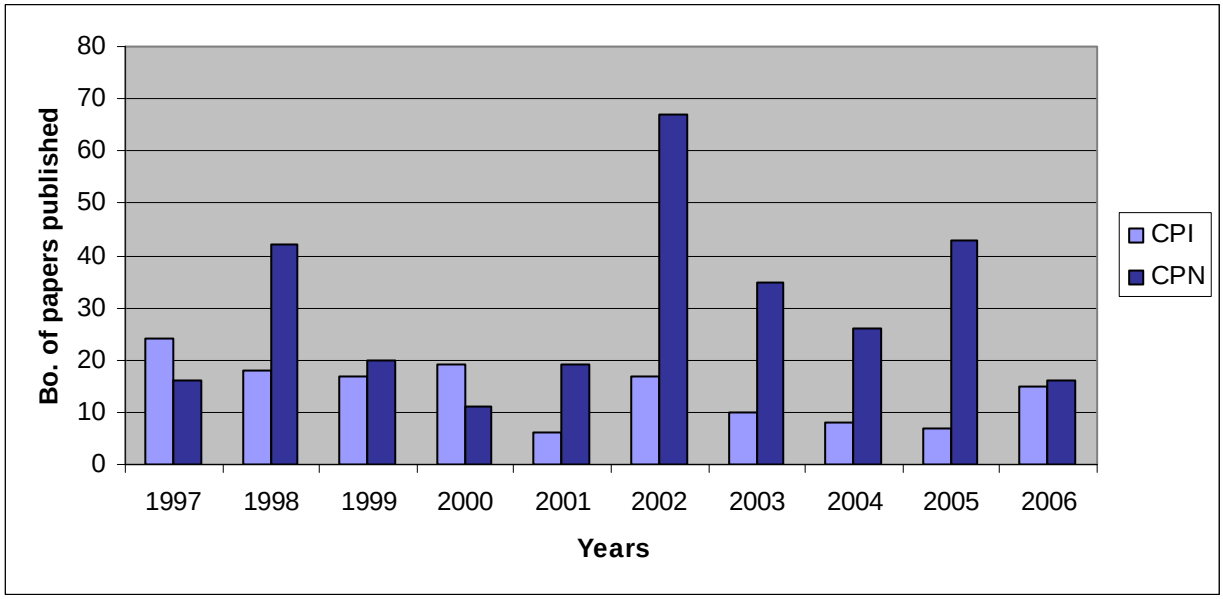
Note : CPI – International Conference Proc. CPN – National Conference Proc.

Table 1.13 and Fig 1.13 show year wise pattern of papers published in conference proceedings by researchers of PRL at international and national level.

Table 1.13 : Year wise Pattern of Papers in Conference Proceedings from 1997-2006

Year	CPI	CPN	Total
1997	24	16	40
1998	18	42	60
1999	17	20	37
2000	19	11	30
2001	6	19	25
2002	17	67	84
2003	10	35	45
2004	8	26	34
2005	7	43	50
2006	15	16	31
	141	295	436

Fig 1.13 : Year wise Pattern of Papers in Conference Proceedings during 1997 - 2006



The above table and figure show that there has been a decrease in number of papers in international conferences' proceedings (CPI) over the years 1997-2006 from 24 in 1997 to 15 in 2006 while almost no change is seen in number of papers in national conference proceedings (CPN).

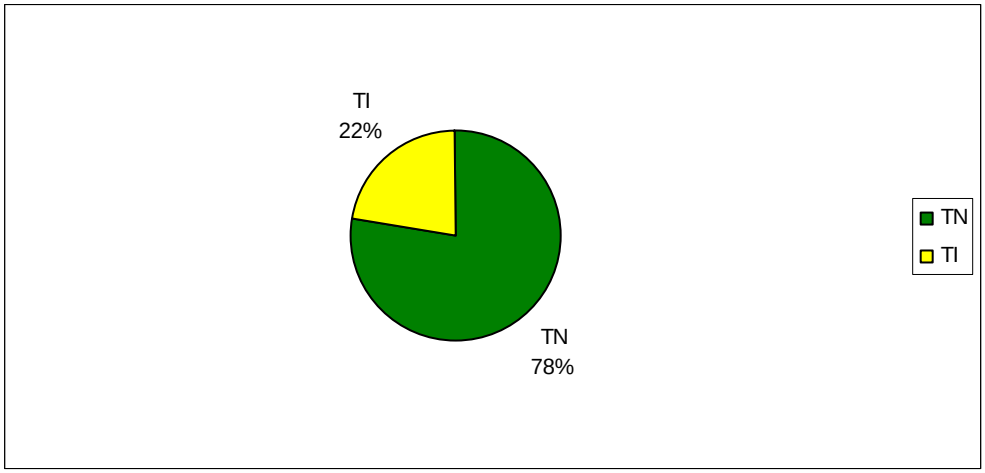
Invited Talks delivered – National / International

Table 1.14 and Figure 1.14 below give the number of invited talks delivered by PRL scientists in India and abroad. Out of 764 invited talks, 593 (77.62 %) were delivered in India (TN) and 171 (22.38%) were delivered abroad (TI).

Table 1.14 : Invited Talks delivered – National / International during 1997-2006

Invited Talks	No. of Talks	%
TN	593	77.62
TI	171	22.38
Total	764	100.00

Fig 1.14 : Invited Talks delivered – National/International during 1997-2006



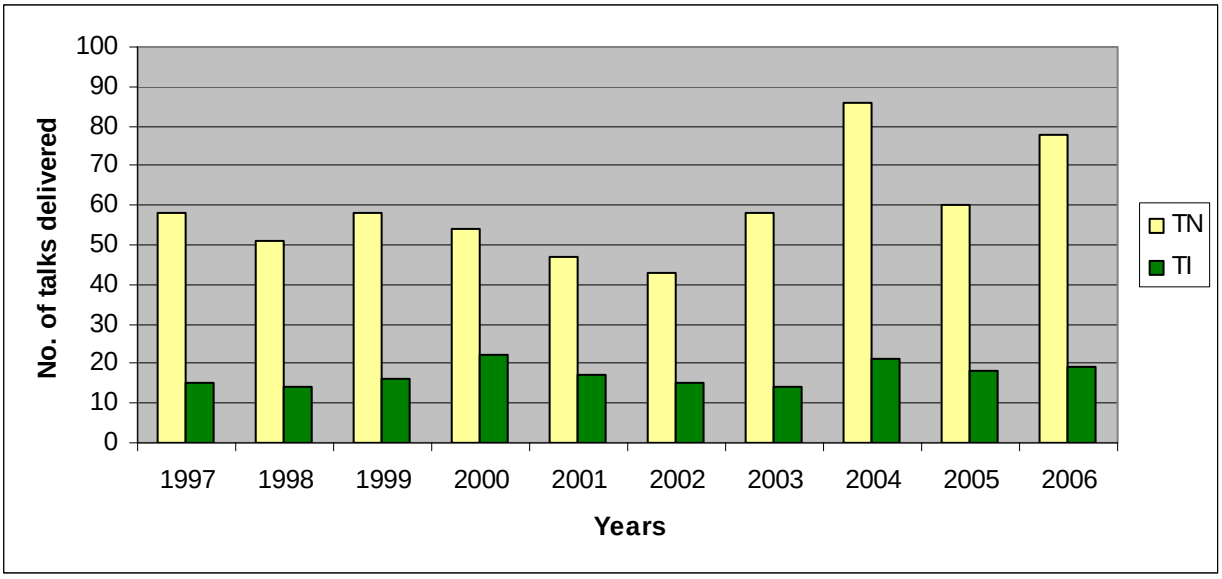
Note : TN – Invited Talk in India, TI –Invited Talk outside India

Table 1.15 and Figure 1.15 give year wise pattern of invited talks delivered at national and international level during 1997-2006. It is evident from the table that there is an increase in the number of invited talks delivered at national level, particularly since 2002.

Table 1.15: Year wise Pattern of Invited Talks – National/International from 1997 to 2006

Year	TN	TI	Total
1997	58	15	73
1998	51	14	65
1999	58	16	74
2000	54	22	76
2001	47	17	64
2002	43	15	58
2003	58	14	72
2004	86	21	107
2005	60	18	78
2006	78	19	97
Total	593	171	764

Fig 1.15: Year wise Pattern of Invited Talks – National/International from 1997 to 2006



Note : TN – Invited Talk in India, TI –Invited Talk outside India

The figure above indicates that peer recognition of PRL scientists seems to be on rise in India. However, there is only a marginal increase in number of invited talks delivered abroad during the years 1997-2006.

Journal Preference for Publication

According to Lancaster (1982) many scientists in developing countries prefer to publish in foreign journals rather than in their native journals for the sake of prestige and recognition. Half of the papers of Indian scientists are published in American journals. It is a matter of pride, if one's paper is accepted in high impact foreign journals like 'Nature' or 'Science'. This is confirmed by the result of the present study. Table 1.16 tells us about the journal preference of PRL scientists. It lists the journal titles which have more than 15 papers published during the 10 year study period. **Physical Review A** tops the list with 83 articles followed by **Current Science** with 68 articles and **Physical Review D** with 50 articles published during 1997-2006 by PRL scientists. Out of the 20 most preferred journals, 4 are Indian – Current Science, Journals of Earth System Science, Pramana, and Bulletin of Astronomical Society of India. All others are international journals of high impact as is seen from the high impact factors. Thus there is clear preference to publish in international journals because it brings recognition.

Table 1.16 : Most preferred journals for publication during 1997-2006

Journal Name	No of Pape	IF
		(2009)
Physical Review A	83	**2.866**
Current Science	68	**0.782**
Physical Review D	50	**4.922**
Journal of Geophysical Research (ALL)	47	**3.082**
Physics Letters B	41	**5.083**
Astronomy and Astrophysics	37	**4.179**
Solar Physics	37	**3.628**
Journal of Earth System Science	34	**0.819**
Physical Review E	33	**2.400**
Advances in Space Research	30	**1.079**
Geophysical Research Letters	25	**3.204**
Meteoritics and Planetary Science	23	**3.253**
Physical Review Letters	22	**7.328**
Pramana	22	**0.349**
Astrophysical Journal	21	**7.364**
Bulletin of Astronomical Society of India	20	**0.310**
Physics of Plasmas	20	**2.475**
Journal of Astrophysics and Astronomy	19	**0.580**
Physics Letters A	18	**2.009**
Geochimica Cosmochimica Acta	16	**4.385**
Monthly Notices of Royal Astronomical Society	16	**5.103**

Summary of results

- With the advent of Big Science has come research collaboration and collaborative authorship. The foregoing pages indicate that multiple authored and double authored papers are on the rise in PRL, especially from 2000 onwards probably due to ease of contact through emails and ease of writing and editing using the computers and the Internet. In 1961 Price had predicted the disappearance of single authored papers. Fifty years hence, this trend is more than obvious as scholarship becomes interdisciplinary, leading to greater cooperation among individuals and institutions.
- The research output of PRL in terms of publication record and invited talks summing upto 2518 units gives an average of about 250 research output units per year. Out of these, 1318 papers in journals give an average of about 130 papers published in journals per year. The average number of academic faculty being 60, gives the output of 2.17 papers per academic faculty per year. According to the study done by Raghuraman, et al (2010), PRL is ranked 9th amongst the autonomous R & D centres in India in terms of publication output.
- Comparing the data of collaborative papers in journals and conference proceedings, international collaboration is higher in journals than in conference proceedings. National collaboration is almost the same in journals and conference proceedings. Domestic collaboration is higher in conference proceedings than in journals. For conference proceedings, national collaborative papers are more than double of international collaborative papers.
- The journals most preferred by PRL scientists for publication are **Physical Review A** (83 articles) followed by **Current Science** with 68 articles and **Physical Review D** with 50 articles during 1997-2006 by PRL scientists. Out of the 20 most preferred journals, 4 are Indian – Current Science, Journals of Earth System Science, Pramana, and Bulletin of Astronomical Society of India. All others are international journals of high impact. Thus there is clear preference to publish in international journals because it brings recognition.

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CHAPTER 5

RESEARCH TRENDS AT PRL

The ever increasing size and specialized nature of research today, makes it difficult for a small group of experts to evaluate fully, the complex landscape of research. The limited availability of funds has made it almost mandatory to measure the research outputs in all the subject fields. Since lot of money is being invested in this endeavour, most of the policy makers in the governments are asking for research output in quantitative terms.

As the science and technology research is becoming an increasingly international pursuit, more and more people are undertaking the quantitative studies to measure science. Such studies point to useful indicators of research such as scientific productivity, thrust areas of research and preferences for publication modes. Tracking citations and understanding their trends in context is a key to evaluate the impact and influence of research. To discern the research trends at PRL, the researcher has studied two components of research output – research publications of PRL scientists and bibliographies of theses of PRL doctoral students.

Elements of Research

According to Lancaster (1991) for assessing the research productivity of an organization and its impact, four major elements are important. These are the inputs, the process, the outputs and the outcomes of research. Lancaster opines that the inputs are the most tangible and hence measurable. The primary input is financial resource which is used to purchase the secondary resource like the human resource and the facilities (laboratories, buildings, libraries, etc.) that make the research possible. Factors affecting the quality of research process include the size of the research group, its composition, the leadership

provided, the institutional climate and the degree of collaboration. Various personal and behavioral characteristics of researchers also affect the research process. Efficiency of the research group can be measured in terms of completion of projects on time and within budget. The research output is the result achieved through the research process. The results become relevant only when they are made known to individuals or organizations that can apply them. This is done by publishing the results in reports, scholarly journals and papers presented at conferences. Cost effectiveness criteria would include the number of research publications produced per person employed. The research outcome is generally considered to be the benefit to the organization or society at large.

The present study is confined to the measurement of research output of PRL only. It has not touched upon other aspects of research – input, process and outcome - as it would be beyond its scope.

The present chapter covers the division wise break-up of the research output, research trends visible during the period of study, identifies the topics of research which attracted more number of papers than the others and most prolific scientists of PRL during 1997-2006.

Division wise break up of research output of PRL scientists

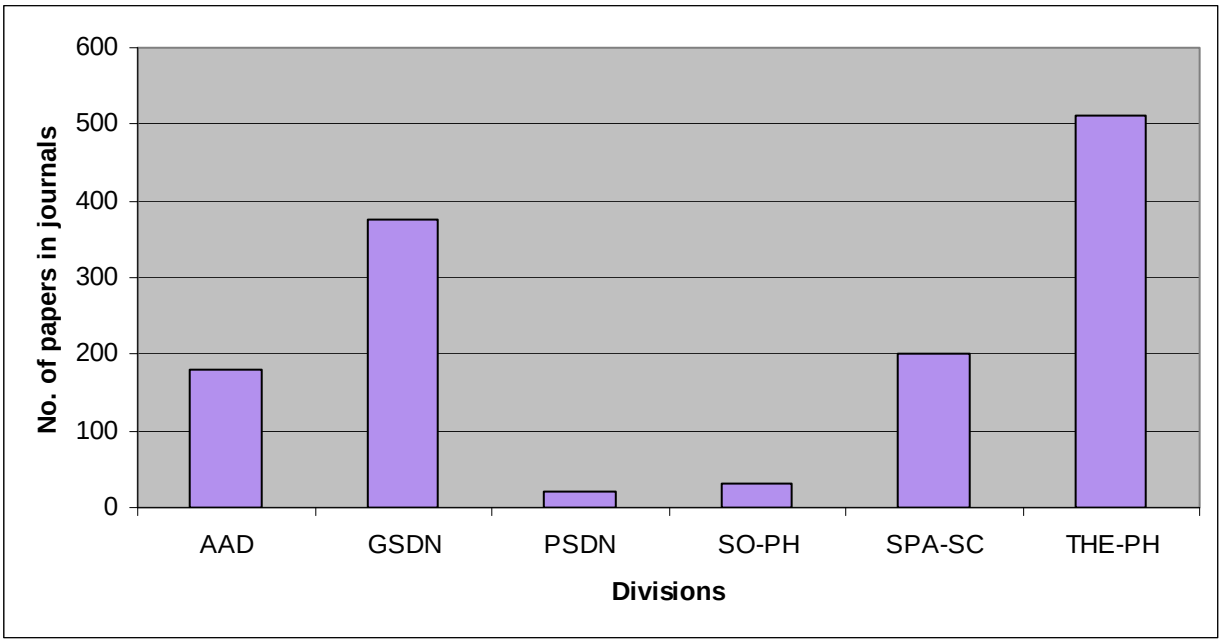
According to research carried out in six broad subjects, there are six divisions in PRL. As mentioned in chapter 3, these are Astronomy and Astrophysics (AAD), Geosciences (GSDN), Planetary Sciences (PSDN), Space and Atmospheric Sciences (SPA-SC), Theoretical Physics (THE-PH) and Solar Physics (SO-PH). Earlier SO-PH was part of Astronomy Division. PSDN, which was formed by merging PLANEX and SOXS projects was part of GSDN. The researcher thought it appropriate to find out the division wise break up of productivity of PRL scientists. Tables and figures 2.1 to 2.6 give the division wise research output of PRL scientists – papers published in journals, papers published in conference proceedings and number of invited talks delivered.

Table 2.1 and Figure 2.1 give an indication of the division wise publication output in journals from 1997-2006. The data for SO-PH and PSDN is from 2002. Amongst all divisions, productivity of Theoretical Physics - THE-PH (38.77%) and Geosciences - GSDN (28.45%) divisions is more than other divisions during 1997-2006.

Table 2.1: Division wise break up of Papers Published in Journals during 1997-2006

Division	No. of Publications
AAD	180
GSDN	375
PSDN	20
SO-PH	32
SPA-SC	200
THE-PH	511
Total	1318

Fig 2.1: Division wise break up of Papers Published in Journals during 1997-2006



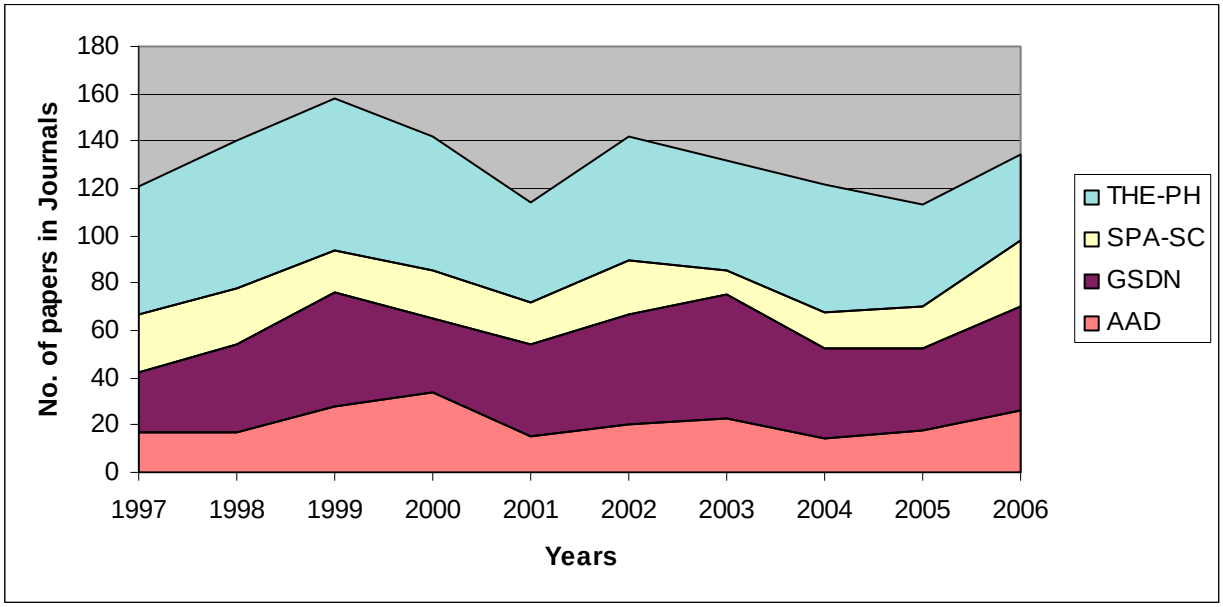
Note : AAD – Astronomy, GSDN – Geosciences, PSDN – Planetary Sciences, SO-PH – Solar Physics, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Table 2.2 and Figure 2.2 give the research output pattern of four major divisions from 1997 through 2006. For broader picture, Solar Physics is included in Astronomy Division and PSDN is included in Geosciences division. AAD produced maximum (34) number of papers in the year 2000, Geosciences Division (GSDN) produced maximum number of papers (52) in 2003, Space Sciences Division (SPA-SC) produced maximum (28) papers in 2006 and Theoretical Physics Division (THE-PH) produced maximum (64) papers in 1999.

Table 2.2 : Year wise pattern of Papers in Journals from 1997-2006

YEAR	AAD	GSDN	SPA-SC	THE-PH
1997	17	25	25	54
1998	17	37	24	62
1999	28	48	18	64
2000	34	31	20	57
2001	15	39	18	42
2002	20	47	23	52
2003	23	52	10	47
2004	14	38	16	54
2005	18	34	18	43
2006	26	44	28	36
Total	212	395	200	511

Fig 2.2 : Year wise pattern of Papers in Journals from 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

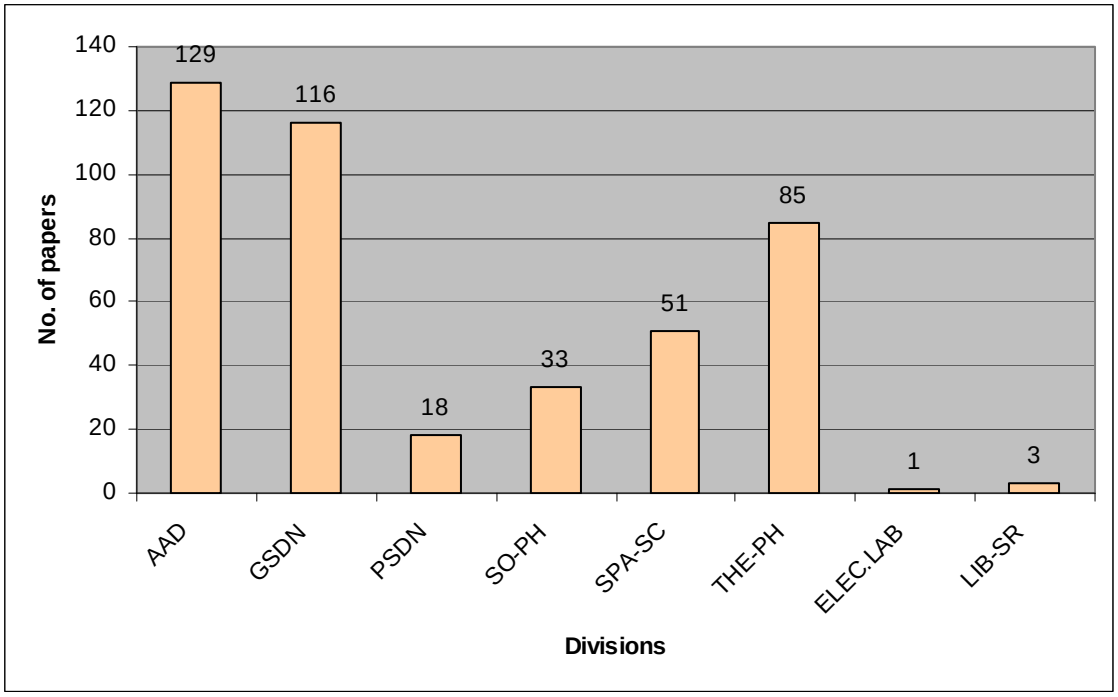
The figure above shows that over the years, productivity of SPA-SC has remained more or less same while it has improved for AAD and almost doubled for GSDN. Most likely reason for this seems to be that more number of faculty joined PRL in Geosciences division during this period. THE-PH has seen a decrease in its research output in journals especially from 2004 onwards.

Table 2.3 and Figure 2.3 below give the division wise break up of papers published in conference proceedings. Out of 436 papers in conference proceedings, maximum of 129 papers (29.59%) are published by Astronomy division followed by GSDN with 116 papers (26.61%) and THE-PH with 85 papers (19.50%). Space Science Division published only 51 papers (11.70 %) in conference proceedings during the 10 year study period. Amongst the Facilities of the institute, 3 papers were published by Library & Information Services and one paper by Electronics Lab. There is no paper from Computer Centre and Workshop published in the conference proceedings during the period 1997-2006.

Table 2.3 : Division wise break up of Papers in Conference Proceedings during 1997-2006

Division	Papers	%
AAD	129	29.59
GSDN	116	26.61
PSDN	18	4.13
SO-PH	33	7.57
SPA-SC	51	11.70
THE-PH	85	19.50
ELEC.LAB	1	0.23
LIB-SR	3	0.69
Total	436	100.00

Fig 2.3 : Division wise break up of Papers in Conference Proceedings during 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, PSDN – Planetary Sciences, SO-PH – Solar Physics, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Table 2.4 and Figure 2.4 below give the year wise pattern of research output in conference proceedings in four major divisions of PRL (by bringing SO-PH under the fold of Astronomy and PSDN under the fold of GSDN as these were formed in the middle of the study period) . The table shows that Geosciences and Theoretical Physics division saw a decrease in number of papers published in conference proceedings, while Space Science division saw an increase in number of papers in conference proceedings from 1997 to 2006. There is an increase in Astronomy division's contribution in conference proceedings till 2005 with a sharp dip in 2006.

Table 2.4: Year wise pattern of Papers in Conference Proceedings from 1997-2006

YEAR	AAD	GSDN	SPA-SC	THE-PH
1997	9	15	0	15
1998	17	13	15	15
1999	13	11	2	11
2000	11	3	7	9
2001	14	4	6	1
2002	37	24	15	8
2003	20	17	2	6
2004	4	21	0	9
2005	29	15	0	6
2006	8	11	4	5
Total	162	134	51	85

Fig 2.4 : Year wise pattern of Papers in Conference Proceedings from 1997-2006

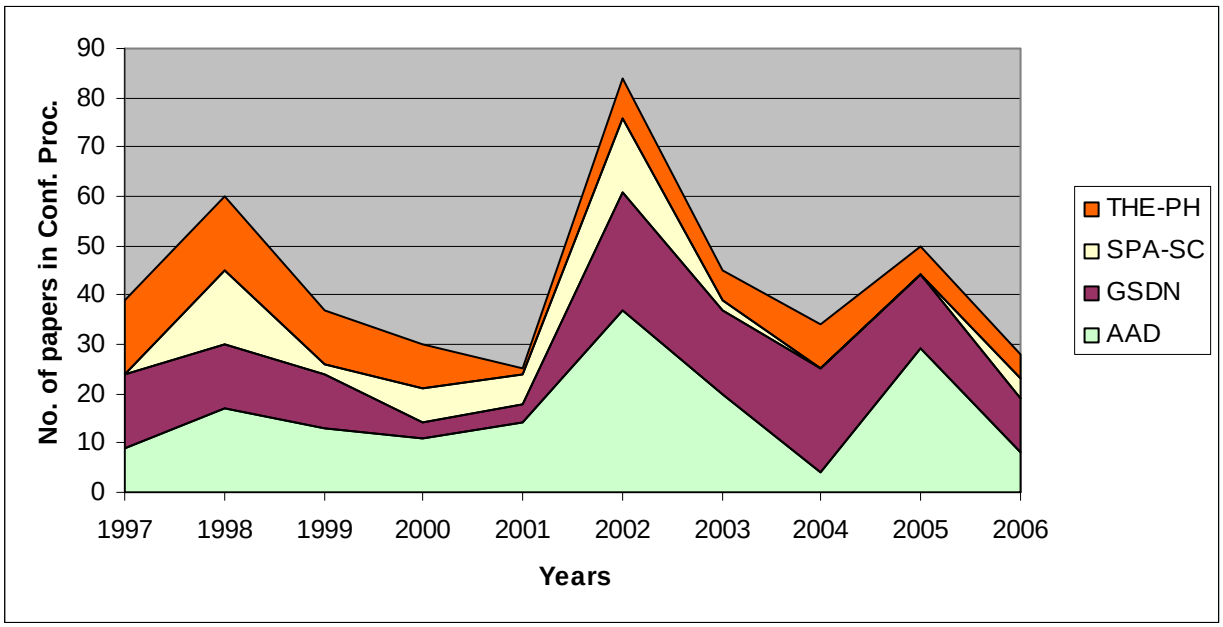
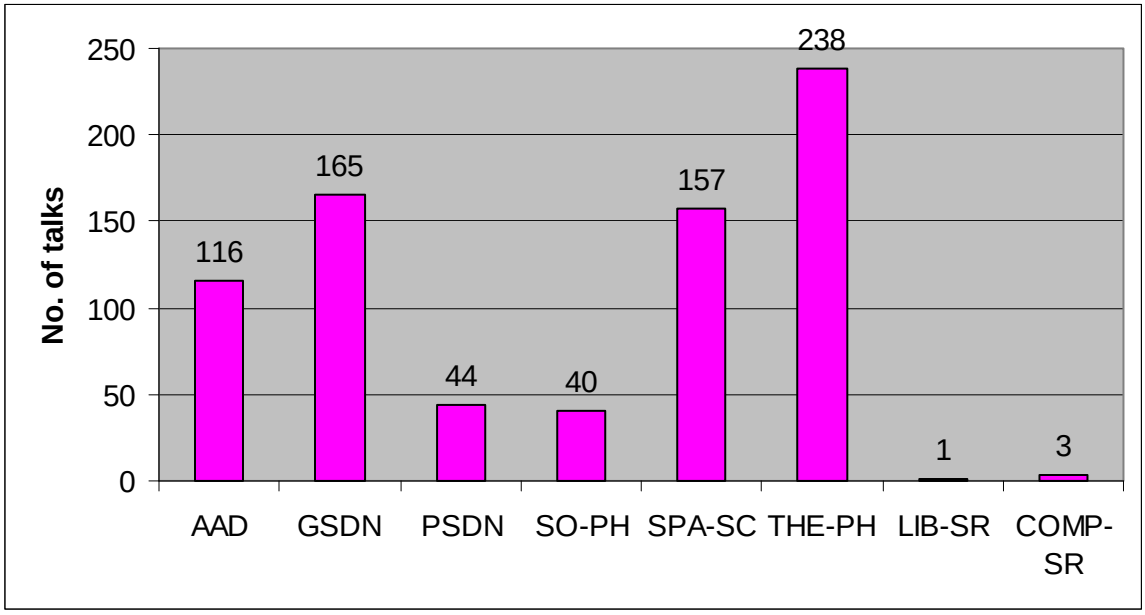


Table 2.5 and Figure 2.5 give the division wise break up of number of invited talks delivered by the scientists of PRL during 1997-2006. Out of the total of 764, THE-PH and GSDN top the list with 238 and 165 invited talks delivered respectively.

Table 2.5 : Division wise break up of Invited Talks delivered during 1997-2006

Division	No. of Invited Talks	%
AAD	116	15.18
GSDN	165	21.60
PSDN	44	5.76
SO-PH	40	5.24
SPA-SC	157	20.55
THE-PH	238	31.15
LIB-SR	1	0.13
COMP-SR	3	0.39
TOTAL	764	100

Fig 2.5 : Division wise break up of Invited Talks delivered during 1997-2006



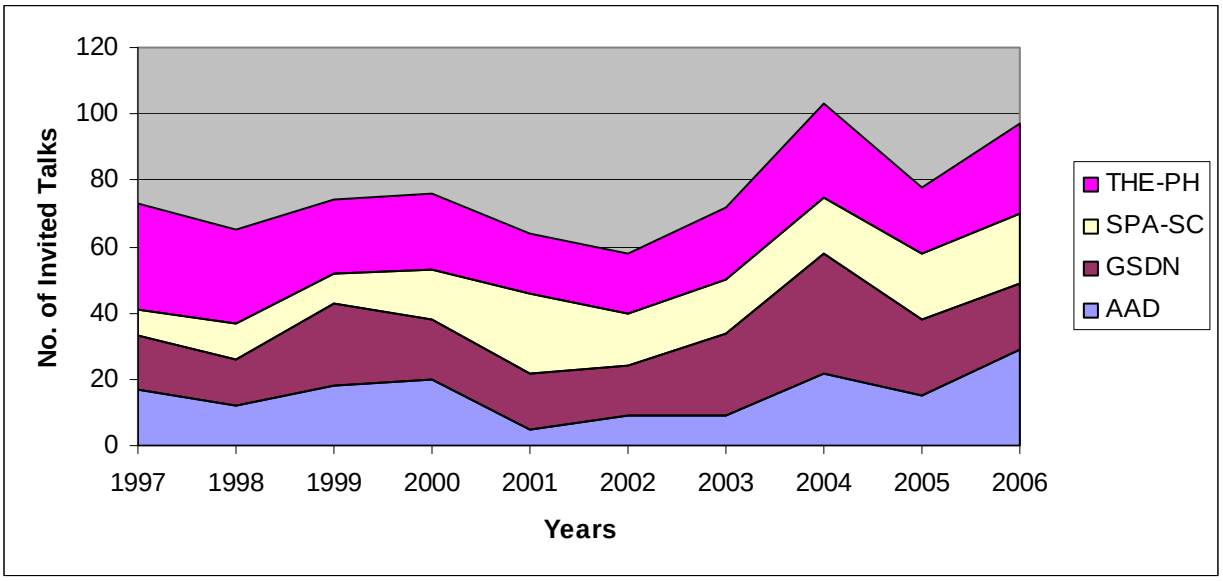
Note : AAD – Astronomy, GSDN – Geosciences, PSDN – Planetary Sciences, SO-PH – Solar Physics, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Table 2.6 and Figure 2.6 give the year wise pattern of number of invited talks delivered by PRL scientists of four major divisions from 1997 to 2006. Here again the data of SO-PH is included in Astronomy and that of PSDN is included in GSDN. The table shows that number of invited talks over the years have decreased for Theoretical Physics division, increased for Astronomy and Space Science divisions and increased marginally for Geosciences division.

Table 2.6 : Year wise pattern of Invited Talks delivered during 1997-2006

Division	AAD	GSDN	SPA-SC	THE-PH
1997	17	16	8	32
1998	12	14	11	28
1999	18	25	9	22
2000	20	18	15	23
2001	5	17	24	18
2002	9	15	16	18
2003	9	25	16	22
2004	22	36	17	28
2005	15	23	20	20
2006	29	20	21	27
Total	156	209	157	238

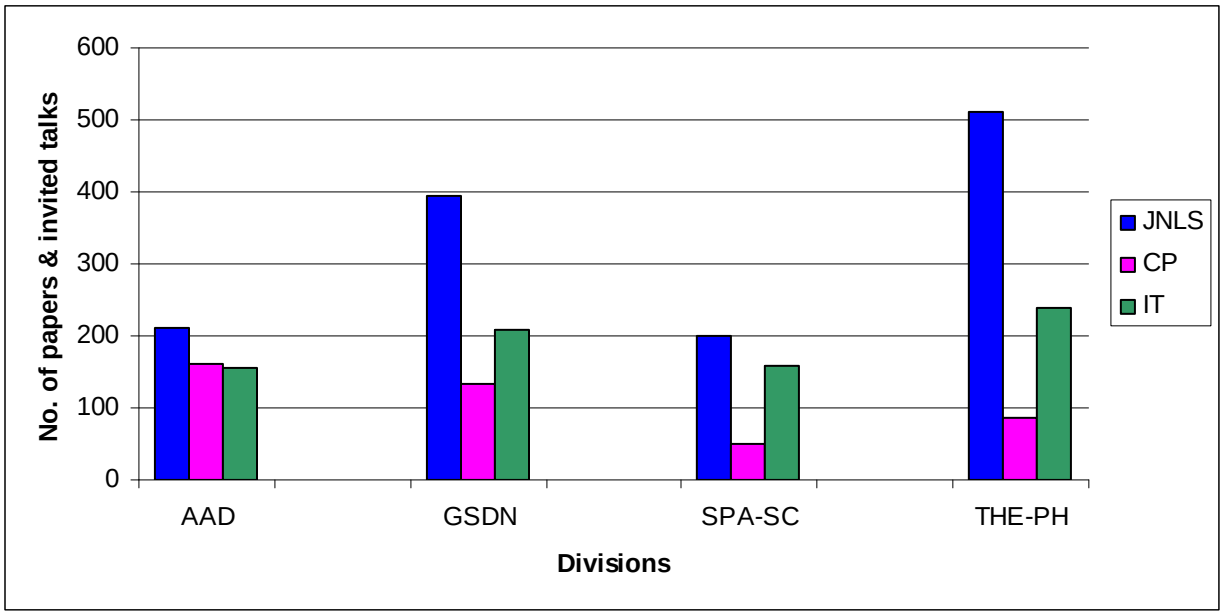
Fig 2.6 : Year wise pattern of Invited Talks delivered during 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Thus the division wise break up of all the research output components (papers published in journals, papers in conference proceedings and invited talks) reveals that Theoretical division is most productive in terms of papers published in journals (511) and invited talks delivered (238). Geosciences division comes second in all the three categories of the research output with 375 papers in journals, 134 papers in conference proceedings and 209 invited talks delivered. Astronomy division produced maximum number of papers in conference proceedings (162) but delivered least number of invited talks (156). SPA-SC produced least number of papers in journals (200) and in conference proceedings (51). Graphical representation of the consolidated research output of four major divisions is given in Figure 2.7 below.

Fig 2.7 : Division wise consolidated research output of PRL during 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Active Research Topics

After the broad division wise break up, it would be logical to take a look at the more specific subject headings under which the research was undertaken. The sample for identifying the research trends is papers published in journals (1318). The subject headings were arrived at by doing content analysis of the articles published in journals in each year and giving 2-3 keywords relevant to the main subject. Then each article was alotted a PACS number. As mentioned in chapter 3, PACS is Physics and Astronomy Classification Scheme, devised by American Institute of Physics. This data was merged for all the years and sorted in descending order in order to determine the number of articles published in each micro topic. Thus a PACS number of 96.3 indicates the micro topic - Moon, where in 96 referes to the Solar System which is a topic under broad subject heading of 90 - *Geophysics, Astronomy and Astrophysics*. Then the number of articles published in all the micro topics under a topic were added up. These were further merged to arrive at a broad subject area. Tables 2.7 to 2.20 give the number of papers published in journals under different subject headings.

Table 2.7 gives the number of articles published in journals (1318) under 10 broad subject areas out of which first eight are under the Theoretical Physics, ninth is interdisciplinary and tenth includes Geoscience, Space Science and Astronomy. This is because the PACS covers the theoretical physics most extensively as it was the first field of physics for which PACS was developed. Gradually Astronomy, Geosciences and Space Science subjects were added by AIP for classification and retrieval of articles in these fields.

Table 2.7 : Number of papers under broad subjects of PACS

PACS No.	Broad Subjects	No. of Papers	%
0	***General Physics***	**136**	10.32
10	***Physics of Elementary Particles And Fields***	**118**	8.95
20	***Nuclear Physics***	**32**	2.43
30	***Atomic And Molecular Physics***	**31**	2.35
40	***Electromagnetism, Optics, Classical Mechanics***	**143**	10.85
50	***Physics of Gases, Plasmas, Electric Discharges***	**43**	3.26
60-70	***Condensed Matter***	**12**	0.91
80	***Interdisciplinary Physics And Related Areas***	**57**	4.32
90	***Geophysics, Astronomy And Astrophysics***	**746**	56.60
	Total	**1318**	100.00

The table above shows that PACS Number 90 (Geophysics, Astronomy and Astrophysics) accounts for more than half of the total share of articles published in journals. Theoretical Physics subject field has been dealt with maximum depth (0-70) by PACS, as this scheme was devised to organise articles in Theoretical Physics. Out of the seven broad PACS subject headings in Theoretical Physics, ***Electromagnetism, Optics and Classical Mechanics*** attracted 143 (10.85%) papers, followed by ***General Physics*** with 136 (10.32 %) papers and ***Physics of Elementary Particles And Fields*** with 118 papers (8.95%).

Tables 2.8-2.16 gives the detailed picture of number of papers on various topics under each broad subject mentioned in Table 2.7.

Under the broad subject of ***General Physics***, 136 papers were published during 1997-2006 by PRL scientists. Out of these 136 papers, the top three topics which attracted maximum number of papers are *Quantum mechanics, field theories and special relativity* (66) followed by *Statistical physics, thermodynamics and nonlinear dynamics* (48) .

Table 2.8 : Number of papers under ***General Physics.***

PACS No.	Topics	No. of Papers
0	***General Physics***	**136**
1	*Communication, education, history and philosophy*	0
2	*Mathematical methods in physics*	3
3	*Quantum mechanics, field theories and special relativity*	66
4	*General relativity and gravitation*	13
5	*Statistical physics, thermodynamics, nonlinear dynamics*	48
6	*Metrology, measurements and laboratory procedures*	0
7	*Instruments, apparatus and components*	6

Table 2.9 gives the number of papers in different topics under ***Physics of Elementary Particles and Fields.*** In this group, the topic *Properties of Specific Particles* attracted the maximum number of papers (56) out of 118 papers published.

Table 2.9 : Number of papers under ***Physics of Elementary Particles and Fields***

PACS No.	Topics	No. of Paper
10	***Physics of Elementary Particles and Fields***	**118**
11	*General theory of fields and particles*	22
12	*Specific theories and interaction models*	22
13	*Specific reactions and phenomenology*	18
14	*Properties of specific particles*	56

Table 2.10 below shows that a total of thirty two papers were published in the broad subject of ***Nuclear Physics*** under which *Nuclear Structure* attracted 17 of papers in the ten year period of 1997-2006.

Table 2.10 : Number of papers under ***Nuclear Physics***

PACS No.	Topics	No. of Papers
20	***Nuclear Physics***	**32**
21	*Nuclear structure*	17
23	*Radioactive decay and in-beam spectroscopy*	1
24	*Nuclear reactions : general*	7
26	*Nuclear astrophysics*	3
28	*Nuclear engineering and nuclear power studies*	2
29	*Experimental methods and instrumentation*	2

Table 2.11 shows that ***Atomic and Molecular Physics*** attracted a total of 31 papers during 1997-2006 out of which 15 were published under the topic *Atomic Properties and interactions with photons* and 10 were published under *Atomic and molecular collision processes*.

Table 2.11 : Number of papers under ***Atomic and Molecular Physics***

PACS No.	Topics	No. of Papers
30	***Atomic and Molecular Physics***	**31**
31	*Electronic structure of atoms and molecules*	3
32	*Atomic properties and interactions with photons*	15
33	*Molecular properties and interactions with photons*	2
34	*Atomic and molecular collision processes*	10
37	*Mechanical control of atoms, molecules and ions*	1

Table 2.12 shows that 143 papers were published on the topic ***Electromagnetism, Optics, Acoustics and Fluid Dynamics***, out of which 134 were published on *Optics*. No papers were published on *Acoustics* and *Heat Transfer*.

Table 2.12 : Number of papers under ***Electromagnetism, Optics, Acoustics and Fluid Dynamics***

PACS No.	Topics	No. of Papers
40	***Electromagnetism, Optics, Acoustics & Fluid Dynamics***	**143**
41	*Electromagnetism, electron and ion optics*	8
42	*Optics*	134
43	*Acoustics*	0
44	*Heat Transfer*	0
47	*Fluid Dynamics*	1

Table 2.13 below shows that ***Physics of Gases & Plasmas*** attracted 43 papers during 1997-2006. It is interesting to note that the topic *Physics of Gases* did not attract a single paper during the study period.

Table 2.13 : Number of papers under ***Physics of Gases and Plasmas***

PACS NO.	Topics	No of Papers
50	***Physics of Gases and Plasmas***	**43**
51	*Physics of Gases*	0
52	*Physics of Plasmas and Electric Discharges*	43

Table 2.14 below shows that the broad subject of ***Condensed Matter*** attracted only 12 papers in the ten year period, clearly indicating that it is not an active area of research for PRL.

Table 2.14 : Number of papers under ***Condensed Matter***

PACS No.	Topics	No of Papers
60-70	***Condensed Matter***	**12**
61	*Structure of solids and liquids, crystallography*	2
62	*Mechanical and acoustical properties of condensed matter*	0
64	*Equations of state, phase equilibria and phase transitions*	2
65	*Thermal properties of condensed matter*	0
71	*Electronic structure of bulk materials*	1
74	*Superconductivity*	0
77	*Dielectrics, piezoelectrics and ferroelectrics*	1
78	*Optical properties, condensed matter*	6

Table 2.15 below shows that under the broad subject of ***Interdisciplinary Physics*** 57 papers were published during the 10 year period of 1997-2006 out of which 37 were published in *Physical Chemistry and* Ch*emical Physics*.

Table 2.15 : Number of papers under ***Interdisciplinary Physics***

PACS No.	Topics	No. of Papers
80	***Interdisciplinary Physics***	**57**
81	*Materials science*	1
82	*Physical chemistry and chemical physics*	37
83	*Rheology*	0
84	*Electronics, radiowave and microwave technology*	4
85	*Electronic and magnetic devices*	10
87	*Biological and medical physics*	2
89	*Other areas of applied and interdisciplinary physic*	3

Since PACS has grouped ***Geophysics, Astronomy and Atmospheric Sciences*** under one broad subject, the researcher thought it appropritate to give the break up of micro topics as indicated by the specific PACS number under each topic. Table 2.16 gives the break up

of topics under the broad subject group of ***Geophysics, Astronomy and Atmospheric Sciences.***

Table 2.16 : Number of papers under ***Geophysics, Astronomy and Astrophysics***

PACS No.	Topics	No. of Papers
90	***Geophysics, Astronomy And Astrophysics***	**746**
91	*Solid Earth Physics*	127
92	*Hydrospheric and Atmospheric Geophysics*	236
93	*Geophysical Observations, Instrumentation*	13
94	*Physics of The Ionosphere And Magnetosphere*	58
95	*Fundamental Astronomy And Astrophysics*	36
96	*Solar System, Planetology*	170
97	*Stars*	67
98	*Stellar Systems, Interstellar Medium, Universe*	39

As seen from the table above, *Hydrospherics and Atmospheric Geophysics* attracted the maximum number of papers (236) followed by *Solar System, Planetology* (170) and *Solid Earth Physics* (127) respectively.

Further classification of these topics into micro topics gives a clearer picture about thrust areas of research under this broad subject. As for example, Table 2.17 below shows that out of 127 papers on the topic of ***Solid Earth Physics***, 45 papers were published in the micro topic of *Geochronology* and 30 papers were published in micro topic of *Properties of Rocks and Minerals* .

Table 2.17 : Number of papers under ***Solid Earth Physics***

PACS No.	Micro Topics	No. of Papers
91	***Solid Earth Physics***	**127**
91.1	*Geodesy and Gravity*	1
91.25	*Geomagnetism and Paleomagnetism*	1
91.3	*Seisomology*	2
91.35	*Earth's Interior Structure and Properties*	7
91.4	*Volcanology*	3
91.45	*Tectonophysics*	7
91.5	*Structural geology*	18
91.6	*Properties Rocks And Minerals*	30
91.65	*Mineralogy and Petrology*	3
91.67	*Geochemistry*	8
91.7	*Information Related to Geologic Time*	2
91.8	*Geochronology*	45

Similarly Tables 2.18-2.24 give the break up of micro topics under the topics falling under the broad subject heading of Geophysics, Astronomy and Atmospheric Sciences (90). And Table 2.25 gives the overall picture of thrust areas of research carried out in PRL.

Table 2.18 below shows that the topic of ***Hydrospheric and Atmospheric Geophysics*** attracted 236 papers, out of which 114 papers were published on *Atmosphere Dynamics and Meteorology* and 70 papers were published on *Hydrology and Glaciology*.

Table 2.18 : Number of papers in under ***Hydrospheric and Atmospheric Geophysics***

PACS No.	Micro Topics	No. of Papers
92	***Hydrospheric And Atmospheric Geophysics***	**236**
92.05	*General aspects of oceanography*	1
92.1	*Physical oceanography*	3
92.2	*Chemical and biological oceanography*	26
92.3	*Paleoceanography*	4
92.4	*Hydrology and glaciology*	70
92.6	*Atmosphere dynamics and meteorology*	114
92.7	*Global climate change*	18

Table 2.19 below gives the information that 13 papers were published under ***Geophysical Observations, Instrumentation*** out of which 9 were in *Techniques and Instruments for Geophysical Research.*

Table 2.19 : Number of papers under ***Geophysical Observations, Instrumentation***

PACS No.	Micro Topics	No of Papers
93	***Geophysical Observations, Instrumentation***	**13**
93.3	*Information related to geographical regions*	4
93.85	*Instruments and techniques for geophysical research*	9

Table 2.20 below gives the break up of the micro topics under the topic ***Ionosphere and Magnetosphere*** and shows that maximum number of papers (49) were published on *Physics of the Ionosphere* in the 10 year study period which goes on to show that almost 5 papers were published every year on this topic indicating that it was an active research area.

Table 2.20 : Number of papers under ***Ionosphere and Magnetosphere***

PACS No.	Micro Topics	No. of Papers
94	***Ionosphere And Magnetosphere***	**58**
94.05	*Space plasma physics*	4
94.2	*Physics of the ionosphere*	49
94.3	*Physics of the magnetosphere*	5

Table 2.21 gives the break up of active research micro topics under the topic Fundamentsl Astronomy and Astrophysics. Under this topic, maximum number of papers (25) were on Astronomical Instrumentation during 1997-2006.

Table 2.21 : Number of papers under ***Fundamental Astronomy and Astrophysics***

PACS No.	Micro Topics	No. of Papers
95	***Fundamental Astronomy And Astrophysics***	**36**
95.1	*Fundamental astronomy*	7
95.3	*Fundamental aspects of astrophysics*	2
95.55	*Astronomical and space research instrumentation*	25
95.85	*Astronomical observations*	2

Under the topic of ***Solar System and Planetology***, maximum papers were published in *Solar Physics* (82) followed by *Solar system objects, Meteorites* (63). It is interesting to note that first article in the micro topic of 'Moon' was published in 2002 indicating that research on Chandrayan I which was launched in October 2008 had begun way back in 2002.

Table 2.22 : Number of papers under ***Solar System, Planetology***

PACS No.	Micro Topics	No. of Papers
96	***Solar System, Planetology***	**170**
96.12	*Planetology of solid surface planets*	1
96.15	*Planetology of fluid planets*	1
96.2	*Moon*	5
96.25	*Planetology of comets and small bodies*	12
96.3	*Solar system objects, meteorites*	63
96.5	*Interplanetary physics*	6
96.6	*Solar physics*	82

Table 2.23 below shows that ***Stars*** attracted 67 papers out of which *Variable and Peculiar Stars* attracted 19 papers followed by 17 papers on the miro topic of *Normal Stars*.

Table 2.23 : Number of papers under ***Stars***

PACS No.	Micro Topics	No. of Papers
97	***Stars***	**67**
97.1	*Stellar characteristics and properties*	16
97.2	*Normal stars*	17
97.3	*Variable and peculiar stars*	19
97.6	*Stellar evolution (including black holes)*	9
97.8	*Binary and multiple stars*	6

Table 2.24 below gives data that under the topic of ***Stellar systems, Interstellar Medium and Universe***, 39 papers were published, out of which 14 papers were published in *Cosmology* and 12 papers in *Quasars and Active Galaxies.*

Table 2.24 : Number of papers under ***Stellar Systems, Interstellar Medium and Universe***

PACS No.	Micro Topics	No. of Papers
98	***Stellar Systems, Interstellar Medium, Universe***	**39**
98.2	*Stellar clusters and associations*	1
98.35	*Characteristics and properties of milky way galaxy*	3
98.38	*Interstellar medium and nebulae in milky way*	2
98.54	*Quasars, active or peculiar galaxies, objects and systems*	12
98.58	*Interstellar medium and nebulae in external galaxies*	3
98.62	*Characteristics and properties of external galaxies objects*	2
98.7	*Unidentified sources of radiation outside the solar system*	2
98.8	*Cosmology*	14

To identify the micro topics which attracted most number of publications, a list was prepared by arranging all micro topics (thrust areas) in an descending order of number of publications. Table 2.25 shows the list of most active research areas (micro topics) on which papers were published during 1997-2006.

The table below reveals that during the study period of 1997-2006, in Astronomy, most active research topics were *Solar Physics (*82 papers)*, Variable and Peculiar Stars* (19 papers) and *Normal Stars* (17 papers).

Thrust areas of research in Geosciences and Planetary Sciences are *Hydrology and Glaciology (70 papers), Solar System Objects*, *Meteorites (*63 papers) and *Geochronology (*45 papers).

Table 2.25 : Most active research topics during 1997-2006

PACS No.	Micro Topics	No. of Papers
92.6	Atmosphere dynamics & meteorology	114
96.6	Solar physics	82
42.5	Quantum optics	80
92.4	Hydrology and glaciology	70
96.3	Solar system objects, Meteorites	63
94.2	Physics of the ionosphere	49
91.8	Geochronology	45
14.6	Leptons	44
3.65	Quantum mechanics	41
82.33	Reactions in various media	36
91.6	Physical properties of rocks and minerals	30
5.45	Nonlinear dynamics and chaos	28
92.2	Chemical and biological oceanography	26
95.55	Astronomical, Space research instrumentatio	25
52.27	Basic studies of specific kinds of plasmas	21
97.3	Variable and peculiar stars	19
11.3	Symmetry and conservation laws	18
91.5	Structural geology	18
92.7	Global climate change	18
42.25	Wave optics	17
97.2	Normal stars	17

The thrust areas in Space Sciences are *Atmospheric Dynamics and Meterology (114 papers)* followed by Physics of *Ionosphere (49 papers)*.

*Quantum Optics (*80 papers), *Leptons* (44 papers) and *Quantum Mechanics (*41 papers) were the most active topics of research in Theoretical Physics.

The researcher hopes that this information will be useful to the institute's decision makers for future research planning.

Productivity of Scientists

Research output of scientists is affected by many factors such as age, education, status, the subject field and funds available for research. Stephan & Levin (1993) showed that there is evidence that, generally scientists produce less output as they age. They also concluded that age – publishing profiles differ across the subject fields. In physical sciences, peak output is generally produced by the young scientists. The result obtained in one of the studies carried out by Jacobs (2001) showed that there is a significant difference between the numbers of papers published by the scientists with doctorates as compared to those without PhDs. There is also a relationship between the importance of the scientist and the number of papers he/she has published during his/her life. According to Price (1986) prestige seems to be one of the driving forces that encourages scientists to publish profusely. That is why promotion remains the driving force behind faculty research and publication, as this upgrades the faculty members in status and pay. Pelz & Andrews (1966) showed that teaching and administrative positions taken up as advancement in career facilitate publishing.

Tables 2.26-2.29 give the list of most prolific scientists in terms of papers in journals, papers in conference proceedings and invited talks delivered.

Table 2.26 gives the list of top most prolific researchers who have published more than 20 papers in journals during the years 1996-2007. Prof. G. S. Agarwal, Director PRL from 1996 to 2005 tops this list with 137 papers, followed by Prof. A. K. Singhvi with 61 papers and Prof Utpal Sarkar with 54 papers published in journals.

Table 2.26 : Most prolific researchers - for papers published in journals

Division	Author	No. of papers
THE-PH	Agarwal G S.	137
GSDN	Singhvi A. K.	61
THE-PH	Sarkar U	54
GSDN	Ramesh R.	50
GSDN	Bhandari N	46
GSDN	Bhattacharya S. K.	42
THE-PH	Kota V. K. B.	42
SPA-SC	Chandra H.	33
THE-PH	Panigrahi P. K.	33
AAD	Ashok N. M.	31
THE-PH	Rao N. N.	31
THE-PH	Rindani S. D.	31
THE-PH	Joshipura A. S.	30
SPA-SC	Lal S.	30
GSDN	Sarin M. M.	30
SPA-SC	Jayaraman A.	29
GSDN	Gupta S. K.	27
PSDN	Murty S. V. S.	27
THE-PH	Mohanty S.	26
GSDN	Somayajulu B. L. K.	26
AAD	Ganesh S.	25
PSDN	Goswami J. N.	25
AAD	Vats H. O.	23
THE-PH	Prasanna A. R.	22
SPA-SC	Acharya Y. B.	21
GSDN	Krishnaswami S.	21
GSDN	Ray J. S.	21

Table 2.27 gives the indication of most prolific researchers to publish more than 10 papers in conference proceedings. Out of these eight are from Astronomy division, five from SO-PH, three each from THE-PH and GSDN, two from SPA-SC and one from PSDN.

Table 2.27 : Most prolific researchers – for papers in conference proceedings

Division	Author	No. of papers
GSDN	Gupta S. K.	25
AAD	Ashok N. M.	21
AAD	Ganesh S.	21
AAD	Baliyan K. S.	20
GSDN	Ramesh R.	20
PSDN	Murty S. V. S.	19
AAD	Vats H. O.	19
AAD	Anandarao B. G.	18
AAD	Joshi U. C.	18
SO-PH	Tripathy S. C.	18
AAD	Banerjee D. P. K.	17
SPA-SC	Jayaraman A.	16
SO-PH	Ambastha A.	14
SPA-SC	Chandra H.	14
THE-PH	Kota V. K. B.	14
THE-PH	Dave H.	13
THE-PH	Agarwal G. S.	12
SO-PH	Bhatnagar A.	12
AAD	Chandrasekar T.	11
SO-PH	Jain K.	11
SO-PH	Jain R.	11
GSDN	Somayajulu B. L K.	11

Thus maximum number of papers in conference proceedings are contributed by Prof S K Gupta (25), Prof N M Ashok (21) and Dr S Ganesh (21).

Table 2.28 gives the names of scientists with more than 10 invited talks to their credit.

Table 2.28 : Most prolific researchers – for Invited talks delivered

Division	Researcher	No. of Invited Talks
THE-PH	Agarwal G. S.	64
SPA-SC	Jayaraman A	46
SPA-SC	Lal S	39
GSDN	Singhvi A K	35
GSDN	Ramesh R	31
SO-PH	Ambastha A	23
PSDN	Goswami J N	22
GSDN	Sarin M M	21
THE-PH	Kota V. K. B.	20
THE-PH	Dave H	19
AAD	Joshi U. C.	19
THE-PH	Rao N. N	16
AAD	Anandarao B. G.	15
AAD	Baliyan K. S.	15
THE-PH	Panigrahi P K	15
SPA-SC	Chandra H	14
SPA-SC	Sekar R	14
GSDN	Bhandari N.	13
PSDN	Murty S. V. S.	13
SO-PH	Srivastava N	13
SO-PH	Jain R.	12
SO-PH	Venkatakrishnan P	12
THE-PH	Amritkar R. E.	11
AAD	Janardhan P	11
THE-PH	Sarkar U	11
AAD	Vats H O	11

Out of these top researchers, seven are from THE-PH, five are from AAD, four each from GSDN, SO-PH and SPA-SC, and two from PSDN.

Table 2.28 above shows that Prof G S Agarwal from THE-PH division has delivered maximum (64) invited talks during the period 1997-2006 followed by Prof Jayaraman from SPA-SC division with 46 invited talks. Prof Agarwal is also the most prolific researcher with 137 papers published in journals to his credit. This finding confirms De Solla Price's remark in his book 'Little Science Big Science' (1969), that 'productivity breeds productivity'.

However, if we consolidate all three kinds of research output considered in this study, following list emerges of top scientists of PRL with more than 30 papers and invited talks put together. Prof. G. S. Agarwal tops the list with 213 papers plus talks, followed by Prof. R. Ramesh with 101 items and Prof. A. K. Singhvi with 96 items to their credit during the period of study.

It is interesting to note that in addition to being such prolific researchers, many of the scientists listed below held adminsitrative positions too. Prof. G. S. Agarwal was the Director of PRL from 1995-2005, Prof Krishnaswami was the Director from 2005-06 and Prof J N Goswami is the Director from 2006. Prof S K Bhattacharya was the Dean during 2004-07 and Prof A K Singhvi was the dean during 2007-10. Besides these, most of the other scientists also held the position of chairman of their respective division during different years of the study period.

Table 2.29 : Most prolific researchers during 1997-2006 with more than 30 papers in journals, conference proceedings and invited talks

Division	Name	No of Papers
THE-PH	Agarwal G S.	213
GSDN	Ramesh R	101
GSDN	Singhvi A K	96
SPA-SC	Jayaraman A	91
SPA-SC	Lal S	79
THE-PH	Kota V. K. B.	76
GSDN	Bhandari N	69
THE-PH	Sarkar U	65
SPA-SC	Chandra H	61
GSDN	Murty S. V. S.	59
AAD	Vats H O	53
AAD	Ashok N. M.	52
GSDN	Gupta S. K.	52
GSDN	Sarin M M	51
THE-PH	Panigrahi P K	48
GSDN	Goswami J N	47
THE-PH	Rao N. N	47
AAD	Ganesh S.	46
GSDN	Bhattacharya S. K.	42
THE-PH	Rindani S D	41
SO-PH	Ambastha A	37
AAD	Joshi U. C.	37
GSDN	Somayajulu B. L K.	37
AAD	Baliyan K. S.	35
AAD	Anandarao B. G.	33
THE-PH	Dave H	32
SPA-SC	Acharya Y. B.	31

Lotka's Law of Scientific Productivity

Having collected the data of research output of PRL scientists, the researcher thought it worth while to check out whether productivity of PRL scientists conforms to the Lotka's Law of Scientific Productivity.

Alfred J Lotka (1926) studied author productivity patterns and developed one of the main laws in bibliometrics. He observed that in a given area of science there are a lot of authors who publish only once, while a small group of prolific authors contribute a large number of publications. This premise is the basis of Lotka's Law also commonly known as the 'inverse square law' for author productivity. This law uses the number of authors contributing one paper as the base number and goes on to predict the number of authors contributing 2, 3, 4, 5, papers and so on using the formula

$$y_x = c * 1/x^2$$

Where y_x is the number of authors contributing x papers and c is the number of authors contributing one paper.

One condition to arrive at a list of prolific authors is to take a time frame such that authors have opportunity to publish more than once. Generally a ten year period is considered to be reasonable. As the period of the present study is also 10 years, the researcher thought it appropriate to look into this aspect of a bibliometric study too. The sample of 1318 articles published in journals was used to see whether the sample follows the Lotka's Law. These 1318 articles have been contributed by 622 authors out of which 333 authors have contributed a single paper in journals during 1997-2006. Using the Lotka's law of productivity, authors contributing two papers would be

$$Y_2 = 333 * 1/2^2$$

$$= 333/4$$

$$= 83$$

In the present study sample there are 75 authors contributing two papers during the 10 year period of study. Similarly, according to Lotka's law there would be 37 authors contributing 3 papers. Actually there are 28 authors contributing 3 papers. Till this point, the present study can be considered to conform to the Lotka's Law. However, for authors contributing 4 papers the actual figure and those derived from the law are too far apart – according to the Lotka's law there should be 21 authors contributing 4 papers while actually there are 40 authors contributing 4 papers. But 5 paper data (15) nearly matches with the Lotka figure of 13 authors contributing 5 papers, number of authors contributing 6 papers is 9 according to Lotka's Law, while actually in the study sample it is 19 authors contributing 6 papers.

Table 2.30 : Non-conformation of Lotka's Law

No. of Papers	Authors (actual)	Authors (Lotka)
1	333	333
2	75	83
3	28	37
4	40	21
5	15	13
6	19	9
7	20	7
8	9	5
9	7	4
10	5	3

The data in the above table indicates that the present study conforms to the Lotka's Law of scientific productivity only partially (up to 3 papers). This could be due to the fact that in the present study, each collaborative author get the count of one paper instead of giving credit to only the first author or giving proportionate credit according to the number of collaborative authors. A few earlier studies (Gupta, 1987) and (Nwagwu, 2006) also found that Lotka's Law did not hold true in their studies.

Summary of results

- The division wise break up of all the research output components (papers published in journals, papers in conference proceedings and invited talks) reveals that Theoretical division is most productive in terms of papers published in journals (511) and invited talks delivered (238). Geosciences division comes second in all the three categories of the research output with 375 papers in journals, 134 papers in conference proceedings and 209 invited talks delivered. Astronomy division produced maximum number of papers in conference proceedings (162) but delivered least number of invited talks (156). SPA-SC produced least number of papers in journals (200) and in conference proceedings (51).
- The content analysis of the articles published in journals and the use of PACS to alott keywords helped to identify the thrust areas of research carried out in PRL. Thrust areas in Astronomy are *Solar Physics (*82 papers)*, Variable and Peculiar Stars* (19 papers) and *Normal Stars* (17 papers). Thrust areas of research in Geosciences and Planetary Sciences are *Hydrology and Glaciology (70 papers), Solar System Objects*, *Meteorites (*63 papers) and *Geochronology (*45 papers). In Space Sciences, maximum number of papers (114) were published on *Atmospheric Dynamics and Meterology* followed by *Ionosphere (*49 papers) and in Theoretical Physics maximum number of papers were published on *Quantum Optics (*80 papers), *Leptons* (44 papers) and *Quantum Mechanics (*41 papers). The researcher hopes that this information will be useful to the institute's decision makers for future research planning.
- The broad subject of ***Condensed Matter*** attracted only 12 papers in the ten year period clearly indicating that it is not an active area of research for PRL. No research was done on the topics *Acoustics*, *Heat Transfer, Physics of Gases* and *Rheology*.
- The sample of this study does not completely follow the Lotka's Law of scientific productivity.

- It is interesting to note that many of the prolific researchers held senior adminsitrative positions too. This confirms the earlier studies carried out by Pelz and Andrews (1976) and Price (1986) that motivation to publish comes from recognition and prestige.

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CHAPTER 6

CITATION PATTERN OF THESES SUBMITTED BY PRL STUDENTS

In recent years, study of research has become an important activity for many universities and research institutes. The most reliable way to know the contribution of research to the world knowledgebase is through publication and citation statistics. The research papers and doctoral theses are the instruments through which results of the research are communicated to outside world. Both these scholarly publications conclude with the list of references. The study of these references (citations) gives an idea about the development of any research topic or a researcher and also indicates the kind of literature referred by the researchers.

In one of the early citation studies, Gross and Gross (1927), discovered that very few journals were cited frequently in the *Journal of the American Chemical Society*, while many journals were only cited once. This observation helped the librarians to build the serial collection such that libraries are able to fulfill most of the needs of the users with a small amount of journals.

The last two chapters dealt with the research output in the form of publications in journals, conference proceedings and invited talks delivered by the scientist of PRL. The present chapter analyses another form of research output – Theses - of the doctoral students of PRL during 1997-2006. It does the citation analysis of the bibliographies present in the end of theses submitted by the Ph. D. students.

At this juncture, it would help the reader if the few terms used are reiterated briefly. Citation analysis is a practical tool to evaluate the library's collection in meeting the

information needs of its users. It is particularly useful because of the interdisciplinary nature of research these days and the heavy reliance on journals. Information obtained about journals not owned can be used in collection management decisions in the future. If the need arises to make cuts to serials budgets and librarians are forced to cancel titles, this data can be used to find the least cited material. This method may also be used if the library needs money to purchase the archives of more heavily used journals (La Bonte, 2005).

Another term which requires elaboration is Dissertation or thesis. Thesis is a document submitted in support of candidature for a degree or professional qualification presenting the author's research and findings. Boyer (1973) describes it as "the capstone to a formal academic training process." Though the doctorate has existed since the Middle Ages, it was only at the beginning of the 19th century that the Ph. D. degree became a diploma associated to the production of original scientific research and the training of new researchers (Lariviere, 2008). Barry (1997) adds that successful doctoral students tend to be "comprehensive and up to date in reviewing the literature." Consequently, their dissertations provide a large amount of bibliographic information useful not only to other researchers but to librarians as well. It gives a pointer to the collection being used by the doctoral students. Keeping this in mind, in addition to the fact that theses comprise an important component of the research output of a research institute, the researcher undertook the study of the doctoral theses submitted by PRL students during 1997-2006.

The present chapter aims to find the change in the citing pattern over the years from 1997 to 2006 for print and electronic documents. It also identifies the most preferred type of resource used by the doctoral students at PRL – journal articles, books, reports, proceedings, etc. The data available is used to see whether the ratio of subscribed to non-subscribed journals remained the same in the 10 year period and to identify the most used journals in each subject division.

Procedure used for citation analysis

By 2001 many of the publishers had started providing electronic version free with print journals and Open Access documents had also started appearing on the horizon. The access to the electronic versions of many journals was provided by giving hyperlinks through the PRL Library homepage. As mentioned in chapter three, the period of the study of 10 years (1997-2006) has been chosen due to the fast changing technological developments (multimedia, multi-formats) in scholarly communications. The study took into consideration this change and divided the 10 year period into two slabs – pre ejournal (1997-2000) and ejournal (2001-2006) periods and tries to find out what effect this transition had on the citing pattern in the doctoral theses.

The Annual Reports for the years 1997-2006 - the basic authentic resource yielded the information that sixty eight theses were submitted during the 10 year study period. No theses were submitted in 2003. These 68 theses comprised the sample of the study. The bibliographies compiled at the end of the doctoral theses have been studied to find out the type of resources being used – books, journal articles, proceedings of a conference, monographs, reports, doctoral theses, etc.

Bibliography sections were photocopied from each of the 68 theses. Information extracted from each included doctoral student's name, year of graduation, year of cited work, journal title of each citation, other type of resources like books, reports, proceedings, monographs, theses, etc. The journal names were then tagged for 'Subscribed title' or 'Non-subscribed title'. The source for the information was the holdings data of the Library. The files of all the theses in each year were combined, so as to see the pattern of 'subscribed or non-subscribed journals in each year.

The entire sample was also classified as 'Print' and 'Electronic' documents. The source for this information was subscription invoices and license agreements of the publishers. Care was taken to consider the backfiles access given by the publisher at the time of subscription. Under electronic documents were CDs and online documents. The study tries to find out if any pattern emerges as regards the use of print and electronic resources from

1997 through 2006. To find out most used unique titles, the files were merged according to the division so as to get the count of journals referred, in each subject field.

Use of Library Resources

The 68 theses submitted during 1997-2006 yielded a total of 10,864 citations. Thus on an average each thesis contained 160 references. Table 3.1 shows that there is a marked increase in number of references in the e-journal period. The reason could be the ease of use of e-re sources as compared to print resources.

Table 3.1 : Number of Citations per thesis

Years	Total no. of citations	No. of Theses	No. of Citations/thesis
1997-2000	4250	29	147
2001-2006	6614	39	170

Tables 3.2 – 3.10 indicate the pattern of use of resources by the PRL doctoral students for their research work.

Electronic vs. Print Resources

Table 3.2 gives the use of electronic vs. print documents during 1997-2000. During this period e-resources had just started appearing on the web and print resources dominated the scene completely as is evident with 2.16% electronic resources and 97.84% print resources being cited by the students. Fig 3.1 and Fig 3.2 is the graphical representation of overall use and pattern of usage through the years 1997-2000 respectively.

Table 3.2 : Use of documents : Electronic vs. Print during 1997-2000

Document	1997	1998	1999	2000	Total	%
Electronic	16	0	1	75	92	2.16
Print	1148	1752	782	476	4158	97.84

Fig 3.1 : Use of documents - Electronic vs. Print during 1997-2000

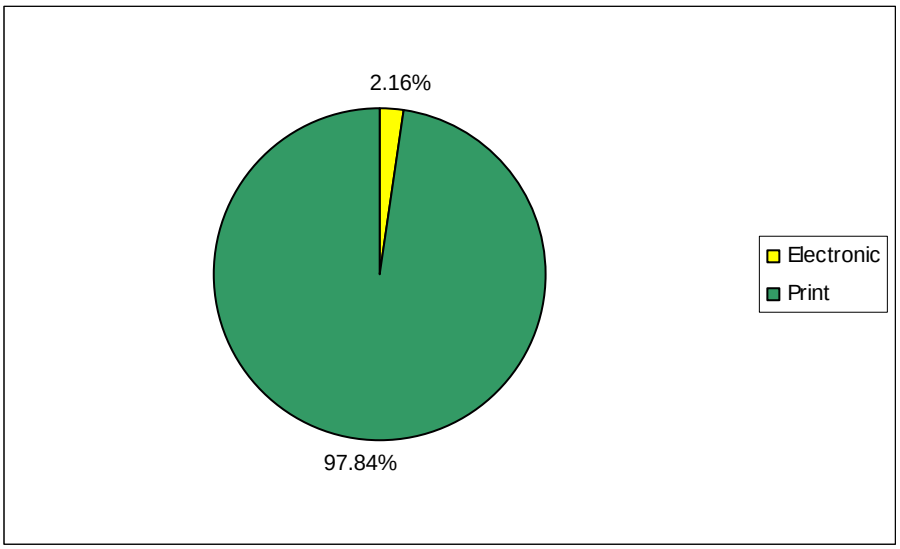


Fig 3.2 : Year wise pattern of use of documens – Electronic vs. Print from 1997-2000

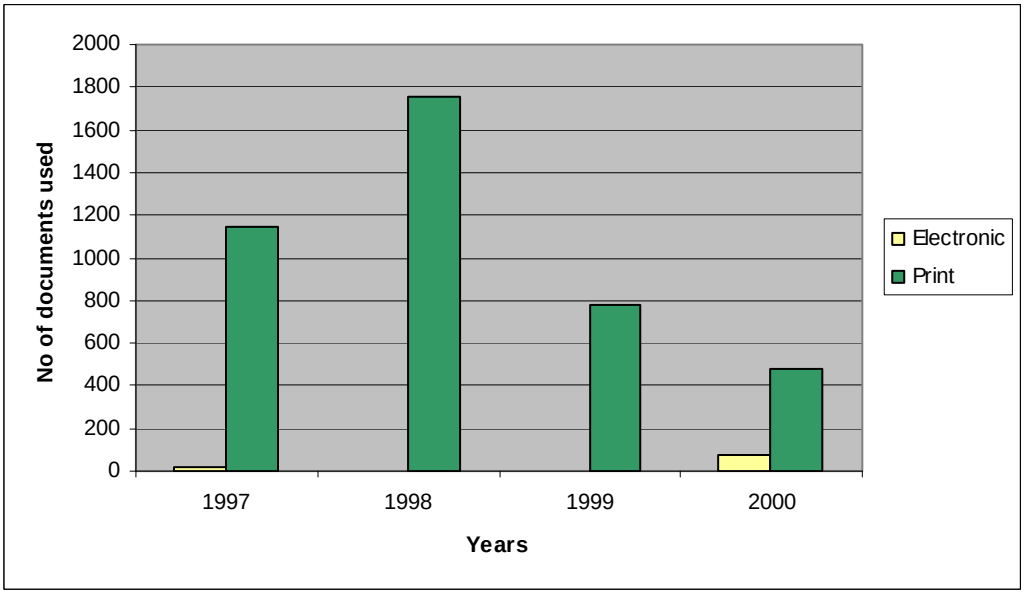


Table 3.3 and Figures 3.3 and 3.3a give the break up of electronic vs. print documents cited by the students during 2001-2006. There is a stark difference between the two time period slabs. The electronic documents now take up 33.76% and print documents take up 66.24% share from the total number of citations.

Table 3.3 : Use of documents : Electronic vs. Print during 2001-2006

Document	2001	2002	2004	2005	2006	Total	%
Electronic	243	306	1023	336	325	2233	33.76
Print	1488	409	1559	538	387	4381	66.24

Fig 3.3 : Use of documents – Electronic vs. Print during 2001-2006

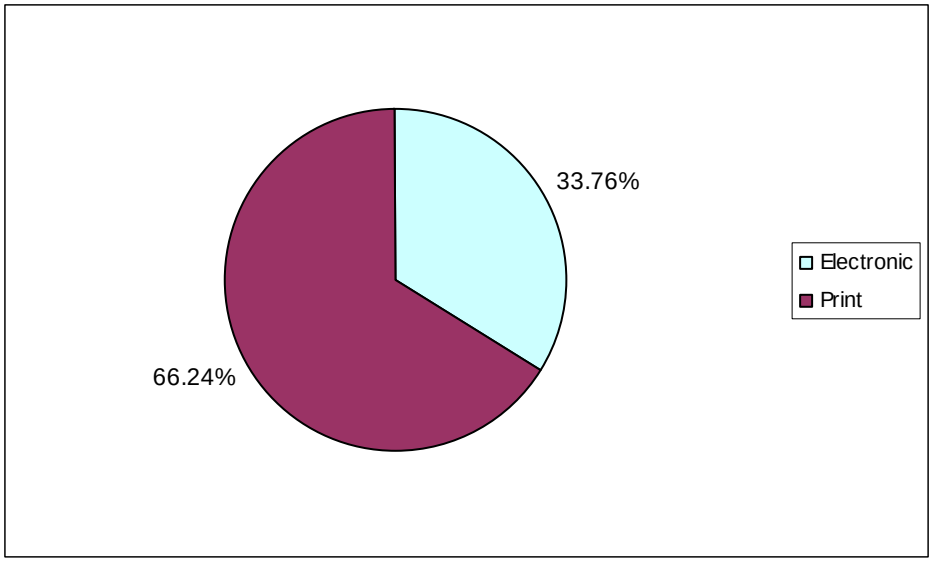
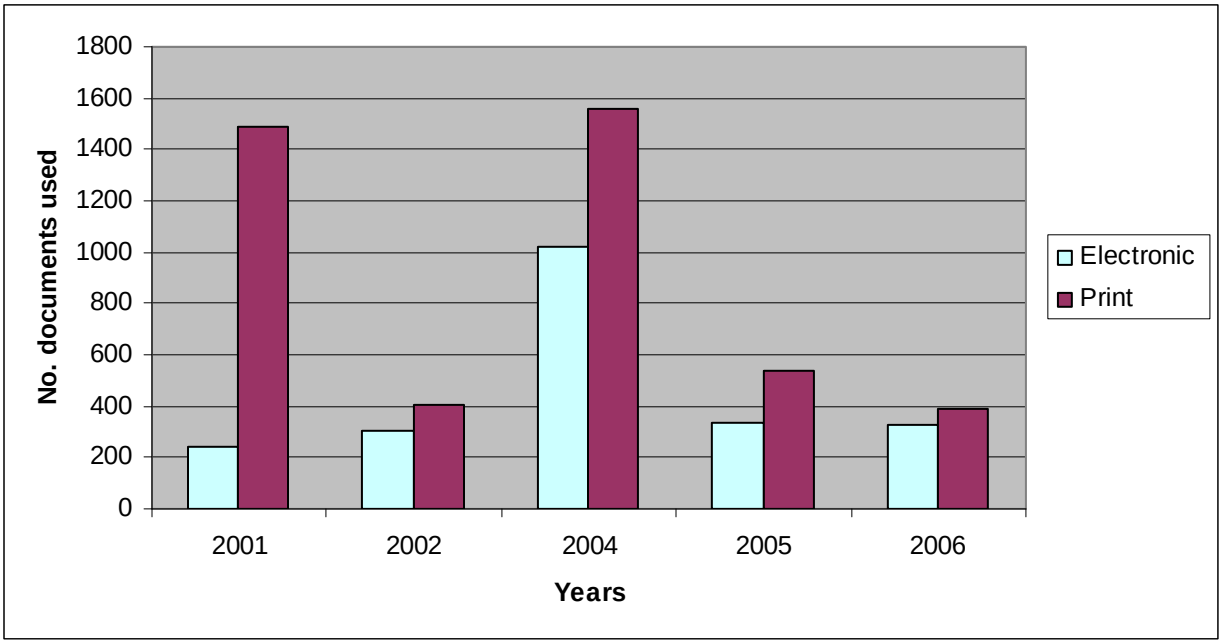


Fig 3.3a : Year wise pattern of use of documents – Electronic vs. Print from 2001-2006



It is evident from the above figure that the difference between the use of Electronic and Print resources is decreasing over the years 2001-2006 and by 2006 it had decreased so much that they seem to be almost equal.

Types of Documents cited

Table 3.4 and Figures 3.4 and 3.4a give the break up of different types of documents cited by the students during 1997-2000. Journals form the major chunk with 84.05% followed by Books (10.78 %) and Other Documents (5.18%).

Table 3.4 : Use of different types of documents during 1997-2000

Documents	1997	1998	1999	2000	Total	%
Journals	927	1531	652	462	3572	84.05
Books	170	142	81	65	458	10.78
Other Docs.	67	79	50	24	220	5.18

Fig 3.4 : Use of different types of documents during 1997-2000

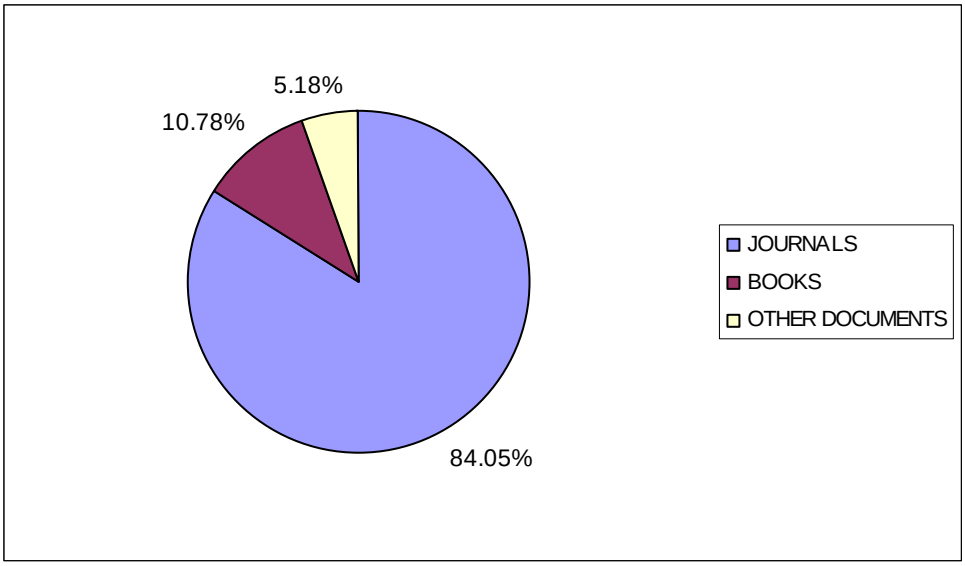


Fig 3.4a : Year wise pattern of use of types of documents during 1997-2000

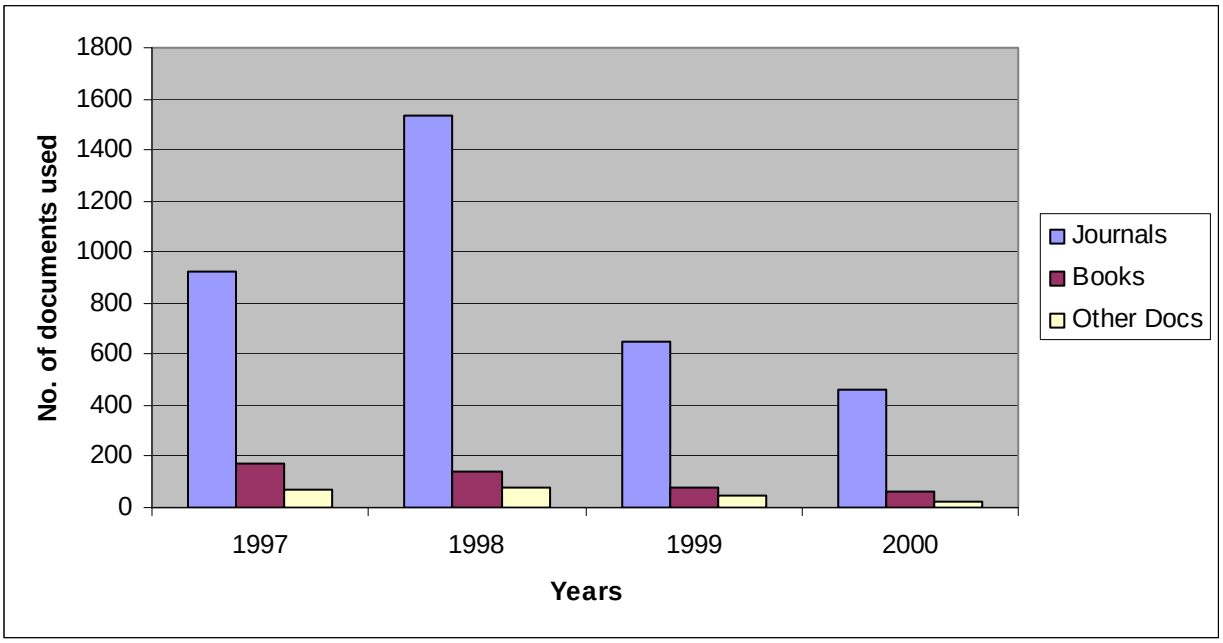


Table 3.5 and Figures 3.5 and 3.5a give the data on types of documents cited during 2001-2006. It shows that there is a slight increase in proportion of books being cited in 2001-2006 (10.89% as against 10.78% in 1997-2000) and slight decrease in Journals and Other Documents (from 84.05% to 84.03% and 5.18% to 5.08% respectively).

Table 3.5 : Use of different types of documents during 2001-06

	2001	2002	2004	2005	2006	Total	%
Journals	1456	612	2187	728	575	5558	84.03
Books	165	55	300	98	102	720	10.89
Other Docs.	110	48	95	48	35	336	5.08

Fig 3.5 : Use of different types of documents during 2001-2006

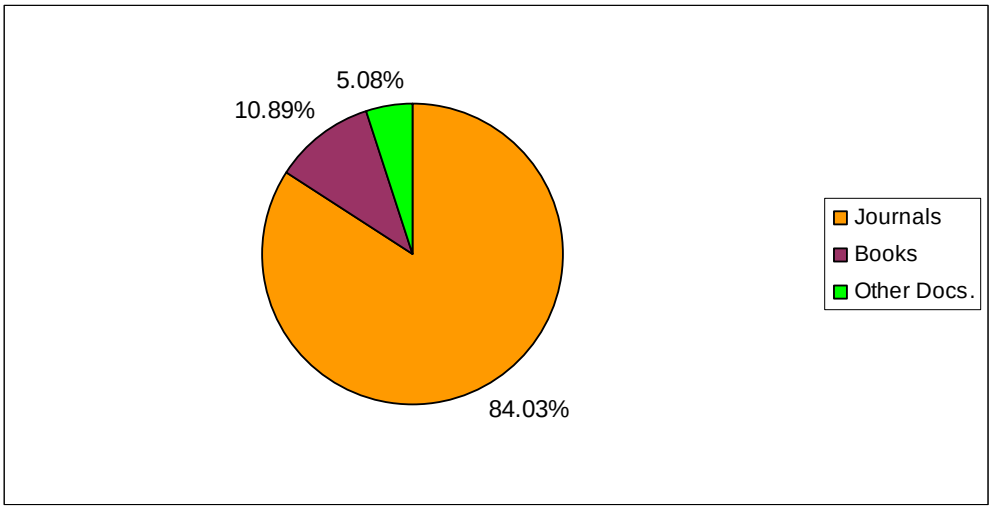
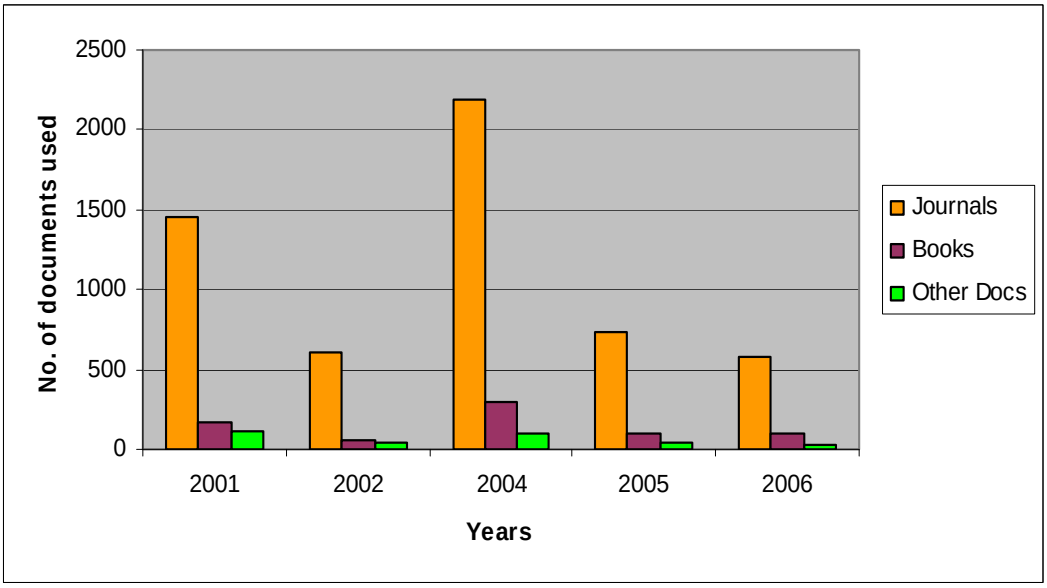


Fig 3.5a : Year wise pattern of use of different types of documents from 2001-2006



The above figures clearly indicate that in both the time slabs, the percentage of journals, books and other documents has remained constant at about 84%, 11% and 5% respectively. This result confirms the findings of earlier studies (Buttlar, 1999 and Gooden, 2001).

Journals cited : Non-subscribed vs. Subscribed

As seen from tables 3.4 and 3.5, Journals are the most preferred type of documents used by the doctoral students at PRL, as is the case the world over. It makes up for almost 84% of all the documents cited. Out of 9,130 total journal citations (84%), the researcher wanted to find the proportion of non-subscribed and subscribed journals cited by the students during pre-ejournal and ejournal period. Out of the total of 3,572 journal citations during pre-ejournal period of 1997-2000, 586 citations (16.41%) are from non-subscribed titles and 2,986 citations (83.59 %) are from subscribed titles.

Table 3. 6 : Use of journals – Non-subscribed vs. Subscribed during 1997-2000

Journals	1997	1998	1999	2000	Total	%
Non-subscribed	151	241	75	119	586	16.41
Subscribed	776	1290	577	343	2986	83.59

Fig 3.6 : Use of Journals – Non-subscribed vs. Subscribed during 1997-2000

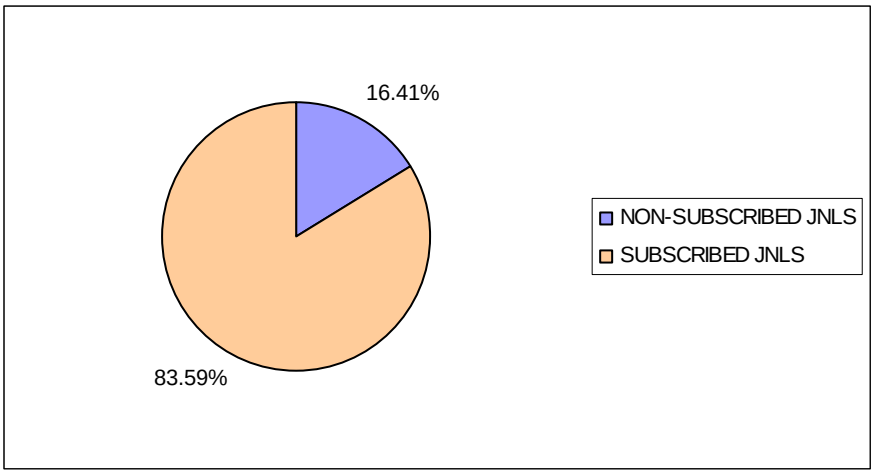


Fig 3.6a : Year wise pattern of journals used : Non-subscribed vs. Subscribed from 1997-2000

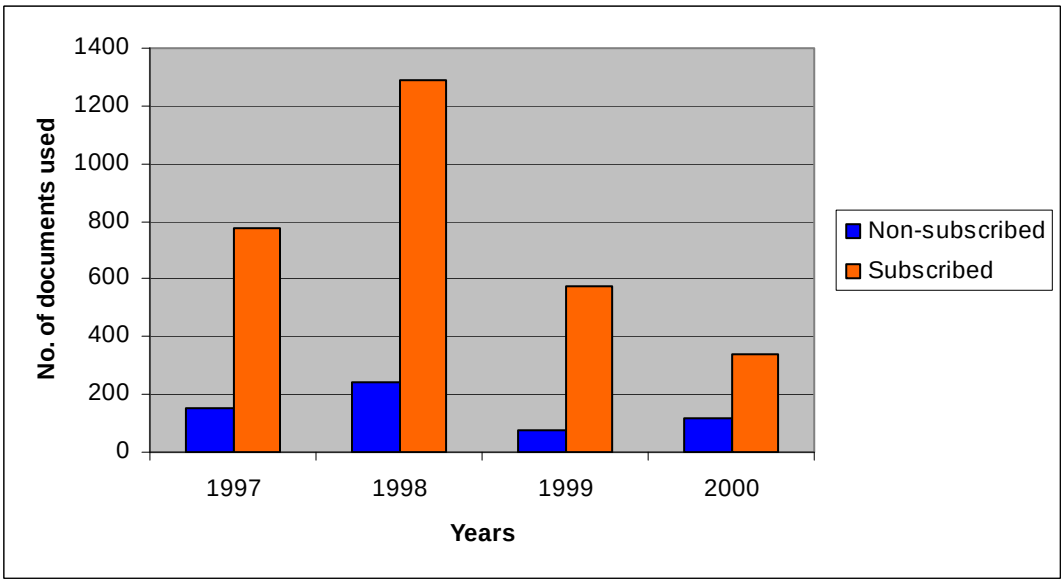


Table 3.7 and Figures 3.7 and 3.7a below give the information about the journals cited – Non subscribed vs. Subscribed during 2001-2006. Out of 5,558 journal citations during 2001-06, 1,033 citations (18.59 %) are from non-subscribed journals and 4,525 citations (81.41 %) are from subscribed journals. Comparing the pre-e-journal and e-journal periods, there is a clear cut increase of 2.18 % in the proportion of non-subscribed titles cited in the e-journal time period of 2001-2006.

Table 3.7 : Use of Journals - Non-subscribed vs. Subscribed during 2001-2006

Journals	2001	2002	2004	2005	2006	Total	%
Non-subscribed	218	79	399	174	147	1033	18.30
Subscribed	1238	533	1788	554	428	4525	81.70

Fig 3.7 : Use of journals - Non-subscribed vs. Subscribed during 2001-2006

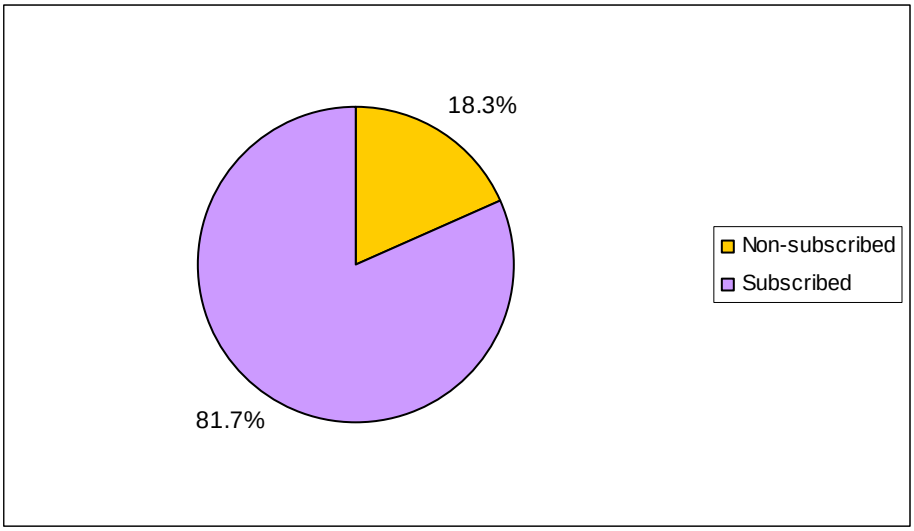
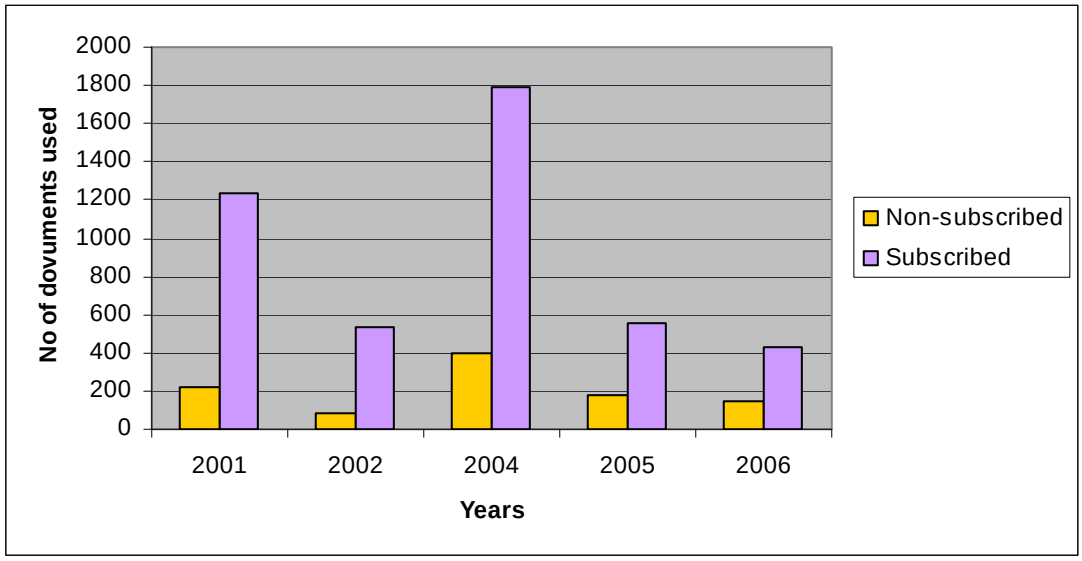


Fig 3.7a : Year wise pattern of use of journals – Non-subscribed vs. Subscribed from 2001-2006



The reason for increased use of non-subscribed journals in the e-journal time slab could be the quick access to articles received through friends in other institutes/countries and Document Delivery Service provided by the Library.

Other Documents cited

As seen from tables 3.4 and 3.5, 'Other Documents' make up for about 5% of the total documents cited by the doctoral students. The researcher wanted to find out which category of 'Other Documents' are preferred by the students and whether there was any change in the category preference in the two different time slabs. Most of the other documents are very commonly used except Eprints and Monographs. Eprints were mentioned in chapter 4 as a quick mode of communicating the research results to the peer community before presenting them in a conference or publishing in a journal. A monograph is similar to a book but deals with one specific topic in great detail. It is

usually written by a single author. Normally the term is used for a work intended to be complete at a level more advanced than that of a textbook.

Table 3.8 and Figures 3.8 and 3.8a give the data of 'Other documents' cited by the doctoral students during 1997-2000. Conference Proceedings (45.45%) are the most cited documents amongst the 'Other Documents' followed by Reports (28.18 %) during the pre-ejournal period of 1997-2000.

Table 3.8 : Use of 'Other documents' during 1997-2000

Other Docs.	1997	1998	1999	2000	Total	%
Eprint	16	0	1	2	19	8.64
Monograph	1	5	0	1	7	3.18
Proceedings	24	39	28	9	100	45.45
Report	20	29	5	8	62	28.18
Thesis	6	6	16	4	32	14.55

Fig 3.8 : Use of 'Other documents' during 1997-2000

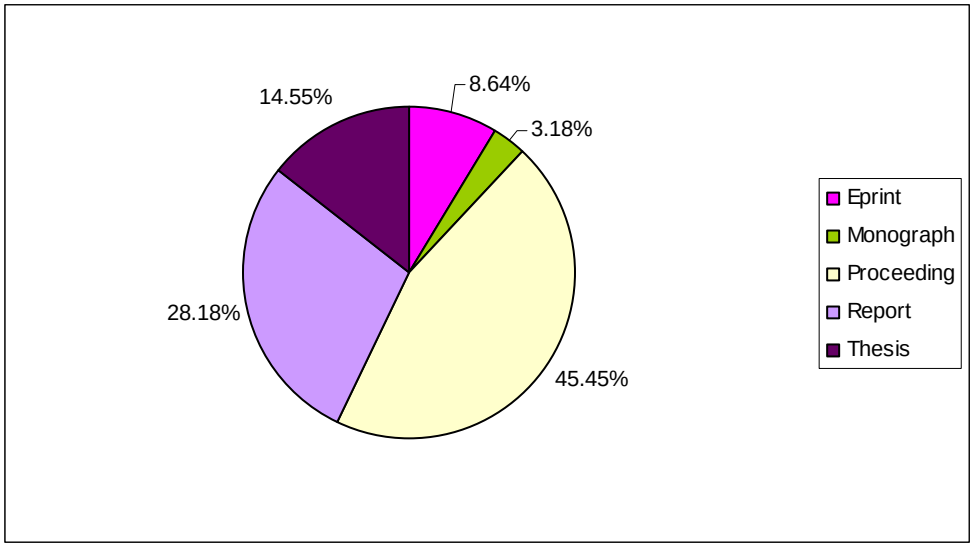
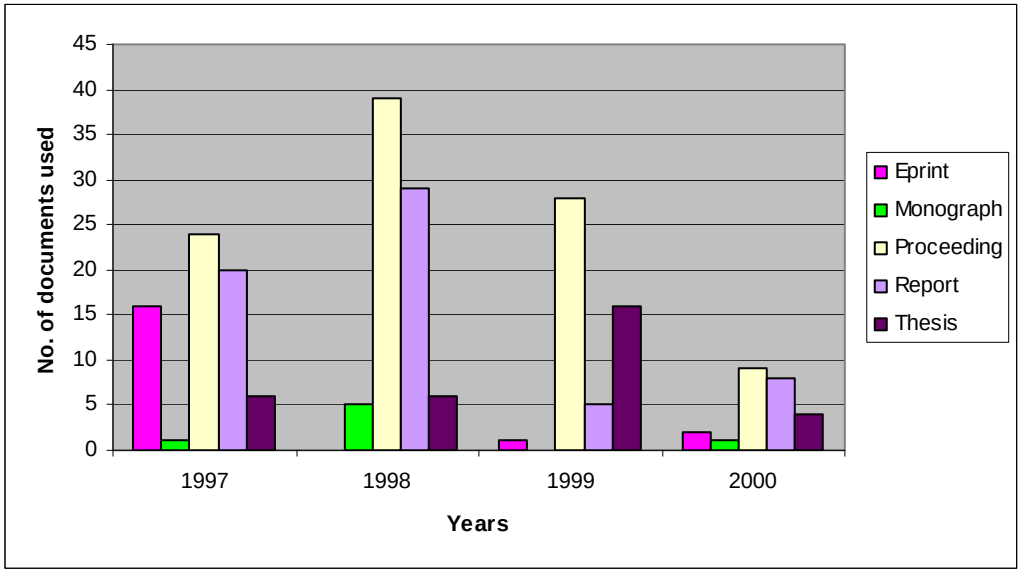


Fig 3.8a : Year wise pattern of use of 'Other documents' from 1997-2000



Thus Monographs and Eprints are the least used resources during the pre-ejournal period.

Table 3.9 and Figures 3.9 and 3.9a below give data of use of other documents during 2001-2006. In this period, Reports account for 44.35% and Conference Proceedings make up 28.57% of total 'other documents' used by the students during the course of their study.

Table 3.9 : Use of 'Other documents' during 2001-2006

Other Docs.	2001	2002	2004	2005	2006	Total	%
Eprint	1	4	12	10	2	29	8.63
Monograph	7	3	1	2	4	17	5.06
Proceedings	45	3	31	11	6	96	28.57
Report	43	33	39	18	16	149	44.35
Standard	0	0	0	0	1	1	0.30
Thesis	14	5	12	7	6	44	13.10

Fig 3.9 : Use of 'Other Documents' during 2001-2006

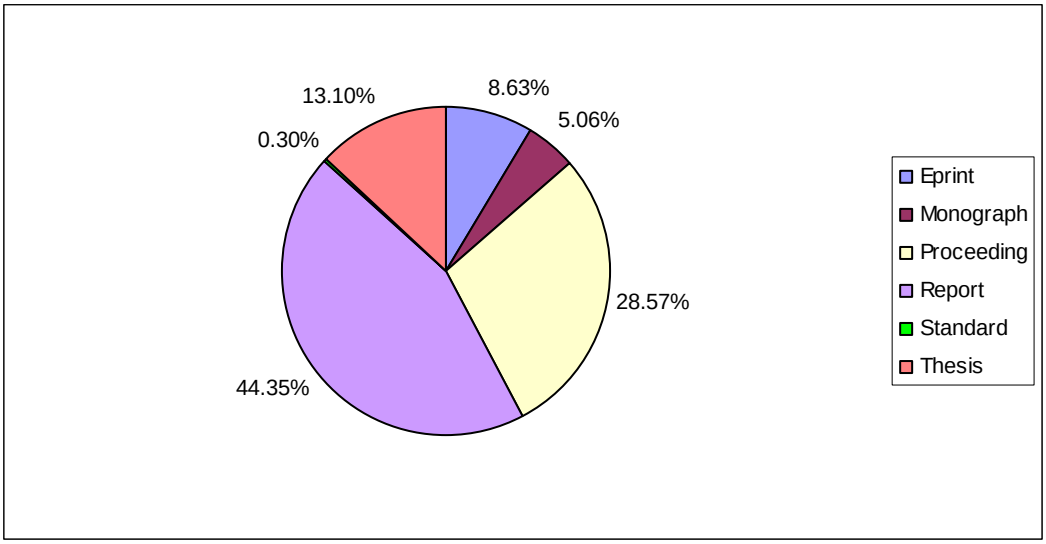
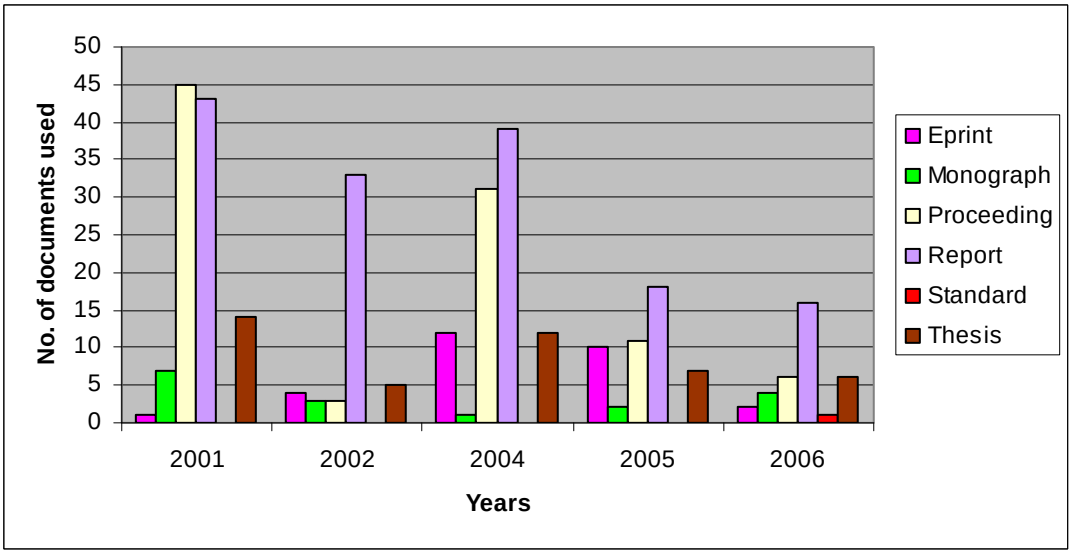


Fig 3.9a : Year wise pattern of use of 'Other Documents' from 2001-2006



Thus during the ejournal period 'Reports' are cited the most (44.35%) followed by 'Conference Proceedings' (28.57%), probably because of the availability of many of the government reports in public domain and easy accessibility through the world wide web. The preference of Monographs has increased during this time slab while proportion of theses has decreased. There is one more category which has been used during this time period – Standard.

Division wise break up of citation data

To get meaningful information about the usage of the library collection by the students, the researcher thought it appropriate to classify the collected citation data according to the subject divisions at PRL. Here, it needs to be mentioned that Solar Physics remains under the umbrella of Astronomy and PSDN (Planetary Science Division) remains under GSDN. Total 68 theses were submitted. Bibliographies of these 68 theses yielded 10,864 citations.

Division wise break of these 10,864 citations is given below. The data presented shows that Space Sciences students have given maximum number of citations (185/thesis) followed by Geosciences (171/thesis).

Table 3.10 : Division wise break up of theses submitted during 1997-2006

Division	No. of theses	Total citations	Citations/thesis
AAD	10	1484	148
GSDN	24	4095	171
SPA-SC	13	2403	185
THE-PH	21	2882	137
Total	68	10864	160

It seems number of citations appended at the end of research article or a thesis is subject specific. Astronomy and Theoretical Physics students tend to cite less number of sources.

According to Edwards (1999) "citation analysis can also be used to determine a core list of journals critical to local users and representative of the research needs of the collection." The citation data of the theses' sample was used to know the core journals for each division. Top 10 most cited journals form the Core Journal Group. Table 3.11 below gives the overall picture of total number of citations, journal citations and core journal group citations during 1997-2006 for four major divisions – Astronomy (AAD), Theoretical Physics (THE-PH), Geosciences (GSDN) and Space Science (SPA-SC) divisions. Astronomy Core Journal Group accounts for 85.71% of the journal citations, THE-PH Core Journals satisfy 64.61% of journal citations, the Core Group for GSDN accounts for 50.29% and Core Group for SPA-SC make up 69.75% of journal citations.

Table 3.11 : Division wise break up of number of Core Journal Group citations

Division	Total No. of citations	No. of Journal citations	No. of Core Journal citations	%
AAD	1484	1253	1074	85.71
THE-PH	2882	2492	1610	64.61
GSDN	4095	3253	1636	50.29
SPA-SC	2403	2132	1487	69.75
Total	10864	9130	5807	63.60

The above finding confirms Edward's study that a set of core journals (10 most cited journals) account for more than 50% of the total number of journal citations used.

However there is a considerable variation amongst the four subject areas. In Astronomy, the Core Group account for 85.71% of total number of journals used; in Theoretical Physics, Core Group of journals make up for 64.61% of the total number of journals used, in Geosciences, the Core Group accounts for 50.29% of total number of journals used, in Space & Atmospheric Sciences, Core Group makes up for 69.75% of total number of journals used. The lower core group percentage in Geosciences (50.29%) of the total journal citations might indicate the existence and availability of more number of important journals in that subject. Thus overall 63.60 % of journal citations come from top 40 journals (10 in each subject division). This study also confirms the Bradford's law that a set of core journals in a subject field satisfy more than 50% of the total number of journal citations.

Most used Journals

One of the objectives of the present study was to determine the usage of the library collection by the doctoral students of PRL. This was done by studying the citations listed by the students in the bibliographies at the end of the theses submitted.

The Table 3.12 below gives the 10 most used journals in Astronomy (including Solar Physics). Important thing to note is that no Indian journal is present in the core group of journals cited by students in Astronomy division during 1997-2006. Out of a total of 1253 journal references cited, Astrophysical Journal is cited the maximum number of times (321) followed by Astronomy & Astrophysics (209) and Astronomical Journal (127). It is interesting to note that these three titles put together satisfy more than 50% of the1253 journal citations of Astronomy division.

Table 3.12 : Top 10 cited journals in Astronomy

TOP 10 JOURNALS CITED IN ASTRONOMY	1074
Astrophysical Journal	321
Astronomy & Astrophysics	209
Astronomical Journal	127
Solar Physics	121
Monthly Notices of the Royal Astronomical Society	119
Astrophysical Journal Suppl.	64
Pub. of the Astron. Soc. of the Pacific	45
Astronomy & Astrophysics Suppl.	38
Pub. of the Astron. Soc. of Japan	15
Space Science Reviews	15

Table 3.13 gives the list of journals most cited in Geosciences. Out of 3,253 journal citations Geochimica Et Cosmochimica Acta was cited 401 times followed by Journal of Geophysical Research (249) and Earth and Planetary Science Letters (239).

Table 3.13 : Top 10 cited journals in Geosciences

TOP 10 CITED JOURNALS IN GEOSCIENCSES	1636
Geochimica Et Cosmochimica Acta	401
Journal of Geophysical Research	249
Earth and Planetary Science Letters	239
Nature	204
Science	163
Chemical Geology	120
Deep Sea Research	79
Geophysical Research Letters	73
Journal of Geological Society of India	55
Current Science	53

Table 3.14 gives the list of core journals most cited in Space Sciences. Out of 2132 journal citations, 1487 are core journal group citations. Journal of Geophysical Research gets the maximum number of citations (746) followed by Journal of Atmospheric & Terrestrial Physics (172) and Geophysical Research Letters (152). Here too, all the three titles put together account for more than 50% of the 2132 journal citations of Space sciences. In this subject too, not a single Indian journal is in the top 10 rank.

Table 3.14 : Top 10 cited journals in Space Science

TOP 10 CITED JOURNALS IN SPACE SCIENCE	1487
Journal of Geophysical Research	746
Journal of Atmospheric & Terrestrial Physics	172
Geophysical Research Letters	152
Atmospheric Environment	96
Planetary & Space Science	85
Nature	59
Science	52
Applied Optics	50
Journal of Chemical Physics	38
Annales Geophysicae	37

Table 3.15 shows the data for Theoretical Physics. It reveals that Physical Review Letters got the maximum number of citations (598) followed by Physical Review A (527) and Optics Communication (77). Total number of journal citations in Theoretical Physics was 2,492 and citations from core journal group were 1610. The above mentioned 3 titles account for about 50% of total journal citations of 2,492.

Table 3.15 : Top 10 cited journals in Theoretical Physics

TOP 10 CITED JOURNALS IN THEORETICAL PHYSICS	1610
Physical Review Letters	598
Physical Review A	527
Optics Communication	77
Nature	76
Physical Review E	68
Physical Review D	62
Physics Letters B	59
Physical Review	54
Optics Letters	48
Physics Report	41

The researcher also identified most used non-subscribed journal titles in each division. These are - *Information Bulletin on Variable Stars* and *Astrophysics & Space Science* for Astronomy division, *Journal of Hydrology* and *Limnology & Oceanography* for Geosciences division, *Canadian Journal of Physics* and *Chemical Physics Letters* for Space Science division and *Optics Communication* and *Annals of Physics* for Theoretical Physics.

On the other hand journals which are subscribed by the institute but have been cited only once or twice in the 10 year study period were also identified from the data collected. These are *New Astronomy, New Astronomy Reviews, Physics World* and *Radiation Measurement.* These journals may be candidates for deletion in the coming years. Thus both kinds of information used in tandem may help in subscription decisions of the institute.

Hence it can be clearly iterated that such studies are useful for identifying the gaps in library collection and subsequently addressing these issues appropriately.

PRL citations

Another objective of the study was to find the extent to which PRL research was cited by the doctoral students. Out of 10,864 citations 760 (7%) are PRL citations. It was also observed that most of the cited works were their own or their thesis supervisor's. Table 3.12 gives the division wise break up of the 760 PRL citations.

Table 3.16 : Division wise break up of PRL citations

Division	Total citations	PRL citations	%
AAD	1484	78	5.26
GSDN	4095	292	7.13
SPA-SC	2403	221	9.20
THE-PH	2882	169	5.86
Total	10864	760	7.00

The major findings of this citation analysis of theses can be summarized as :

- Average number of references per thesis has increased from 147 in pre- e-journal period to 170 in e-journal period.
- The preference for electronic resources from 1997 through 2006 confirms the findings of earlier studies. By 2006 use of electronic resources had increased so much that print and electronic resources cited, seemed almost equal.

- Journals comprise of major part of the documents cited, followed by Books and Other Documents. From 1997 through 2006, the use of the non-subscribed journals is on the rise. In 'Other documents' category, most used documents are the *Reports* followed by *Proceedings*.
- Core Journal Group (top 10 used journals) in each subject division satisfies more than 50% of the reference needs of the doctoral students at PRL. No Indian journal appears in the Core Journal Group in Astronomy, Theoretical Physics and Space Science divisions. Only in Geosciences division two Indian journals are amongst the top 10 most cited journals.
- Most used non-subscribed journal titles in each division were identified. These are - *Information Bulletin on Variable Stars* and *Astrophysics & Space Science* for Astronomy division, *Journal of Hydrology* and *Limnology & Oceanography* for Geosciences division, *Canadian Journal of Physics* and *Chemical Physics Letters* for Space Science division and *Optics Communication* and *Annals of Physics* for Theoretical Physics.
- On the other hand, the researcher also identified those journals which are subscribed by the institute but have been cited only once or twice in the 10 year study period. These are *New Astronomy, New Astronomy Reviews, Physics World* and *Radiation Measurement*
- PRL work is cited only 7% of the total citations by the doctoral students. It was also found that in Space Science Division and Geosciences Division, PRL research is cited more than Astronomy and Theoretical Division.

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CHAPTER 7

CONCLUSIONS AND SUGGESTIONS

The aim of the present bibliometric study was to discover a better and complete understanding of what is actually taking place in research at PRL. It has fulfilled its objectives of discerning the publication pattern and research trends of PRL. The results of the study will help those charged with making difficult choices about allocating the resources. It will also help in taking human resource decisions as regards the induction of faculty members in different divisions. Identification of well cited non-subscribed journals and not cited/very less cited subscribed journals will help in taking subscription decisions in the coming years, resulting in optimum fund utilization. Thus knowing the use of library resources by the doctoral students will help in taking future decisions about the collection development.

In the process of discerning the publication pattern and the research trend at PRL, following conclusions can be drawn from the consolidated findings of the study.

1. The research output of PRL in terms of publication record and invited talks summing upto 2518 gives an average of about 250 publications per year. Out of these, 1318 papers in journals give an average of about 130 papers published in journals per year. The average number of academic faculty members being 60, gives the output of 2.17 papers per faculty per year.

2. The result of the present study shows that the multiple authored and double authored papers are on the rise in PRL, especially from 2000 onwards probably due to ease of contact through emails and ease of collaboration in terms of writing and editing using the computers and the internet. In 1961 Price had predicted the disappearance of single authored papers. Fifty years hence, this trend is more than obvious as scholarship becomes interdisciplinary, leading to greater cooperation among individuals and institutions. High

percentage of multi-authored and double authored papers in journals is in accordance with the world pattern.

3. Comparing the data of collaborative papers in journals and conference proceedings, international collaboration is higher in journals than in conference proceedings. National collaboration is almost the same in journals and conference proceedings. Domestic collaboration is higher in conference proceedings than in journals. For conference proceedings, national collaborative papers are more than double of international collaborative papers. The reason could be that funding is available for national conferences but it is more difficult for international conferences.

4. Out of the articles published in journals, a very high number of articles are in international journals and very few are in national journals and lesser still are as chapters of a book. Thus, most preferred mode of publication of PRL scientists is Journal. The journals most preferred by PRL scientists for publication are **Physical Review A** followed by **Current Science** and **Physical Review D** during 1997-2006.

5. Out of the 20 most preferred journals, 4 are Indian – Current Science, Journals of Earth System Science, Pramana, and Bulletin of Astronomical Society of India. All others are international journals of high impact. Thus there is clear preference to publish in international journals because it brings recognition.

6. The study reveals that Theoretical division is most productive in terms of papers published in journals and invited talks delivered. Geosciences division comes second in all the three categories of the research output. Astronomy division produced maximum number of papers in conference proceedings.

7. Thrust areas in Astronomy at PRL are *Solar Physics, Variable and Peculiar Stars* and *Normal Stars*. Thrust areas of research in Geosciences and Planetary Sciences at PRL are *Hydrology and Glaciology, Solar System Objects*, *Meteorites* and *Geochronology*. In Space Sciences, maximum number of papers were published on *Atmospheric Dynamics*

and Meterology followed by *Ionosphere* and in Theoretical Physics maximum number of papers were published on *Quantum Optics*, *Leptons* and *Quantum Mechanics*.

8. Very few articles were published in the subject of *Condensed Matter*. No research was done on the topics *Acoustics*, *Heat Transfer, Physics of Gases* and *Rheology*.

9. The most prolific researchers are : Prof G. S. Agarwal, followed by Prof. R. Ramesh and Prof A. K. Singhvi during the period of study followed by researchers like Prof. A. Jayaraman, Prof. Shyam Lal and Prof. V. K. B. Kota. It is interesting to note that quite a few of these highly productive researchers held senior adminsitrative positions at PRL like Director, Dean or Chairman of a Division.

10. The sample of this study does not follow completely the Lotka's Law of scientific productivity. This could be due to the fact that collaborative authors each get the count of one paper instead of giving credit to only the first author or giving proportionate credit according to the number of collaborative authors.

11. The citation analysis of the bibliographies of theses submitted by the doctoral students at PRL revealed the preference for electronic resources from 1997 through 2006 which confirms the findings of earlier studies. During 1997-2000 period e-resources had just started appearing on the web and print resources dominated the scene completely. During 2001-2006, the electronic documents took up considerable proportion of the print documents' share of the total number of citations. By 2006 use of electronic resources had increased so much that proportion of print and electronic resources cited seemed almost equal.

12. This citation analysis of bibliographies of theses also revealed that journals comprise major part of the documents cited, followed by Books and Other Documents. From 1997 through 2006, the use of the non-subscribed journals is on the rise. In 'Other documents' category, most used are the 'Reports' followed by 'Proceedings'.

13. It seems number of citations appended at the end of research article or a thesis is subject specific. Space Sciences students have given maximum number of citations followed by Geosciences. Astronomy and Theoretical Physics students tend to cite less number of sources.

14. Important result of the present study is that a set of core journals (10 most cited journals) account for more than 50% of the total number of journal citations used. However there is a considerable variation amongst the four subject areas. .

15. No Indian journal appears in the Core Journal Group in Astronomy, Theoretical Physics and Space Science divisions. Only in Geosciences division two Indian journals are amongst the top most cited journals.

16. In each subject area two most cited non subscribed journals (currently) were identified for further follow-up, to find out which of them may be subscribed by the institute. These are - *Information Bulletin on Variable Stars and Astrophysics & Space Science* for Astronomy division, *Journal of Hydrology and Limnology & Oceanography* for Geosciences division, *Canadian Journal of Physics and Chemical Physics Letters* for Space Science division and *Optics Communication and Annals of Physics* for Theoretical Physics division. Attempt was also made to identify those journals which are subscribed by the institute but have been cited only once or twice in the 10 year study period. These are *New Astronomy, New Astronomy Reviews, Physics World* and *Radiation Measurement*

17. It was also found from the number of PRL citations, that in Space Science Division and Geosciences Division, PRL research is cited more than in Astronomy and Theoretical Division.

The above conclusions clearly indicate that the present bibliometric study has fulfilled its objectives and further added to the existing knowledge corpus of this subject field. The researcher hopes that this information will be useful to the institute's decision makers for future research planning.

Suggestions

a) The policy makers will find the information about the quantum of research (PRL research output in journals per faculty per year) useful which will aid in taking steps to increase this publication rate so as to improve the ranking amongst the other research institutes in India as well as abroad.

b) The publication output of PRL during 1997-2006 shows that international collaboration needs to be developed by publishing more international collaborative papers. This could be achieved by more scientists attending and presenting their research results in international conferences which would lead to more collaboration. As international joint authored papers tend to be cited more often, increased international collaboration would increase the citation rate of PRL papers.

c) Collaborative ties with other institutes in the country need to be strengthened too so as to make the optimum use of the national facilities available and increase the number of national collaborative papers.

d) Scientists of PRL should be encouraged to contribute chapters in books, as books have long lasting impact on students and play an important role in diffusion of knowledge.

e) The high productivity of Theoretical Physics division could be due to more number of faculty and students in the division. Induction of more faculty members in other divisions could help in increasing the overall productivity of PRL.

f) Higher productivity might have direct correlation with more number of journals subscribed pertaining to Theoretical Physics. It is interesting to note here that out of all the currently subscribed titles of journals, Theoretical Physics has the maximum number of journals. Hence, more journals should be added in other subject areas as well to increase the overall productivity of PRL.

g) The subjects which attracted very few papers in the ten year period clearly indicate that these are not an active area of research for PRL. The reasons for non-active research areas could be looked into.

h) The findings of the present study confirm the earlier studies carried out by Pelz and Andrews (1976), Fox (1983) and Price (1986) that motivation to publish comes from recognition and prestige. Recognition by way of promotions and additional adminstrative

i) Citation analysis of bibliographies of theses shows that more than 60 % of journal citations come from top 40 journals (10 in each subject division). It would be worthwhile to explore reallocation of funds to other more needed databases or archives like WoS or JSTOR.

j) Subscribed journals cited only once or twice during 10 year period could be replaced with non-subscribed journals cited more often by the students.

k) Inter-division citations are not visible in the bibliographies of theses during the 10 year period of study. Availability of articles published by PRL scientists through the institutional repository created in 2006, could remedy that. However, doctoral students should be encouraged to use and cite the PRL research work.

After arriving at the above conclusions and suggestions, the researcher feels appropriate to furnish a few pointers to the areas of future research. Going through the various studies during the literature survey, the researcher found that very few bibliometric studies have been carried out in the field of Geosciences and Space Sciences. These would be interesting subject fields to study. Also, citation analysis of the papers published by the scientists of PRL would help in determining CFY of PRL. PFY (papers per faculty per year) and CFY (citations per faculty per year) are considered to be more objective indicators to assess the impact of any research institute as compared to the total number of papers and total number citations. Comparative study may be undertaken of research institutes in similar research domain. Collaborating institutes can be identified so that non-collaborating institutes can be taken into the fold of collaboration which in turn may lead to increase in number of publications and number of citations for PRL.

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