CHAPTER-5

FINDINGS, CONCLUSION, SUGGESTIONS AND FURTHER AREA RESEARCH
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Findings, Conclusion, Suggestions & Further Area Research

1 INTRODUCTION

Evaluating the productivity of an institutional research and development activities highlights the contribution of the institution and the individual scientists engaged in research. It also provides some insights into the complex dynamics of research activity and enables policy makers and administrators to provide adequate facilities and gauge the research activities in a proper direction. A well-known productivity indicator is the number of publications produced by scientists, institutions, or research group. Over the year, scientometric and bibliometric techniques have become tools to evaluate the productivity of research institute and individual researcher, as well as to map the growth of the research area.

Findings, Conclusion, Suggestions, and Further Area of Research of the case study have been made on Productometric Analysis of NML publications, which embodied a 58 years long publication history of NML. The study encompasses more than twenty parameters and the resultant data are organized for in analysis and interpreted with the help of 27 tables and 75 figures. Success in an investigation depends on the hypotheses made earlier should provide tentative answer to the proposed problem, which was made during beginning stage of research.

5.2 TESTING OF HYPOTHESES

A knowledge or fact could be accepted only when it has validity. The validity of such knowledge could be accepted only when it is tested with regard to its usefulness or truth. Hence, to accept hypothesis, which are mere hunches or guesses, as facts, they
are to be used. Testing of a hypothesis primarily denotes some sort of empirical scrutiny so as to determine if they are supported or refuted by what the researcher observes. It provides appropriate and most valuable direction to a piece of research. It ensures the collection of data necessary to answer the research questions. It serves the function of linking together related facts and information and organizing them into one comprehensible whole.

As hypotheses are considered as the primary instruments in research for suggesting new experiments and observations, the testing of formulated hypotheses for this study became imperative and results are given as follows:

**Hypothesis 1**

The hypothesis that, "Since the current infrastructure in the field of Material Science & Technology is better compared to other area of R&D, a major chunk of research contributions made by NML must be in the field of Material Science & Technology (MST)." has come true as evident from the analysis of publications data that, Materials Science and Technology (MST) contributes 1504 papers, followed by Non-ferrous Metallurgy (634) and Applied Chemistry and Corrosion (573). The study therefore, proved the above hypothesis true.

**Hypothesis 2**

The next hypothesis that, "Since quality being the sole motive of the NML and the impact of foreign publications in the above disciplines is more effective, a majority of research publications made by NML must have been contributed to foreign Journals "comes true, as the study reveals that during 1950-2007, the R&D papers in SCI journals dominated as shown in table 4.3., followed by National Proceedings and Non-SCI shared third rank.
Hypothesis 3

The hypothesis that, "most of the contributions in the above disciplines Minerals, Metals, Metallurgy and Materials Science (4-M) are interdisciplinary in nature, a majority of research contributions made by NML are by collaborative efforts of a team of scientists other than individual contributions" also came true, as it is found that, out of 4397 papers, only 845 (19.21%) papers have no collaboration and the remaining 3552 papers were published with collaborative effort. Two-authored collaboration recorded highest (1245) having 28.31%, followed by Three- authored (1206) with 27.42% and Four- authored having 650 (14.78%) respectively. as shown in table 4.4 and figure 4.4

Hypothesis 4

The hypothesis that, "the research in NML is concentrated with latest development and innovations in the respective field majority of such publications must have been published in journals compared to other forms of information sources." also came true as finding reveals that, during the tenure of study period, (1950-2007) 2648 papers were communicated in primary source (s) which recorded 60.22%. Out of 2648, a majority of the publications i.e.1349 (30.65%) were appeared in peer reviewed SCI journals and 1188 in Non -SCI recorded 27.01%.

Hypothesis 5

The hypothesis that, "Since NML is a premier R& D laboratory in the field of Minerals, Metals, Metallurgy, Materials Sciences (4-M), and working under the banner of Council of Scientific and Industrials Research, Government of India, so the quality and quantity in terms of Citations and their impact Factor should be highly impressive" proved true, as the finding reveals that, during 1972-2007, a total of 2830 citations have been received by NML publications that spread over 500 peer reviewed
journals in 12 language by 655 world reputed organizations/institutions under the categories- Academic institution cited 471. The Impact Factor of cited journals varies from 0.01-30. The IF range >1.00-2.00 include 128 journals, that cited 1065 papers, followed by IF-range >0.51-1.0 which contain 98 journals and IF-range >0.01-.05 fall in 95 journals and cited 371 papers respectively.

_Hypothesis 6_

The hypothesis that, "Since the core journals, determined by the majority of the Scientometric Studies, reflects that they carry maximum number of papers and citation of reputed scientists, the present Productometric Study may establish the same trend" came true, since the application of Bradford's Law of scattering in publication profile of NML scientists is found well fitted as number of periodicals contributing papers to each zone increases by multiplier or 7.665.

**5.3 CONSTRAINTS ENCOUNTERED DURING STUDY**

No investigation is free from constraints. During the present study, the investigator has encountered the following constraints making the study not only difficult, but also partially inconclusive:

1. To present scientometric profile of NML during for last 58 years, data were collected mainly from three sources as mentioned in table 4.2. However, other sources were consulted for taking the full bibliographic details and for verification of data and selecting suitable key words particularly in determining the research trend. This study was broadly divided into three parts, for the sake of convenience namely; (i) Publications Analysis (1950-2007); (ii) Research Trends (1950-2007); (iii) Citation Analysis (1950-2007) respectively.

2. To determine the growth and trends of NML papers, data were collected from Annual Reports. But the Reports were available for 1957-2007 only. Therefore, for getting data of earlier period, the reference data appended with full text articles were
referred to and noted down for further verification. On the other hand, the subject area/R&D areas assimilated with various branches of Sciences were also examined to determine the research trend. So, the broad R&D area was framed according to the existing R&D core domain of NML and classified according to the Universal Decimal Classification Scheme for grouping of narrow subject areas. The citation data was similarly classified for presenting citations received as per subject area according to the classified order.

3. The investigation initially intended to incorporate HRD (Human Resource Development) aspect of NML in the study. However, due to non-availability of data, the idea was dropped. The earlier data was available form 1970 towards only, hence felt inconclusive. However, NML Annual Reports when first appeared in 1957-58, the Human Resources data were not incorporated. In the present study, 58 years data became mandatory to present publications profile along with manpower and expenditure. Had the same were available, and then the task would have become easier to calculate the cost benefit ratio.

4. The Citation was solely based on On-line Science Citation Index retrieved through Web of Science by login www.isiknowledge.com. To determine the Growth and Development of Citations and publications, the citation data from 1972-2007 could be accessed and verified from the NML Annual Reports, Data reflected in Web of science are found inadequate.

5. Since the present study encompasses the long time span of 58 years, the decadewise distribution and analysis of data was initially proposed, but in the first ten years data pertaining to 11 years was included that required additional effort. This was inevitable for the study. On the other hand, for the remaining part of the study, data of 10 years were incorporated in each decadewise time slot for analysis, which became essential to complete the decade as required in the study.
6. Some bibliographic data were not clear, hence Metadex was looked upon through off-line CD-ROM (1966-2007) and the last 3 years data were retrieved through On-line.

7. The required data for the analysis of knowledge transfer in the form of Patents (Filed, Accepted, Sealed, MOU, Copyright, Soft Ware) was not available. Similarly, the first official NML Annual Report was published after 7 years of its inauguration. So, the technology reported data were collected from 1957. The foregoing are the few shortcomings that hindered the present study even though these are not so significant, but considerably influenced the work.

5.4 SUGGESTIONS AND FURTHER RESEARCH

National Metallurgical Laboratory, since its inception contributed to nation in terms of Basic Research, Applied Research and Invented R&D products i.e. reflected by a good nos. of papers appeared in various forms. Since the present investigation of publications of national and international repute carried out for 58 years, the obtained result can be further compared with similar type of National/International R&D organizations for making a comparative study. The above study can also be broaden to incorporate more parameters for evaluation. A separate study can be made, which are based on Science Citation Index (1950-2007) with addition of others parameters. However, the present studies only incorporate data for last 36 years as per present availability. The institutions/organizations cited NML papers may be further broaden and it will work as market for future technology transfer and open the avenue for collaborative research.

Since, NML contributed 530 papers in their in-house journal i.e. Journal of Metallurgy and Materials Science, so a separate bibliometrics study can be possible. It will be helpful to have a view of status of Journal. The same may be compared with journal of similar status like Transactions of Indian Institute of Metals or any other of the same status/similar subject domain.
5.4.1 National and International Comparisons with other Research institutions may be made in future covering the following:

- Selection of National and International institutes in the field can be compared;
- Growth and Development of the number of citations for the institutes to be compared can be investigated;
- Top core journals of each of the institutes compared can be unmasked;
- Top journal articles of the institutes compared with the highest increase of citation per year can be investigated.

If the NML authority implements the following suggestions, the productivity of research output can be substantially improve in the day ahead:

(a) The NML scientists and R&D workers should substantially increase their efforts to publish their contribution in the journals of high IF, such as – Nature, Progress in Materials Science;

(b) The dental Amalgam Alloys patented in the year 1976 by NML needs a new look with more refined research may be continued for the furtherance of the product as it has a high utility value and demanded by the consumer in the market to make this product of global value, more efforts may be put;

(c) The NML scientists and R&D workers should explore the possibilities of undertaking more projects of high research value in collaboration with overseas researcher in the field of materials interest. In this connection approach may be made with the reputed Academia/R&D Institutions/Organizations/Industries who cited NML's research papers, which has been reflected in table-4.25; and

(d) The library should be encouraged to subscribe those core journals, which are unfolded in research output of scientometric study of different researcher from time to time on the subjects of NML interest.
5.5 CONCLUSIONS

Scientific publications seem to provide the best available basis for measuring the research output. It constitute key component of any research and development activity. Studies like this will provide some insight into the complex dynamic of research activity and enable scientists, policy maker and science administrators to provide adequate facilities and proper guidance in which direction the research has to be conducted.

In the light of above facts, a study on Productometric Analysis of the research publications of National Metallurgical Laboratory for has been carried out to present a complete history (1950-2007). The subject area of NML fall within the ambit of Minerals, Metals, Metallurgy, and Materials Sciences. The road map of the study was based on figure 1. The study determined scientometric profile under three broad parameters – Publications Analysis, Research Trend (1950-2007) and Citation Analysis (1972-2007). The key findings and conclusions of the study are as follows:

5.5.1. PUBLICATIONS OUTPUT

5.5.2 Publications Output During 1950 to 2007- A total of 4397 (60.12%) research papers and NML scientists have published 2916 (39.87%) technical reports during the last 58 years. Out of 4397 papers (table 4.3 and figure 3), 1349 (32%) papers were found in SCI and 1188 (28%) in Non-SCI, 1275 (30%) are National Proceedings, 306 (7%) are in International Proceedings and others constitute 279 which constitute only 3% of the total which is quite insignificant

5.5.3 Authorship Pattern clearly indicates that, the contemporary trend of research is moving very fast towards collaborative study, which further shows that, the group of two out of the 14, constitute 28.31% of the total; followed by 3 authors with 27.42%; and single author constitute only 19.21% of the total 14 categories and as such rank first, second and third respectively. So far the period is concerned, the more number
of works of Co-authors have been reported during 1961-70 (250); 1971-80 (289); and 1991-00 (270) respectively. *(Table-4.4 and Figure-4.4)*

5.5.4 **The most prolific author** is **V.A. Altekar** Ex Director, National Metallurgical Laboratory (1969-1985) who topped the list with 266 papers and could share 6.04% of the total papers during the period under study, followed **R. Kumar** (1962-1987) Ex-acting Director, NML with 245 papers shared 5.57% and **B.R. Nijhawan**, the first Indian Director of NML during (1950-1966) contributed a total of 221 papers and got the 3rd rank and shared 5.02% of the total output which are quite significant. *(Table-4.5 and Figure-4.5)*

5.5.5 **Collaboration Trend**- The R&D publications contributed with Intra collaboration was recorded 1963 having 44.75% followed by Inter collaboration with 873 papers and recorded 19.85% where as 845 papers published by different R&D division with no collaboration. Therefore, solo research produces 19.21%. The National and International collaboration recorded 545 (12.39%) and 171 (3.88%) respectively. *(Table-4.7 and Figure-4.6)*

5.5.6 **Technology Reported.** NML noticed to have successfully transferred 277 technologies based on Minerals, Metals, Metallurgy, Materials Science and allied subject areas to various industries located in India/overseas. The technology related data solely based on NML Annual Reports, which shows that, 355 patents, were filed. The period 2001-2007 seems to have registered maximum 113 number of patents were filed, out of which 38 are accepted, 3 sealed and 96 technology transferred and during the same period, 12 copyright/software were developed, followed by the period 1991-2000, during which, 86 patents were filled out of which 12 are accepted, 8 are sealed and 33 patents have successfully been transferred to industries and 14 copyright /software developed. The period 1981-90 registered 3rd rank by filling 56 patents out of which, 6 were sealed and 20 patents were transferred to various Mineral and Metallurgical- based industries. *(Table-4.8 and Figure-4.7)*
5.5.7 Channel Preferred by NML Scientists - To determine the source of publications for a total of 4397 papers, about 2648 papers were spread over 405 Journals as depicted in table 4.9 arranged according to number of papers. While 1483 papers were published in Indian Journals the remaining, 1165 were covered in overseas peer reviewed journals. The Journals were further categorized into SCI and Non-SCI. while, SCI published 1349 papers covered in 227 Journals and Non-SCI covered 178 journals and appeared 1188 papers. The findings show that, In-house Journal – Journal of Metallurgy and Materials Science (erstwhile NML Technical Journal) published 530 number of papers and shared 12.05% of the total; followed by Transactions of Indian Institute of Metals (India) which covered 233 papers constitute 5.41% of the total (4397) papers and Materials Science and Engineering “A”: Structural Materials Properties Microstructure and Processing placed in 3rd rank with 76 papers, which constitute 1.72% respectively. Further, 405 Journals are categorized according to their source countries, where Journals are published. The findings clearly depicted in figure 4.8 reflect that, while 1483 papers were published in Indian Journals, the overseas Journals covered 1155 (43.68%) papers, which is quite significant.

5.5.8 Impact Factor- During 1950-2007, a total of 4397 papers published in 405 Journals. It is observed that, only 178 journals (43%) are without Impact factor and remaining 227(56%) are with IF. Table-4.11 depicts the Journals which are classified according to their IF range that varies from 0.01-30.00, followed by papers. The findings reveal that, IF range >0.01-2.00 covered a maximum of 83 journals with 377 papers, followed by IF range >0.01-0.5 covered 65 journals with 550 papers, and IF range fall between 0.51-1.0 could which include only 54 journals published 318 papers. Further, the highest impact factor of the journals where NML research findings published are Nature: IF-29.271, followed by Progress in Materials Science: IF-5.5867 and Journal of Applied crystallography: IF 5.248. Table-4.8 and Figure 4.10 depicts the number of papers at different impact factor range for last 58 years, which can be referred to judge the quality of Research, and Development carried out in National Metallurgical Laboratory9 (NML).
5.5.9 Application of Bradford's Law - It is also observed that, the number of periodicals contributing papers to each zone increases by a multiplier or 7.665. Specifically the first zone, containing 6 periodicals, contributes 1009 papers, the second zone consisting 46 periodicals produces 794 papers, and the third zone accounting for 353 periodicals provides 845 papers. Thus, the Bradford's Law almost fits well in this case.

5. 6 RESEARCH TREND OF NATIONAL METALLURGICAL LABORATORY (NML)

5.6.1 Ferrous Metallurgy - Figure 4.12 clearly depicts the trend regarding the number of papers and Technical reports verses year. The number of papers published during the period 1961-1980, shows an increasing trend and after 2001 onwards, the nature of curve shows the decreasing trend. The reason for the same may be due to inclusion of only seven-year data instead of ten years. But, after the completion of decade, one can hope that, the trends of curve will be in increasing order. The nature of curve for technical reports more or less horizontal but after 1981-1990, it has showed an increasing order.

5.6.2 Non-ferrous Metallurgy - In case of Non-ferrous Metallurgy, figure 4.13 shows parallel trends for papers and reports. The nature of graph is in ascending order.

5.6.3 Materials Science and Technology - The nature of curve (depicted in figure 4.14) for research papers and technical reports during 1950-1980 appears in ascending order and is maintained upto 1990 and, afterwards the said trend reflects in the increasing order.

5.6.4 Mineral Processing - The R&D trend for MNP area is based on publications during 1950-2007 as projected in figure 4.15. The nature of curve from 1950-80 shows increasing trend and, thereafter, in decreasing order upto 1990, but from 1991 onwards, it shows in ascending orders.
5.6.5 Applied Chemistry and Corrosion Science- Study on research papers versus number of years in decade reveals that, from the beginning i.e. from 1950-60, the tendency increased up to the decade 1971-80 and from 1971-80 and 1981-90, the rising of curve goes down for a shorter-decade and, again from 2001-07, the curve rises very steep (figure 4.17). But, for the technical reports, the curve became straight up to the decade 1981-90 right from the initial decade and after this decade, the curve went up steadily, which is a clear indication of healthy outcome.

5.6.6 Refractories and Ceramics- The nature of curve from figure 4.18 for papers depicts an increasing trend from 1950-1980 which further inclined in 1990 at present, it shows an increasing trend, whereas the technical reports moves parallel.

5.6.7 Pollution Control and Environmental Science- The nature of curve as depicted in figure 4.19 for research papers and technical reports shows that the period 1950-80 maintained the publications output right from beginning, but after 1990 onwards both shows an increasing trend.

5.6.8 Powder Metallurgy- The nature of curve (figure 4.20) for number of research papers gradually increases from 1950-1980, but during 1990 it has show a decreasing trends and the period up to 2007 reflects an ascending order, whereas, the trend for reports were witnessed an increasing trend. It is interesting to note that, during 1950-2007, the curve for reports and papers cut each other for three times at different time intervals. It means during this period, the number of publications and reports were found equal. Figure 4.20 clearly depicts the above facts.

5.6.9 Management of Science and Technology- The nature of curve based on publications output for Management of Science and Technology as depicted in figure 4.21 shows that, the trends of research papers in this field appeared in ascending order for the first-three decades which further declined during 1981-1990 and after that it followed an increasing trend. Technical reports seem to have maintained the output from 1950-1980 and have shown an increasing trend. It is
Interesting to note that, during long 57 years, the curve lines intersect each other during the period 1981-1990 which means that, the number of publications for technical reports and papers remain equal.

**5.6.10 Mathematical Modeling and Simulations** - R&D trend for MMS, as shown in figure 4.22, clearly reflects that, the publications of technical reports was maintained from 1950-1980 and further, it shows an increasing trend. The publications trend for research papers too reflects almost a similar trend.

**5.7 CITATION ANALYSIS (1972-2007)**

5.7.1 During 1972-2007, NML received a total 2830 citations. The average number of citations per year was 78. The highest number citations were 572 received in 2007. The continuous growth of citations was found throughout. The citation rate was peaked during 2007 as the maximum citations were received during the period 1992-2003. The main reason for receiving more papers (617) was manifold increase in the publication during 1992-2003 and some important papers, which were published earlier have also, continued to receive citations. These indicate that both quality and quantity analysis went hand to hand. The citation rate obviously increased due to increase in publication of qualitative papers. Table 4.15 reflects the status of citation during 1972-2007 and Fig. 4.23 presents the growth and trends of citation.

**5.7.2 Citedness of NML Publications during 1972-2007** - During 36 years, a total 2830 citation received by NML publications. Total self-citations were 207 (7.31%) and citation by others was 2623 (92.68%). The highest number of citations were 572 (20.21%) recorded in 2007, followed by 475 (16.78%) in 2006 and 322 (11.37%) in 2005 respectively. Out of 1187 papers, 595 papers have received citations, while the remaining 592 papers did not receive any citation. Significantly, one paper was cited 51 times that was in the area of Materials Science & Technology, followed by 44 times published during 1978-79 in Applied Chemistry and Corrosion Science R&D area and the one that was cited 41 times published during in 2002-2003 in the same R&D
area. The study, therefore, clearly reflects that the Materials Science & Technology R&D area of NML received recognition worldwide.

5.7.3 Subjectwise Distribution of Citations- To judge the quality of NML citations according to subject area, the data and broad key-words, which were downloaded from SCI database, are further analyzed and categorized as per UDC classification scheme. The findings reflect that, Materials Science, Multidisciplinary (620.1) got maximum of 1123 citations with 28.30%, followed by Metallurgy & Metallurgical Engineering (669) include 521 citations and shared 13.13% and Physics, Multidisciplinary got 182 citations with 4.58%. Besides these, 46 subject area with number of citations and their percentage are depicted in table 4.17. Distribution of citations further classified and condensed into 6 broad subject area as depicted in figure 4.24.

5.7.4 Highly Cited Papers of NML- The highly cited papers received a total of 51 Citations during 1991-2007, out of which, 6 were self-citations. This paper has received citations after one year of its publication. The average Citations per year was 2.68. There were 25 journals Citing this papers. Diachronous self-citation rate was 11.76.

5.7.5 Highly Cited Journals-During 1972-2007, NML received a total 2830 citation spread in 500 Journals. It was observed that, only 96 journals (19.20%) are without Impact factor and the remaining 404 (81.45%) are with IF. Table 4.20 depicts the Journals which are classified according to their IF range that varies from 0.01-30.00 followed by citations. The findings reveal that, IF range >1.00-2.00 covered maximum of 128 journals and 37.63% citations followed by IF range >0.51-1.0 covered 98 journals with 26.89% citations and IF range fall between 0.01-0.5 include 95 journals published 13.10% citations of the total 2830. Further, the highest impact factor of the journals were NML research findings cited are Nature: IF-29.271, followed by Nanoletters: IF- 9.847 and Advanced Materials: IF 9.103. Figure 4.25 giving number of
citations at different impact factor range for last 36 years can be referred to judge the quality of Research and development carried out in National Metallurgical Laboratory.

5.7.6 Core Authors Citing NML Papers- The core citing authors were obviously from the NML itself. It is interesting to note that most of the cores citing authors are also the highly productive scientists. The core citing authors whose names have appeared in the citing papers of NML with their authorship in citing papers were S.K.Das cited 45 papers and shared 1.59% followed by A.K.Ray cited 36 papers (1.27%) and A.Mitra cited 31 papers with 1.09% of the total 2830 citations.

5.7.7 Core Institutions Citing Papers- The most prolific institutions/organizations cited papers are National Metallurgical Laboratory with 327 citations (11.55%), followed by Indian Institute of Technology (All IIT’s) cited 174 citation (6.14%) and Banaras Hindu University cited 61 (2.15%).

5.7.8 Languagewise Distribution of Citation- During 1972-2007, NML papers received 2830 citations in 12 languages as depicted in table 4.27 and figure 4.32. English remain the dominant language, where 2738 citations with 96.74% cited, followed by Chinese with 30 papers (1.06%) cited and Japanese language cited 20 (0.70%) of NML research findings. The other languages are Russian (10), French (8), Spanish (8), German (7), Czech (3), Portuguese (2), Rumanian (2) and Hungarian, Polish cited 1 each which are not so significant.

5.7.9 Form of Document- Out of 2830 citations, 2672 (94.41%) citations were Journal Articles, followed by 131 (4.62%) technical Reports, 11 (0.38%) Notes, 9 (0.31%) Letters, 2 (0.07%) Other categories (Correction Notes-1, Meeting-1). The types of documents citing NML papers are given in figure 4.33.
The overall performance of the present investigations reflects that, NML contributed a total 4397 research papers (spread over 405 journals of National and International repute) and 2916 technical reports during a long time span of 58 years of its existence (1950-2007). The expert team of Scientists contribute, on an average, 75 number of research papers annually (1950-2007) However, the average growth of literature per year for last two decades (1991-2010, actual 17 years but projected up to 2010) reached more than 121 papers. Similarly; the year 2006-2007 became the milestone in the publication history of NML, as it broke the record of previous years with a record publication of 239 papers and received more than 572 citations.

The core authors, who contributed maximum papers, were V.A. Alteker (Ex. Director, NML) with 266 papers, where as intra collaboration constitutes 1963 papers with 44.75%. The R&D trend of publications reflects that, Materials Science & Technology at present has occupied the centre stage in publication front with 1504 papers and 893 technical reports. The quality of NML papers are well reflected through citation and Impact Factor, the study shows that during last 36 years NML publications received 2830 citation that spread over 500 periodicals with impact factor range varying from 0.02-30.00. The NML's valuable research were cited by a total 655 world reputed institutions /organisations in 12 languages involving 73 countries in citing NML research publications as per the findings of this investigation.