CHAPTER 5
FINDINGS AND CONCLUSION

This chapter highlights the findings, recommendations, and conclusion to the research work carried out.

5.1 Findings

Each of the objectives is revisited, and the key findings against each are listed in the subsequent paragraphs.

5.1.1 Objective no. 1: To analyze the research publication pattern of Asian countries in the field of mechanical engineering.

Web of Science data shows that the top ten countries with respect to global research output in mechanical engineering in the span of 2000-2014 are the United States of America with a major share of 21.71%, followed by China (12.33%). Japan (5.43%), South Korea (4.35%), and India (3.70%) occupy 5th, 7th, and 9th position respectively. The Asian productivity trends of literature published in the mechanical engineering are traced, and it is found that China contributed 69,515 articles, Japan 30,578, South Korea 24,494 followed by India with 20,836 articles.

In comparison with other Asian countries, China’s contribution is above the mean value. The publication pattern has been discussed in the earlier chapter and barring Japan, and the growth has been on the rise for the other three countries. The results of the current scientometric study emphasize that there is a larger scope to improve the efforts in the three countries. Japan, in particular, needs to put more efforts in expanding the R&D activities. Japan has recorded a negative trend while others have shown positive growth. Japan’s contribution has not improved compared to the other three countries. There is a need to study the increase in China, and evaluate how that country’s strategies have influenced the growth of research and development. Surely, China’s focus on industrial growth has a positive impact. China, India and South Korea continue to show an upward trend, though Japan’s article output in mechanical engineering has been consistent recently.

The findings in the tables 4.1-4.4 and figure 4.1 support the above statements.
5.1.2. **Objective no. 2**: To study the collaborative research patterns in mechanical engineering.

Collaboration among others from different countries is rising along with the increase in total number of articles published. China, Japan, and South Korea have the higher percentage of articles published by three authors. India scores highest with two authors. As far as the degree of collaboration (DC) is concerned, China has the highest collaboration ratio with 0.97. The DC trend was flat for China from 2007 until 2011. India has more consistency in terms of growth compared to China with an upward trend beginning 2003. In the recent years, collaboration in India has been on the rise and hit the peak with 95% multi-authored articles in 2014. South Korea showed a lower trend in the middle years of the study, beginning 2006 but started picking up from 2009, with 95% multi-authored articles, which is the highest in the span of the study. The multiple authorship in Japan is also on the rise, but at a rate lower than the other countries in this study. The researcher also studied the collaboration coefficient (CC). The trend indicates that collaboration is on the rise with collaboration in China picking up apparently. The trend of mean-authors-per-paper has been high for Japan at the beginning (the year 2000), and has experienced minimal change downwards/upwards till 2012, but started trending upward in 2012. The trend for India remained constant, showing that the mean number didn't deviate much. There was a significant change in South Korea where the collaboration rate rose significantly over the period studied in this research. China’s collaboration rate placed it second in the beginning, but the mean-author-rate significantly increased and reached a peak, when compared to other countries, in the year 2014. Overall, the entire period studied (2000-2014), China leads other countries in their upward growth; only in Japan did the rate remain consistent.

The findings here also answer the research question no. 4 laid out in the beginning - “Is collaborative research gaining prominence in mechanical engineering?”

The findings in the tables 4.5-4.8, 4.17-4.20 and figures 4.2-4.10, 4.22-4.24 support the above statements.
5.1.3. **Objective no. 3**: To study the growth of publications in mechanical engineering.

Barring Japan, Asia continues to record increasing number of publications in the mechanical engineering literature. In the 15-year span since 2000, China’s publications grew by 5.61 times, India by 2.64 times, South Korea by 1.3 times. Japan was slightly on the negative trend with a drop in publications by 17.87 percentage during the time span 2000-2014.

The total number of references vary on the number of articles, with an average of 26 references per article for articles published by India, 23 for China, followed by 20 for South Korea and Japan with 18. Overall, the number of references is on the rise for each country which also is a promising factor that the research is on the upward trend.

This also answers the research question no. 1 laid out in the beginning: ”Did contributions from Asia significantly grow in the area of mechanical engineering?"

The findings in the tables 4.1-4.4, 4.11-4.12, 4.29, 4.42-4.45 and figures 4.1-4.2, 4.10, 4.45 support the above statements.

5.1.4. **Objective no. 4**: To test for the goodness-of-fit of bibliometric laws to the discipline of mechanical engineering.

The authorship study with the help of Lotka’s law proves that it is on the lines of the law. China produced 61% single-authored articles, 16% two-authored, and 7% three-authored. When we look at ten-authored articles, the rate was around 4%. India followed a similar trend with 64% single-authored articles, 15% two-authored, 7% three authored; ten-authored articles were less than 3%. Japan, even though its publication rate declined, continued to satisfy Lotka’s law, with 64% articles being single-authored, 15% two-authored, 7% three-authored, and only 3% contributed articles where more than ten authors collaborated. South Korea showed a similar trend with 62% single-authored articles, 15% two-authored, 7% three-authored, with ten-authored articles accounting for less than 4%.

The analysis of journals distribution also shows that the trend fits Bradford’s law of distribution for all the countries. The analysis of journals shall help scholars in
getting an overview of prominent journals listed in the one of the sections in the earlier chapter (# 4.7).

The Journal of Materials Processing Technology and International Journal of Heat and Mass Transfer top the list in the study from the section 4.7 from all countries. Indian data also identifies the latter journal as the most favored one. The top journals preferred by the researchers in the country have been identified in the section.

The findings also answer the research question no. 3 laid out in the beginning: Do the research publications in mechanical engineering follow the classical bibliometric laws?

The findings in the tables 4.21-4.28, 4.30-4.41 and figures 4.31-4.34 support the above statements.

5.1.5. Objective no. 5: To analyze the international collaboration in the area of mechanical engineering.

There is an increase in multi-authored articles, over the time span studied, as well as an increase in articles published by authors from more than one country. The United States of America (USA) tops the list of collaborating countries analyzed. South Korean research has the highest collaboration rate with USA. China follows with 7.72% articles written in collaboration with USA authors, Japan with 6.43%, and India with 4.84%. Other than the USA, England, Germany, and Canada are the countries high in collaboration with Asian authors.

The findings in the table 4.55 and figure 4.45 support the above statements.

5.1.6. Objective no. 6: To develop activity profiles of the countries and compare with the global research outcome.

When compared with the global research output in mechanical engineering, China has topped the recent rankings, followed by India and South Korea. In the early 2000s, Japan ranked first in international collaboration rates, compared to the other Asian countries, but after a steady decline now ranks last among those. India followed a similar trend as the world's, with a slight drop in the beginning, and South Korea which was high in the beginning compared to the world's output, but didn't experience continued growth as compared to India and China.
The findings in the tables 4.13-4.16 and figures 4.18-4.21 support the above statements.

5.1.7. **Objective no. 7**: To identify the institutions in Asia with the most prolific output in mechanical engineering research.

An important parameter in looking at the progress of research is to study highly contributing institutions. The Chinese Academy of Sciences, Shanghai Jiao Tong University, and Tsinghua University are the top three contributing institutions in China. In India, the three most prolific institutions are Indian Institute of Technology Madras, Indian Institute of Technology Kharagpur, and Indian Institute of Science Bangalore. University of Tokyo, Tohoku University, and Kyoto occupy the top three positions in Japan. University of Science Technology (UST), Korea Advanced Institute of Science Technology (KAIST) and Seoul National University in South Korea contribute the highest articles in the area of mechanical engineering. By seeing the trend and the top positions occupied it can be seen that the biggest collaborators in the field of mechanical engineering are the academic institutions.

The findings in the tables 4.46-4.53 support the above statements.

5.1.8. **Objective no. 8**: To adopt visual mapping techniques to depict the collaborations, core journals in mechanical engineering research.

There are several tools which display the connections between articles, citations, authors, journals, the collaboration between countries, and countries citing the other countries’ articles, etc. These tools help one understand the collaborative patterns, trends and to map the overall contribution and strength of one country's publications. Majority of the findings above reinforce the outcome as seen in VOS Viewer, which maps the networks as portrayed in section 4.12.

The findings in the figures 4.45-4.44 support the above statements.

5.1.9. **Objective no. 9**: To understand the citation dynamics in mechanical engineering research and thereby to reveal the trends and fluctuations.

Citations are the ‘footprint’ of the impact of research contributions. China’s 69,515 publications received 6,02,045 citations in the ratio 1:8.66. It tops the list concerning citations received. The articles (30,578) and citations (266,902) ratio for Japan is 1:8.73. South Korea published 24,494 articles which received 2,04,393 citations in the ratio 1:8.44.
citations with the ratio of 1:8.34. Articles from India have a higher citation ratio compared to the other three countries. India’s 20,836 articles received 1,97,679 citations with a ratio of 1:9.49. From the perspective of yearly citations received, Indian articles in 2007 and 2009 have attracted a higher number of citations than other years. Analysis of higher citations per year for other countries are as follows: China, 2007 and 2010; Japan, 2000 and 2005; and South Korea, 2002 and 2003. The highly cited articles from each of the countries are also provided in the section 4.3.

This also answers the research question no. 2 - What is the citation pattern among the Asian authors in mechanical engineering?

The findings in the tables 4.9-4.10 and figures 4.11-4.16 support the above statements.

5.1.10. Objective no. 10: To determine the cited half-life of the most prominent journals.

In addition to the top four countries, Taiwan was also included in this while determining the cited half-life, so making it a total of five countries in Asia. The nine prominent journals with the highest citation data, from section 4.7 were considered to calculate the cited half-life. Journal of Sound and Vibration has the highest cited half-life score with 12.2, followed by Journal of Materials Processing Technology with 9.1, and International Journal of Heat and Mass Transfer with 8.8.

The findings in the table 4.54 support the above statements.

5.2 Findings related to India

Though it may be redundant, the findings related to India, the researcher’s home country, have been collated in this section. It is hoped that this section will be of some help to Indian readers.

- The contribution in mechanical engineering from Indian authors for the period 2000-2014 is 20,850 articles. India is at the 9th position when compared with other countries in the world, and 4th position in Asia. India recorded a publication growth of 2.6 times in 2014 when compared to 2000.

- Two-authored articles were prominent in India, their overall share is 37.15% of the total number of mechanical engineering articles by Indian authors. As
the trend in other countries, there was a decrease of one-authored articles year on year in India.

- Publications from India have a higher citation ratio compared to the other three countries with a ratio of 1:9.49, with an average of 26 references per article. The trend of publications from India suggested that it is following the global trend of publications.

- The trend of mean-authors-per-paper has been growing for India. The collaboration strength has picked up for India beginning 2000 and has generally been growing stronger year over year.

- The journal publications data fits well with Bradford's law of distribution with five journals (21.62%) being in the nucleus zone, followed by 15 (29.33%) and 358 (49%) in zone 2 and zone 3. The dataset for India satisfies the Lotka’s statement referring to the contribution of authors and their productivity in mechanical engineering.

- *Journal of Materials Processing Technology* and *International Journal of Heat and Mass Transfer* are the journals with the greatest number of articles authored by Indian researchers. Indian Institute of Technology Madras, Indian Institute of Technology Kharagpur, Indian Institute of Science Bangalore, Council of Scientific Industrial Research CSIR laboratories, and Indian Institute of Technology Kanpur have the five highest publication rates in the mechanical engineering field.

- India has a higher rate of collaboration with United States of America (USA) followed by Germany, England, and South Korea.

### 5.3 Recommendations for further studies

Based on the experience gained by the researcher during the study, the following future research work could be taken up in the areas as follows:

- One can undertake a scientometric study in different branches of engineering, and other professional fields such as medicine, paramedicine, etc. These studies are to be done regularly so that the longitudinal comparison of the data can be attempted to compare the research outcome.
• The contributions of institutes of national importance need to be explored in the areas of science and technology, as many of these institutions are finding a place as the top ranking academic and research institutes worldwide. For example in India, the highest academic contributions in science and technology are from Indian Institute of Technology, IITs. National Institute of Technology (NIT) could be considered in future studies so as to bridge the gaps.

• Data analysis using altmetrics may be applied to areas like big data, internet of things, cloud computing, mechatronics, etc.

• There are many new inventions in the area of robotics and artificial intelligence. An in-depth research to compare global output to Asia’s output will help identify the gaps.

• Patents form an important part of the scientific progress of a country. Hence a scientometric study on the revenue generation, innovation, research funding, future citations of patents in a subject will complement the overall scientometric study of a topic in a country or a region.

• Applying a scientometric approach to the products from manufacturing industries in Asia may help policy makers in the respective countries for an effective R&D roadmap.

Appendix B provides additional reading material and highlights important journals, conferences relating to scientometrics.

5.4 Conclusion

The study carried out does show that the publications in mechanical engineering are on the rise. China’s contribution is larger when compared to the rest of the countries. There may be a larger scope to improve the efforts in the three countries, and Japan, in particular, needs to put more efforts to catch up with its neighboring countries in Asia. The study has indicated insights into the growing share of mechanical engineering articles published by Asian countries. In spite of fluctuations in research hot spots, the most prolific or research-leading countries did not change over the 15 years studied, with the exception of Japan.

Collaboration has gained momentum along with the growth in article
publications over the years. Policy-making organizations can use the results of co-authorship studies to test or evaluate various assumptions by the government agencies, which can be used a foundational data to lay down better plans. However, with more economic growth and funding to research, China has evolved as one of the key contributors in the mechanical engineering discipline in recent years. India might identify the most promising areas for its own investment.

The mechanical engineering community is well connected which is visualized through the VOS viewer tool. This shows that there is a growing acceptance amongst the scholarly community in working with researchers worldwide. There has been a progressive growth in all countries studied, with the exception of Japan.

This study examined several of the important scientometric indicators to study the progress of mechanical engineering in Asia. The study also identified the highly cited journals, and the top publishing institutions in each of the countries. A few of the analyzes helped plot patterns to measure the impact and productivity of research. The results may also help in evaluating the progress and performance of institutions mechanical engineering. These results will also help various levels of academicians in their research endeavors.

The activity index shows that China, India and South Korea are well within the worldwide trend of increasingly publication productivity; Japan remains the exception. The citations and references continue to grow which infer that there is a larger scope of research activities in future, considering the rise in publications. The altmetric way of looking at the article is the new way of learning the impact of one's publication, and it is growing.

Within the mechanical engineering literature, publication counts generally increased every year for China, India and South Korea, as did the number of journals in mechanical engineering. By applying Bradford's law, we observed that the percentage of journals categorized as core journals likewise increased over the period of study. Such changes indicate that the mechanical engineering discipline has been growing. The mechanical engineering literature in Asia does satisfy the bibliometric laws - Bradford’s law of distribution and Lotka's law considered for this study. The number of article publications in Japan has come down, but cannot relate to obsolescence. The ratio of articles to citations is 1:2 (nearly).
The policymakers in the countries where mechanical engineering publications are either static or declining, may consider doing a SWOT (Strength, Weakness, Opportunities, Threat) analysis and relate to the strong growth of other countries. They can factor scientometrics into SWOT analysis to perhaps identify ways to make their mechanical engineering research more robust.

Collaboration studies can be instrumental to developing research policy, as they provide an overview of the scientific communication pattern. Developing countries might use these communication patterns and output trends to help identify the strategies that are propelling China and other top-publishing Asian countries. There are a few potential areas, including the following, which may be considered to improve the scientific research outcome in mechanical engineering.

- Government should encourage the research performance in every sector in the field of mechanical engineering.
- It should support research infrastructure and funding, and provide the optimal number of full-time equivalents.
- It should identify top scholars in the country and work towards strategic goals in improving research performance.
- A model of incentives should be developed to encourage research, and promote international collaboration.
- To improve products in the mechanical engineering sector, there should be more investment and support for existing industries and entrepreneurship.
- Increasing the scholarly productions by promoting international collaboration, which exposes one to the international arena.
- Lay out a mechanism to monitor the research carried out with the support from the government funds.

Developing countries would need to address an array of issues relating to research, skills development, technology development, regulations and governance to improve their competitive position in the mechanical engineering field. The findings of this study will help to understand the behavior and the impact of mechanical
engineering literature, and may assist policymakers as well as the academic community, in determining gaps to be addressed