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A SUMMARY OF BIBLIOMETRIC ANALYSIS ON THE PUBLICATION TRENDS IN TECHNOLOGY ROADMAPPING

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INTRODUCTION

Technology roadmapping is "a technique to capture diverse information in technology evolution and new product development" (Petrick & Echols, 2004, p.89). It is part of technology planning that deal with increasing competitive environment (Garcia & Bray, 1997). Technology roadmapping is crucial for creating alignment between technology and organizational goals (Phaal, Farrukh, & Probert, 2005). One of the applications is to support strategic planning in relations to technology, product, and market (Phaal, Farrukh, & Probert, 2004). It can also be applied for service planning, capability planning, long-range planning, knowledge asset planning, program planning, process planning, and integration planning (Phaal, Farrukh, & Probert, 2001). The initial works on technology roadmapping was appeared for the first time in the late 70's (Phaal, Farrukh, & Probert, 2005). With over two decades of literatures, the ground works of technology roadmapping have been well established. As a result, this study will summarize the publication trends in technology roadmapping based on the bibliometric analysis of references.

RESEARCH METHOD

A bibliometric analysis that was based solely on the references and article titles was applied due to proven applications in previous studies. One example of the studies has categorized the article titles into methods-describing titles and results-describing titles (Paiva, Lima, & Paiva, 2012). Meanwhile, another study has classed the types of article titles into descriptive, declarative, and question (Jamali & Nikzad, 2011). Prior to that, a study has

classified the article titles according to the methods, dataset, results, conclusions, and topics (Goodman, Thacker, & Siegel, 2001). For the purpose of this study, the analyses are focused on the types of publications, contexts of publications, and key themes, where the types of publications are grouped into books, journals, proceedings, and theses and dissertations. Meanwhile, the contexts of publications are grouped into international, national, and organizational context. In a similar fashion, the key themes are grouped based on the emphasis, focus, context, or topic highlighted in the article titles. The data for these classifications were extracted into six groups, each with a five-year interval time-periods from pre-1991 to 2011-2015 group. The database is taken from a list of more than 700 references in Phaal (2015). Prior to analysis, the quality of all 739 references were inspected, and have found 23 of them written in non-English, 12 listed twice, four without year, and one without title, all of which were omitted from the database. This analysis was performed according to the following methods: (1) mapping the field through a scoping review, (2) comprehensive search, (3) quality assessment, (4) data extraction, (5) synthesis, and (6) write up (Jesson, Matheson, & Lacey, 2011). The summary of bibliometric analysis is reported as follows.

TYPES OF PUBLICATION TRENDS

The findings have suggested four main types of publications for technology roadmapping. Out of 699 articles, 95 of them were published in books and reports, 295 in journals, and 280 in proceedings and conferences. Meanwhile, regardless of the type of publications, a total of 58 case studies have been published begun with just one study in 1996-2000 to 20 studies in 2011-2015 time-periods. This shows that case study has started to get attention as an alternative method to study technology roadmapping. Further descriptive analysis has found all types of publications have reached the highest peak in 2006-2010 time-periods. Although the numbers of publications in journals and proceedings have not much different over time, journals have replaced proceedings to be the most preferred type of publications after 2001-2005 time-periods. It can be concluded that knowledge on technology roadmapping was initially developed, discussed, and shared mainly in conferences (especially between 1991 and 2005) before started to gain popularity among wider group of scholars. This suggests that conferences are the effective platform to promote technology roadmapping. Similarly, although studies on technology roadmapping can be tracked back way before 1991, it was only becoming obvious in the radar after 1995. It is worth noting that all types of publications were suddenly dropped in 2011-2015 time-periods. This was believed to happen due to not all publications in the most recent time-period have been made available and recorded. Despite of that, the trend of all types of publications was relatively unchanged.

Publication Trends in Journals

A total of 15 main peer-reviewed and indexed journals are recorded in the analysis. With 48 articles, Technological Forecasting and Social Change is the most preferred journal for technology roadmapping, followed by Research-Technology Journal (19 articles), and

International Journal of Technology Intelligence and Planning (14 articles). In contrast, the other 12 journals only published 49 articles in total. Meanwhile, 165 articles were published in various journals under "others" category. Although Technological Forecasting and Social Change, Research-Technology Journal, and International Journal of Technology Intelligence and Planning are the top three journals for technology roadmapping, the trend was appeared to have slightly changed in the recent years. The findings have found that the total numbers of publications in both Research-Technology Journal, and International Journal of Technology Intelligence and Planning were declining in the recent years. In contrast, Technology Forecasting and Social Change has continued to be on the top of the list. At a meantime, Technology Analysis and Strategic Management has emerged to be the second most popular journal. In summary, various peer-reviewed and indexed journals have started to publish articles on technology roadmapping since 2001. However, most of these journals have published very few articles each.

Publication Trends in Proceedings

With 72 articles published in proceedings, it was very clear that the Portland International Conference on Management of Engineering and Technology (PICMET) is the top conference in the list. Other important conferences are the International Conference on Management of Technology (14 articles), IEEE International Engineering Management Conference (11 articles), and Waste Management Conference (10 articles). Meanwhile, half of the top conferences have been organized by IEEE, which make IEEE as the most active and important organizer of conferences. The findings have found top nine conferences for technology roadmapping, where PICMET that was initially very much at the same level with the other conferences in 1996-2000 time-periods has become the best conference for technology roadmapping and maintained the top place until now. The same trend was also observed for the International Conference on Management of Technology that maintained the second place in the recent years, but with much smaller numbers of articles. Meanwhile, with the last conference recorded in 2006-2010 time-periods, the IEEE International Engineering Management Conference has lost its third place to the R&D Management Conference in the recent years.

Publication Trends on International Context

All studies at the regional level, treaty, or economic bloc are classified under the international context. In details, there are three studies each focusing on Asia Pacific and Europe, two studies recorded on Pacific Northwest, and one study each in the context of EU-China, Latin America, Nordic, and North America. With the first study appeared in 1996-2000 time-periods, the findings have suggested very few studies been done on the international context. A detail inspection on the findings has found 10 of the studies were published in 2001-2005 and 2006-2010 time-periods. In contrast, there was only one study published, each before and after the above time-periods. Meanwhile, no study has attempted to look into the Africa context. This result could be implying that organizing a study at the international context is very challenging. In overall, it can be concluded that

most studies at this level continue to focus in the context of Asia Pacific, Europe, and Pacific Northwest.

Publication Trends on National Context

This context included studies that focus on the states, districts, and governmental agencies, institutions, and bodies at the national level. The attention at this level was only started to increase from 2001-2005 time-periods onwards with 18 studies in 10 countries, followed by 35 studies in 14 countries (2006-2010), and 23 studies also in 14 countries. In details, most studies were focused on China (11 studies) and Japan (10 studies), followed by the US (8 studies), and UK and Korea (7 studies each). Further inspection on the data has identified 51 studies performed in 10 developed countries, and 27 studies in eight developing countries. Therefore, the focus at this level is still inclined towards developed countries. In addition, studies at the national level were focusing at the western countries before shifted to Asia (i.e., China and Japan) from 2006 onwards. In fact, the studies were led by Japan in 2006-2010 time-periods, while China has taken the lead in 2011-2015 time-periods. Nevertheless, studies on the USA and UK remain relevant.

Publication Trends on Organizational Context

It was found that all firms studied in the analysis were either private or profit-oriented organizations. Four of these firms are USA origins, namely Cisco (with 1 study), Ford (1 study), Microsoft (1 study), and Motorola (3 studies). Accordingly, Shimano (1 study) and Sony (1 study) are the Japanese origins, while the other two are the European origins with Rolls-Royce (2 studies) in the UK and Siemens (4 studies) in Germany. Although the low numbers of studies on organizations may not necessarily means lacking of emphasis at the organizational level, more studies should have been done and reported to enhance our understanding on technology roadmapping at this level. The analysis has shown very few scholars have discussed and reported their studies on the specific organizations since pre-1991. In addition, these organizations have at least two similarities – they were all multi-national corporations, and founded in developed countries. As for this reason, there is so far no study has been done especially on the SMEs and in developing countries. Furthermore, study focusing on the non-technological or services organizations should also be explored.

Publication Trends on Key Themes

It was found that ICT (with 70 studies), innovation (55 studies), energy (48 studies), and sustainability (40 studies) are the top key themes of technology roadmapping, all of which are related to technology disciplines. In contrast, there were also five key themes with 10 and below publications, namely, semiconductor (10 studies), SMEs (10 studies), social (10 studies), risk (8 studies), consumer (4 studies), and financial (2 studies). At a meantime, semiconductor and nanotechnology have received less emphasis compared to the other

technological related themes. Nevertheless, these results also implying technology roadmapping is also relevant to non-technological related themes. Therefore, the non-technological related themes, such as knowledge, social, and finance which are growing between 2006 and 2010, should be continuously emphasized in future studies to further enhance our knowledge.

DISCUSSIONS

In general, the numbers of publications on technology roadmapping is on the growing side. In fact, the publications have been increased from just two studies reported in pre-1991 time-periods to five studies in 1991-1995, followed by 38 studies in 1996-2000, jumped to 168 studies in 2001-2005, and 305 studies in 2006-2010 time-periods. Although the numbers of publications were declined to just 181 in 2011-2015 time-periods, this could be happen due to not all studies in the recent years have made their ways into the lists. Nonetheless, following are the summary of key findings: Firstly, despite of being more than two decades in literature, most studies are still emphasizing on the conceptual or fundamental works. Secondly, there were almost 1:1 ratio between journals and conferences, suggesting their co-development functions on technology roadmapping. Thirdly, Technological Forecasting and Social Change is the top journal for technology roadmapping, and continue to dominate in the recent years. Fourthly, PICMET maintained to be the top conference, while IEEE appeared to be the top organizer. Fifthly, studies on international context were started significantly during the first decade of 21st century, but have seen to slow down in the recent time-periods (2011-2015). Sixthly, the emphasis at national level was only begun during 2001-2005 time-periods. Although China is leading the current numbers of studies, the overall focus are still towards developed countries. Seventhly, all studies on organizational context were dominated by the big corporations from developed countries. Lastly, key themes of studies were mainly interested on the technological related topics. However, future studies should also pay attention on the potentials of SMEs, developing countries, and non-technological related topics.

CONCLUSION

Technology roadmapping is a technique to capture information on evolving technology. As time passing by, hundreds of studies have been recorded in literature, which make this discipline well established in time. With abundant of publications, this study has attempted to identify the trends in technology roadmapping by analyzing the references with bibliometric analysis. In details, this study has found balanced numbers of articles published in both journals and proceedings. Notwithstanding that the analysis have found high variety of journals and proceedings, most articles were either published in Technological Forecasting and Social Change or presented in PICMET. Although the list of references was taken from a single source of database written in English, which has increased the consistency and quality of references, doing this has also limited the numbers of data to be analyzed. Nevertheless, since most studies were emphasized on developed countries, big corporations, and technological related themes, it was recommended that

future studies should shift the focus to developing countries, SEMs, and non-technological related topics.

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