

Framing Patent Indicators for Innovation Study

Peng-I Lee, Hsin-Ning Su

Graduate Institute of Technology Management, National Chung Hsing University, Taichung, Taiwan

Abstract--Patent indicators are increasingly used to assess competitive advantage or technology development trends for innovation studies. There are a number of patent indicators proposed in the literature to access such technology-based innovativeness. However, most of the studies arbitrarily select patent indicators for their investigations without optimizing the choice of indicators. Only a limited researchers attempt to classify patent indicators to assist the selection of indicators for diverse research objectives. In this paper, a novel framework structure is provided to frame patent indicators accepted in scientific literature after extensive review on patent related journal papers. The framework provides insights on comprehensive correlations as well as management implications of obtainable patent indicators. It is expected that this framework can be served as a channel for innovation studies to uncover much wider and systematic insights from the application of patent indicators.

I. INTRODUCTION

In recent years, the global competition is becoming increasingly fierce. In this fast-changing competitive markets, the new technologies serve as main drivers of firm growth and success. If the enterprise does not recognize the potential of new and disruptive technologies, it will leading the company be driven out of the market. Therefore, identifying and finding new technology opportunities by monitoring technological changes and analyzing technological innovation activities becomes an indispensable part of setting up a successful organizational strategy [1], [2]. Technological change has been found that it has a decisive influence on the competitive structure in many industries. It is said that innovation comes from a recombination of knowledge and the development of technology [3]. Sometimes, combining the knowledge with the different technology field and different industry has the possibility to bring new innovation [4]. In order to understand the degree of development of knowledge and technology, finding some suitable method to measure the intellectual capital is necessary. Intellectual Property is the output of knowledge activities and invention activities, it is an important tool that helps to improve the competitive position and the innovation of firms in the market [5]. For the above reasons, some studies mention that manage and use of intellectual property is quite important [6], [7].

Patent, as a kind of intellectual property, it not only can defend and safeguard the inventions of enterprises or inventors and bring about economic benefits [8], but also can use the data and information to measure or analyze the objective. The previous studies had shown that patents have several advantages to use as a technology indicator. First, in addition to being open information, patents also offer a plenty of detailed information, and comprehensive coverage of

technologies, enterprises and countries. Second, patents are the high reliability data and have a long time-series. Based on the above characteristics, patent information ought to have the big research potential. Until now, the patent information has been frequently used to study technological developments, technology potential and technology innovation [9], [10], or used in competitor monitoring and measured the technology portfolio [1]. In addition, patent information also can be used on related decision making and analyze the others innovation activities [11], [12]. Patents also can serve as an indicator of the innovation capability of countries, industries, or enterprises [10]. Through patent analysis, the researchers can identify and understand the trends in the industry and technology as well as the competitive power of enterprises or countries [13], [14].

The increasing research on measure different objective by using patent and being aware of the importance of innovation guided the research question explored in this paper. That question is: how to optimize the choice of indicators and endow them some management implications, as well as linking the patent indicators to innovation study?

According to the research, patent indicators are used across scientific disciplines and for a range of purposes—such as assessing the business activities, technological change and innovation performance or tracking the emergence of new technologies [14]. The past few years have seen a sharp increase in the use of patent-based indicators by scholars. However, most of the studies arbitrarily select patent indicators for their investigations without optimizing the choice of indicators. Only a limited researchers attempt to classify patent indicators to assist the selection of indicators for diverse research objectives. In this situation, the readers cannot quickly sorting out the indicators that they need and can be used, and they also may be confused about what objective can be measured by indicators.

Patent information, which are regarded as important sources of innovation and technology growth, are closely related to innovation strategies and R&D strategies, as well as data from patent registrations are frequently used in innovation studies. About the research by using the patent for innovation studies, some of the researchers had used the patent databases such as the USPTO, EPO, JPO to collect the data, and proposed three perspectives, innovation targets, participants and activities to study [15]. This kind of research discussed the characteristics of the databases and did the patent databases or information satisfy the conditions for use in innovation studies. There were also some researchers studied on the use of patent indicators, such as analyze the technology of specific industry [16] or the innovation capability of the country [17], etc. However, although discussion the related issues by using patent data and

individual indicators has been frequently researching, but there are still limited researchers attempt to classify patent indicators to assist the selection of indicators for diverse research objectives. In this study, it will focus on optimizing the choice of indicators, and link it with the technology management as well as innovation activities.

This study optimizing the choice of indicators by a systematic framework, the user may comprehend the indicators can be used to measure what kind of objectives, and obtain relevant management implications. The aim of the paper is to present a framework of patent indicators that can significantly improve the convenience of assessment and give users useful suggestions.

In this paper, it will using some management activities process to link the frequently used patent indicators and point their management implications. In order to discuss the indicators from different angles, we also explore the relevance of patent indicators and the five technology management activities. Furthermore, we expected that the framework can be served as a channel for innovation studies to uncover much wider and systematic insights from the application of patent indicators.

The remainder of this paper is structured as follows. Section 2 examines the literature review of this research, we discuss different kinds of innovation and patent related literature. Section 3 presents this study's data and method. The result and discussion of the study are derived in Section 4. Finally, section 6 describes this study's contribution and possible future research directions and offers some conclusions.

II. LITERATURE REVIEW

A. Discussion of the technical innovation

Definitions of innovation are different, but generally emphasize the commercialization of new knowledge or technology to produce increased sales or business value [18], [19]. In this highly competitive business environment, technological innovation is not only one of the causes of economic growth [20], [21] but also an important factor for sustainable development of companies. Therefore, innovation has become the main basis of productivity improvements, sales growth, and a company's competitiveness [22], any technology strategy ignoring these aspects of the innovation can have grievous strategy results. In view of this, it increases the importance of innovative behavior. So, the innovation has been a primary concern issue by many industries, link the innovation to company performance has been studied extensively [23], [24] and research has also analyzed innovation at multiple levels.

The literature has mentioned, successful innovation depends on technological, strategic and market-related [19], especially depends on the technology research and development [25], [26]. On the other hand, through correction of the strategy and under continual innovation, the business advantage and the competitive position of the companies will be sustained [22], [27]. Increasing global

competitive pressures are also forcing companies to continuously develop and innovate to improve competitiveness [28]. For these reasons and the short life cycles of the product as well as the technologies are easy to imitate, a company must upgrade its innovation capability for developing and promoting new technologies more rapidly than other companies and competitions, also, it must facilitate the creation and dissemination of technological innovations within its organization to strengthen its competitive advantage [22].

B. Analyze innovation by the patent data

Innovation usually related to technology R&D and corporate strategy. The technological innovation of companies usually has the inseparable relationship with the intellectual property that they had [29]. Patent, as a part of the intellectual properties, is suitable for measuring the technology capabilities and innovation performance of corporations [30], moreover, the previous studies indicate that patents can properly reflect technological performance of companies, sectors or countries [31], [32] because patents are one output of technologically successful R&D activities [33]. Patents are one of the most prevalent measures of innovation, and there are some good reason: patent data are not only easy to search but also measure in an objective way, and the researchers often can get long-term data to display plenty information and are classified in categories according to technology fields [34]–[36]. Although there are many difficulties and reservations, patent data is still a unique and useful resource for the study of technical change [37]. The measure of companies' technological activities based on patent data presents many advantages [38].

For the above reasons, there are more and more researchers and firms use the patent data to achieve their own objectives [14]. For instance, the information in patent data can be used for developing strategic planning by the companies [1], and the patenting provides a good indicator of companies' innovative capacity[36].

C. Promoting innovation with patent indicators

The past decades have seen a big increase in the use of patent-based indicators by researchers and scholars. Patent data are used across scientific disciplines and for various purposes, such as assessing a country or company's innovation performance or tracking the emergence of new technologies. However, a large number of data sources and different counting methodologies bring out multifarious indicators [14]. Since Holger Ernst had summarized several important and essential patent-based indicators that can be used to analyze companies' patenting strategies [1], the patent indicators he defined had been frequently used on following researches that are related to patent strategy or even extended to another research field. According to counting the use of patent indicators on each research field, It can be found that the 'number of patents', 'patent citation' and 'patent application' are the indicators that are most commonly be used to evaluate the research objectives. Research objectives

can be roughly into the following categories: Measure the different industries corporate performance and strategy [1], [39], explore the flow of knowledge [40], [41], [35], analyze the countries or companies’ technology development and innovation activities [42], [43], etc. However, even the researchers frequent use these three patent indicators to analyze so many objectives, their most and final important objective are to find the possibilities of innovation and also surmounts others.

III. DATA AND METHOD

A. Data

The relevant patent indicators for analysis were obtained from retrieved literature by using keywords 'patent indicator' and 'patent index' in top ten journals of technology management ('Research Policy', 'R&D Management', 'IEEE Transactions on Engineering Management', 'Research Technology Management', 'Journal of Product Innovation Management', 'Technovation', 'Technology Analysis and Strategic Management', 'Technological Forecasting and Social Change', 'Journal of Engineering and Technology Management' and 'International Journal of Technology Management')from ‘WEB OF SCIENCE’ since 1992 to 2015. However, by searching the keyword 'patent indicator' in 'Technology Analysis and Strategic Management', we found no related literature, so in the research, this journal will be ignored. Finally, about the number of searching literature, we found a hundred sixty from the rest of nine journals.

We summarize those frequently used patent indicators from the literature that had be search, such as the basic indicators like “number of patents”, “patent application” and “patent citation” or the indicators that can be used to measure the technologies related information, for instance, “patent growth rate”, “technical scope”, “relative patent position”, “revealed technology advantage”, “relative patent growth”, “patent granted”, “technology strength” and “patenting activity”. In order to give these indicators systematic classification and link the indicators with innovation study at the end, we attempt to find the possible assessment methods from the literature and then improve it to fit this study.

B. Method

As we know one reason for generating innovation is to manage and develop the intellectual output, as a kind of knowledge output, patent is easy to search and have the legally valid. From the discussion of previous studies, patent data are a valuable information source, and patent information can be using as a core component of knowledge management that allow decision makers making appropriate decisions [1].

This study attempt to link the patent indicators with management implications and further influence to innovation behavior. About the definition of management implications, the first seven we were consulting and extending from the management implications that identified by Ernst [1] (2003). These seven management implications investigated various important components that related to patent activities. It had demonstrated the different aspects that can be measure by patent data. However, as the global competition increasingly fierce, the internationalization issues such as international R&D collaboration and cross-country patent activity has been attached great importance in recent years. The research that were exploring about the relevance of Internationalization and innovation activities has been increased [44, pp. 1980–2005], [45], [46]. Based on the above reasons about the importance of internationalization, we decide to add the international that including co-inventor and cross-border R&D cooperation as the eighth management implication.

IV. RESULT AND DISCUSSION

A. Discussion of data and method

Through calculate the patent indicator related literature issue number since 1992 to 2015, we found that the literature has increased year after year (Figure 1). It is represent the research about patent indicators are gradually being taken seriously by the researchers, we can see more and more researchers focus in this research areas. In addition, the proportion of literature we selected from Top 10 Journals of technology management are shown in Table 1. After computing the proportion of these ten journals, it displays that 'Research Policy' has the highest percentage as the result, and relatively speaking, there is still no relevant research in 'Technology Analysis and Strategic Management'.

TABLE 1. THE PERCENTAGE OF TEN JOURNALS LITERATURE

Journal Title	Amount	(%)
Research Policy	71	44%
R&D Management	8	5%
IEEE Transactions on Engineering Management	5	3%
Research Technology Management	1	1%
Journal of Product Innovation Management	3	2%
Technovation	25	16%
Technology Analysis and Strategic Management	0	0%
Technological Forecasting and Social Change	40	25%
Journal of Engineering and Technology Management	4	3%
International Journal of Technology Management	3	2%
Total	160	100%

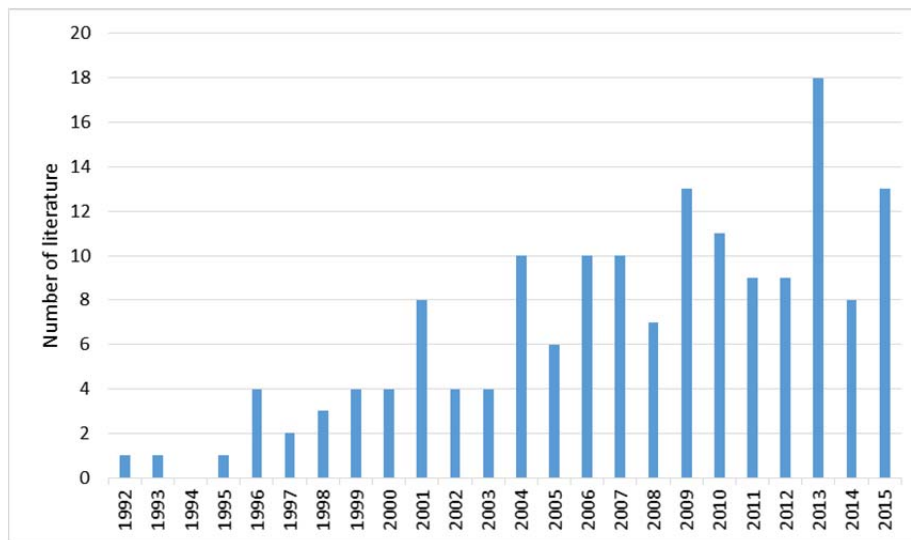


Figure 1. The number of literature in the period 1992–2015

About the research methods of this study, the final framework has contained eight management implications, as follows:

(1) To assess the own technology portfolio and compare with the competition

In this competitive era, in order to run the business successfully, to understand the own technology portfolio and technical conditions will be necessary [11], [47]–[51]. For the purpose of chosen the right technology to increase investment and let the competitive position be better than competitor, some research has used several indicators to solve the problem [52], such as "number of patent" and "patent application" can show that which of the technologies has been invested more, and by using "patent growth rate" can let them know the important technologies in the industry, on the other hand, this indicators also show the technology development trend of the industry, furthermore, the analysts may have a chance to find out the direction of innovation of their companies. In addition, "patent citation" and "technical scope" can present the own technologies quality and are value [50]. Moreover, "patent citation" also can analyze who is the leader of this technology. In summary, based on the above information, the company can find some method to develop their technology portfolio.

(2) To assess the attractiveness of technologies

Attractive of the technology can let companies know which technology has more companies invest in and which technology is more important [53]. Only the important technology need to be continuing development and finding a way to innovation [54]. In addition to using "number of patent" to realize which technology has already been researched more, the attractiveness of each technological field can be measured by using "relative growth rates" of patent and "patent applications". The

higher relative patent growth rate is mean the technology has more attractive [11].

(3) To recognize strategic changes in the firm's competitive environment

In the era of global competition, companies in response to the environment change will change their strategy in order to survive in the current market or let the direction of innovation meet the demand of the companies [55]–[57]. For the purpose of understanding strategic changes of firms, this study has sorted out the relevant indicators as a reference. "Patent application" can know the trend of future market change, therefore, enterprises can prepare in advance [58]. "Patent citation" can track the root of technological, and will change the referenced technical field with the advent of new technologies. "Patent growth rate" can directly see the trend of the market, the number of patents will increase in high demand areas and vice versa.

(4) To identify and evaluate external sources for knowledge generation

The source of knowledge is not only from the organization inside, some of the new technology and knowledge will also come from outside [35], [59]–[61]. Generally, flow of knowledge can be finding out from the patent information. Through analyzing the "number of patent", "patent granted" and "patent application", the technology that industry focus on will be shown, and the researchers also can found out which technology has been increased research. Finally, by "patent citation", the companies can cited the important patents or get the knowledge from outside, and by further discuss, it will have the possibility to develop the new technology or do the innovation activities.

(5) To assess the new business areas patent activities which may be explored

Patent activities can support the assessment of the company's strategy [1], [50], [62]–[65]. Companies can

analyze the situations such as: does the company's technology has the competitive advantage in the new business areas, and is their competitive technological position good or not. By measure the patent activities of the companies, the managers may aware the opportunities and the shortages of their companies technology.

(6) To evaluate important technology partners and determine is the firms R&D strategy targeting to its major customers

As the importance of R&D cooperation has increased, partner selection has become an important strategic issue for firms [66]–[68]. Choosing the technology partners that meet the company's needs can promote the technology growth of the company and collaborative R&D has been considered a useful measure of technology acquisition [69][70]. In addition, collaborative R&D also may be a chance to generate innovative ideas. Finally, after chosen the partners, determine the company's R&D strategy targeting to its major customers is very important. The previous study has used "patenting activity" and "technology strength" to discuss this kind of issue [71]. Through this two indicators, the company can realize which technology did they focus on and who is the suitable partner in this technology field.

(7) To improve leading inventors management in specific technological fields

Technological innovation is an important source of competitiveness of companies, and technology R&D is originated from the inventors, so the management of the inventors are quite important. In order to measure the quality of inventor's invention output and which technical fields is worth more investing by the company, some researchers had already attempted to use the patent

information and indicators to analyze, such as "patent citation" and "patent application" [72]–[74]. "Patent citation" shows the value of the patent and the invention, the company can use it to measure whether to invest more. "Patent application" is an indicator that reveals the trend and the objective of the company's R&D.

(8) Discuss the international strategy that including co-inventor and cross-border R&D cooperation

Internationalization of the company and cross-border R&D cooperation may have the chance to improve the competitiveness of the company [44, pp. 1980–2005], [46], [75]. In this situation, different companies R&D cooperation may have a chance to let two companies techno-complementarity and increase the opportunities for their technology growth. Finally, it will lead the companies competition be improved. The researcher has used the "number of patents" and "patent application" to measure how many technologies and patents were producing by co-inventor and from cross-border R&D cooperation [45]. On the other hand, by using "patent citation", the researchers can found out are this kind of technologies and patents valuable or not.

Figure 2 provides a graphical overview of the main management implications that used to classify the patent indicators in this study. In this study, we designed a framework by using these eight management implications, the composition principle is based on organizations business activities, the direction of the arrow in dotted line has shown the activities that from organization inside to outside, by using this framework, we want to give the patent indicators more detailed classification. In this framework, we summarize some important and common use indicators that select from literature, and in this study, we discard the indicators that were rarely used in the literature we searched.

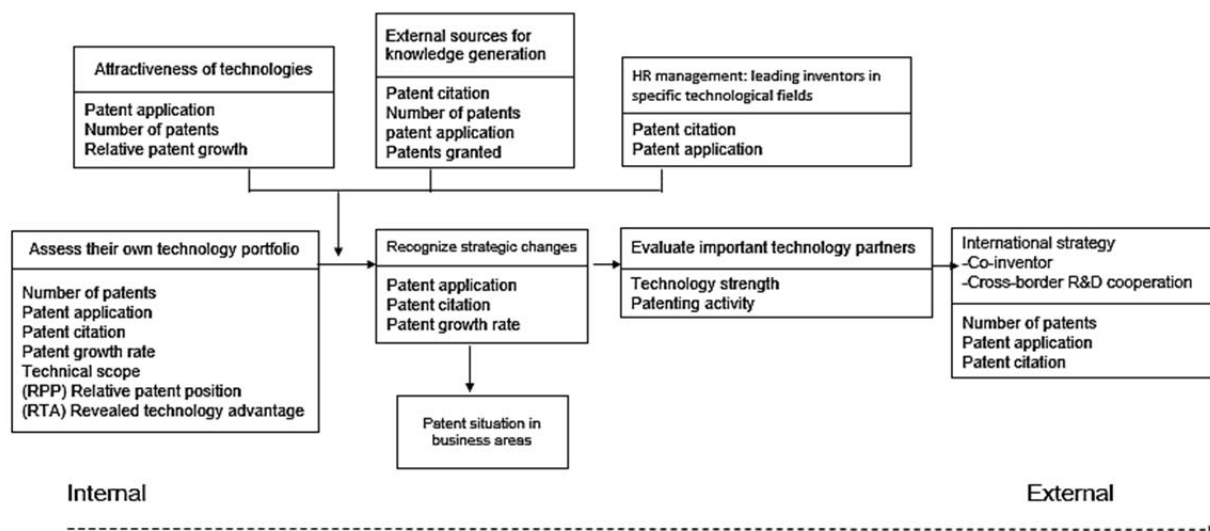


Figure 2. The Integrative Framework of Patent Indicator-based Research

In this situation, we can see there are some indicators appearing repeatedly in our framework, it is because this kind of indicators are more fundamental and multipurpose, they can be used for many different purposes, so a lot of researchers had used them to measure or analyze their own objectives. In this framework, by using these indicators to measure each objective, the researchers may get the different and useful suggestion that related these eight activities. Or even further, by analyzing the technology development and knowledge dynamics of the organization, it has the possibility that can promote the innovation activities be occurred. In this framework, patent indicators need to be used as a tool that helps the strategic making and further affect the companies' innovation activities, which contributes important information to the effective and efficient management of technology and innovation.

B. Classification into technology management activities

In addition to classifying the patent indicators by eight management implications, we also attempt to understand patent indicators by important technology management activities. An advantage of the technology management is its applicability to all companies regardless of their size, for this reason, using technical perspective to manage technology-related issues had been discussed by the researchers in the past few years. Technology management is based on the idea that technology is a key resource of the companies, by effective technology management and technological capabilities developed, a company can let the technological knowledge turned into products, processes and services. Gregory's study suggests that there are five basic processes need to be considered when the manager is managing technology: identification, selection, acquisition, exploitation and protection [76] and these five processes also has been frequently used in subsequent research [77][78]. This study attempts to link the collected patent indicators to this five important technology management activities. The purpose is to understand the current indicators research progress and the future further advancement of the present analysis.

(1) Identification of technologies

Identification of technologies are to uncover key technologies to be used to develop core competence based on which products or services can be provided. The identification of technologies from patent database require tactical patent search by the use of keyword query or patent classification which cannot be simply completed by the use of patent indicators.

(2) Selection of technologies

Selection involves the choice of technologies that need to be supported and promoted in the organization, it is a process of decision-making that needs to consider relevant strategic issues, which requires effective assessment or appraisal capacity. Select suitable patented technologies to be developed for building or defending competitive advantages in order to create values based

on the selected patents. A proper selection process is based on the following criteria: 1) awareness of key technologies, 2) motivation of developing selected technologies, 3) estimation of necessary resources. The above three criteria also cannot be completed by patent indicators but significantly relies on the development strategy of who selects the technologies.

(3) Acquisition of selected technologies

There are several ways to acquire the selected technologies, but they can be divided into two types: Technologies may be acquired internally or acquired externally. When technologies acquired from internal, most of them through conventional R&D activities or organizational knowledge creation. But when technologies acquired from external, through licensing and joint venture arrangements, or cooperate with the technology owners that have an interest in developing the technology are the general method to acquire external technologies. No matter how, based on the cost considerations, companies will only attempt to acquire the valuable technology and patent. By using patent indicator such as patent citation, it can shows the importance and value of the technology and patent, and provide a decision basis for manager. Because of the patent indicator only can used to determine the value of patents or technology and cannot completed the acquisition of technologies, so in this part, the patent indicators cannot be directly use, but it still can be used as an auxiliary.

(4) Exploitation of technologies

Exploitation of technologies refers to commercialize the technology and it is also a kind of managerial function. An efficient technology development system should be constituted by decision system, execution system, information system, and support system. Through the technology development activities, the owner of the technology is possible to use it to create the competitive advantage, maintain core competencies or become an opportunity to innovation. Strategic planning of technological development can be supported by analyzing the patent data and using patent indicators, the frequently used indicator to measure the exploitation of technologies in the literature had been shown on Table 2. Although all these five patent indicators can be used to analyze the technical developments, but "number of patents", "patent citation", and "patent application" usage count were far higher than others. The one reason is that these three patent indicators can directly help managers to assess the technologies usefulness, originality, and the relevance of an innovation, they can show that do the patents and technologies have great developing value or not [50]. And the other reason is because both these three data were relatively easy to obtain. There are still some patent indicators can be used in this part, such as "technology cycle time" and "patent growth rate", "patent growth rate" shows the annual

patent or technology growth and the development trend [79], then, about "technology cycle time", it can let the users to understand how long the technology or patent will be replaced and also find out the level of competition in this area, it allowing users to consult the necessity of developing the technology and join the competition [80]–[83].

(5) Protection of knowledge

Protection of knowledge is concerned with the preservation of the knowledge and expertise that are embedded in products, technology, and manufacturing systems. In the traditional, to achieve this capability, protection has been obtained through legal routes, such as patenting and licensing. Patent protection should always be considered by an inventor during the initial stages of their invention. A patent right is an exclusive right to an invention, it is the right to prevent others from commercially making, using, selling, importing, or distributing a patented invention without permission [84]–[86]. Patents also can be used for other purposes, such as blocking competitors by obtaining wider patent protection than truly required, or improving the company's position in negotiations with other firms. In summary, patent itself, is a kind of legal protection to technical knowledge and innovation, so the user do not need to use the patent indicators in this part.

As we mentioned in literature review, definitions of innovation are different, but no matter how, the ultimate goal of innovation is to enhance competitiveness and let the organization continuing operations. Innovation activities have been measured from various perspectives. Although we had discussed some management activities, however, in this study, we paid more attention to the technical activities and technological innovation, because the patent-based indicators can reflect more information about technical aspects.

Synthesizing our research results, we found that by the above research methods, our findings can broadly serve to present an enterprise-level analysis of innovation that could be used by decision-makers in the company itself to consider its innovation or R&D strategies. In addition, the choice of

indicators also can be optimizing by the eight management implications and the ISAEP activities.

V. CONCLUSION

After searching the relative literature of patent indicators from journals, patent indicators that were frequently used were identified from literature. The final objective of this study was to optimizing the choice of indicators and provides insights on correlations as well as management implications of obtainable patent indicators, and ultimately to connect them with eight management implications, five important technology management activities and innovation studies. In conclusion, this study provides much wider and systematic insights from the application of patent indicators.

As mentioned in this study, about the eight management implications that we used to frame the patent indicators as our research method, seven of them were consulting from the management implications that identified by Ernst (2003), and one of them were extending and adding by this study. Moreover, we also have a further discussion of the indicators on the result and discussion part by using the five technology management activities. However, these above two research framework have some deficiencies, they led to the scope of the study be limited in the enterprise level and the technical level. If the future studies want to explore a wide range of circumstances, the new research component will need to be add in.

The Integrative Framework of Patent Indicator-based Research is proposed in this study to summarize those frequently used patent indicators obtained from scientific journals. This study attempts to uncover management implications for patent indicators as well as connect the framework with technology management activities. Furthermore, the framework (Fig. 2) and Technology Management activities help optimize the selection of patent indicators in a systematic ways. In other words, the framework improves effectiveness and efficiency of patent indicators-based investigation on business and innovation activities.

TABLE 2. CLASSIFY PATENT INDICATORS INTO TECHNOLOGY MANAGEMENT ACTIVITIES

Technology Management Activities	Patent indicators used in the literature
Identification of technologies	Lack of patent indicators in current research
Selection of technologies	Lack of patent indicators in current research
Acquisition of selected technologies	Lack of direct patent indicators to calculate, but patents can be used as indirect indicators
Exploitation of technologies	(1) Number of Patents (2) Patent citation (3) Patent application (4) TCT (5) Patent growth rate
Protection of knowledge	Patent protection: Patent itself give legal protection to the knowledge and innovation

Despite all these meaningful contributions, this research has the limitations that indicate the need for future research. The limitation pertains to diversity of indicators. In this study, we select the indicators from top 10 journals of technology management by using keyword 'patent indicator', it only let us obtain the indicators that commonly used in the researches and indirectly led the indicators that mentioned in this study were not very exhaustive.

Through the above structure of five important technology management activities (Table 2), we can be seen that only exploitation and protection part have been researched and analyzed by patent indicators, the other three activities have not yet been explored, so we suggest the future research can attempt to investigate this area and further study of the relationship between patents information and ISAEP.

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