BENCHMARKING TECHNOLOGICAL COMPETITIVENESS OF PRECAST CONSTRUCTION THROUGH PATENT MAP ANALYSIS

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Abstract: Technological advancement plays a key role in business competitiveness of a construction firm in the market. Nowadays, there are many free patent databases worldwide, which provide important sources for information of the technological advancement of construction firms. By combination of patent mapping techniques and properly selected commercial patent analysis software, the knowledge of technological competitiveness from patent databases can be discovered. With such knowledge, the construction firm can benchmark its own technological competitiveness with other competitors'. As a result, better technology innovation strategies and appropriate investment portfolio are determined. In this paper, the patented precast construction technology (PCT) adopted in construction of high-tech plants are considered for analysis. The patent map analysis (PMA) techniques are employed for the analysis. The USPTO patent database is used as the major source for analysis; other databases such as WIPO and TAPAT are for supplement. A local leading PCT firm is selected for case study. The results of case study show potentials of patent mapping techniques in planning technological innovative strategies.
Keywords: Patent analysis, Patent maps, Technology innovation, Precast construction

1. MAJOR HEADING

According to the statistics of WIPO for economically valuable human innovation results, 90~95% are retained in patent databases [1, 3]. The patent databases provide information of advanced technologies, including construction technologies, which constitute core competitiveness of the firms. Patent analysis techniques, such as patent search techniques and patent maps, offer powerful tools for analyzing intellectual property (IP) capacity and strength of a construction firm in specific domain. Such IP information depicts not only the technology competitiveness but also the innovation strategy of the firm in a period of time. Moreover, by analyzing IP information of the major competitors, the construction firm can determine appropriate patent portfolio and identify the most appropriate areas for innovation investment, so that valuable corporate resources are optimally utilized and competitive strength of the firm is improved.

This paper will show how to utilize the combination of free patent databases and a specific patent analysis software to perform patent analysis tasks, and how to interpret the results of patent analysis for technological competitiveness analysis among construction firms in high-tech precast construction technology (PCT) domain. Specific commercial patent analysis software named PatentGuider® [2] provided by Learning Tech Inc. is adopted for analysis of IP information retrieved from major internet IP databases such as WIPO [3], USPTO [4], EPO[5], JPO [6], and TWPAT [7]. A specific domain of PCT for High-Tech construction project is selected for case study. A local leading construction firm, R. Construction Inc. (RCI), is selected as the target firm for benchmarking with other international leading High-Tech manufacturing factory construction firms from US, Japan, and Taiwan. Various patent analysis techniques such as Patent counts analysis (PCA), Country analysis (CA), Assignee analysis (AA), Citation rate analysis (CRA), and International Patent Classification analysis (IPCA) are employed to compare the technological competitiveness between the leading PCT firms from Japan and US with the target firm.

Innovative strategies are recommended according to the current technological status reflected in the patent maps. As a result, the technology innovation investment and appropriate patent portfolio are suggested in the direction that optimizes the firm's technology competitiveness. It is found that patent map analysis provides a useful and systematic approach for corporate technology innovation strategy planning.

The rest of the paper will be presented in the following manner: the patent map analysis techniques used as the major research methodology in this paper is described in Section 2; the PCT is briefly reviewed in Section 3; Section 4 presents a case study of precast technology competitiveness benchmarking using patent map analysis techniques; finally, conclusions are drawn in Section 5.

2. PATENT MAP ANALYSIS (PMA)

Patent statistics has been used to reflect the technological innovation levels for a country, an industry, and a firm [8]. Many technological strategy planning methods have adopted patent statistics as a useful tool [9]. As a result, various patent analysis techniques have been developed. The patent strategy aims to find out the connection between technology advancement and economic growth [10]. Others

considered patent strategy as a vehicle to figure out the processes of technology innovations by enterprises [11, 12]. The major methodology adopted in this research is patent mapping analysis to discovered trends and patterns in construction related patents.

The tool adopted for patent search and analysis in this research is the commercial patent analysis software, Patent Guider V. 2.0 provided by LearningTech Inc. [2], to facilitate the search for PCT patents. The on-line databases employed for patent search including USPTO [4] (as major source), WIPO [3] and TWPAT [7] (as complementary sources). The patent search used "precast" and "prefabricate" keywords and their variations as the basis for preliminary search in the "Title" and"Abstract" of the records of the three databases mentioned above. The obtained patent records are then reviewed to identify their International Patent Classification (IPC) classes. The resulted IPC classes are grouped to determine key categories of PCTs. Such categories form the basis for patent map analysis. The search was conducted from March to May of 2006. The patent map analyses consist of: (1) patent count analysis (PCA)—counting the quantity of patents includes the technology life cycle chart and the patent quantity comparison chart (the application date and issue date); (2) country analysis (CA)—comparing the patents from various countries; (3) assignee analysis (AA)—comparing detailed data on R&D, citation ratio, cross-citation, event charts, ranking chart, and competitors; (4) citation rate analysis (CRA)—comparing the number of citations made by other patents during its valid period; and IPC (International Patent Classification) analysis (IPCA)—including IPC patent activity chart and No. of IPC patents of competitor companies.

3. HIGH-TECH MANUFACTURING PRECAST CONSTRUCTION TECHNOLOGY

Precast structures have experienced extremely cost effective, durable, stable, and of the highest quality and strength. This section reviews several important features of PCT.

3.1 Applicability of PCT

There has been misconception that PCT lacks flexibility. In fact, irregular and challenging architectural designs on many occasions have been successfully constructed by PCTs. Theoretically there are no restrictions on the use of skeletal framed precast construction. Within the Victorian market, for example, it has been found that the niche market for this type of construction is in multi level buildings, where the site can be readily accessed and erection can be carried out by mobile crane [13].

3.2 Advantages of PCT

Following are a number of advantages of precast construction.

(1) Speed of Construction—PCT allows not only the speedy erection of the structure, but also flexibility and overall project shortening. This is achieved by allowing the production of components simultaneously while the footing system is being prepared. Minimum amount of supporting allows all trades to commence work on the structure earlier than conventional construction methods.
(2) Off-site Manufacture—manufacturing of the major components of the building off-site reduces the site labor component and working space, which in turn, reduces site costs and time.
(3) Quality Control—production of components off-site, in a factory environment allows each of the facets involved in manufacturing to be strictly controlled and resulted in best quality.
(4) Appearance and Finishes—factory produced precast components can be produced with a wide range of finishes, including colors, surface finishes and carefully molded surfaces allow the designer considerable flexibility in the overall aesthetic appearance of a structure compared with conventional methods.

3.3 Development of Precast Technology in Taiwan

The early development of PCT in Taiwan encounters several difficulties such as the requirement of seismic-resistant design, the complexity in fabrication of the precast products, and the lack of knowledge on the concept of precast fabrication and construction. However, several construction firms have invested tremendous efforts in innovation of precast technologies. Some of the firms even export their technologies overseas to other countries such Singapore and China. The current precast technology used in buildings in Taiwan is the partial PCT method. It typically involves precast beam and columns combined with cast-in-place beam-column connections, slabs, and other non-critical components. It has been applied in the construction of shopping malls, the high-tech plants (including the waffle slabs), the administration office buildings, and the parking towers. The construction speed of a building structure can be as fast as one floor per three days. For waffle slab, 1000m2 per day can be achieved. The partial construction method developed is currently the fastest construction method in Taiwan. In the future, more research effort will be concentrated on complete precast/prestressed systems.

4. CASE STUDY

4.1 Background of Case Construction Firm

(1) Company background

The patent map analysis techniques described in Section 2 are employed to analyze the technological competitiveness of precast technologies of a local construction firm—R. Construction Inc. (RCI). RCI is a member of the R. Groups, an international enterprise comprising of six business groups: (1) textile garment retail business group; (2) construction and development business group; (3) finance business group; (4) distribution business group; (5) medical services group; and (6)

education group. The R. Construction and Development Business Group consists of 10 business units including two developers, two A/E firms, three contractors (including RCI), two facility management firms, and one community management firm. The annual volume of the R. Groups exceeds 4 billions USD.

(2) Technology background

In the recent years, RCI has specialized in the development and application of PCTs for high-tech plants, and experienced great success. According to the internal report of RCI, the schedule of high-tech plant construction project can be shortened from 8 (with traditional construction method) to 5 months with their advanced PCTs. This has been a great competitiveness in high-tech construction market, since the shorten schedule means not only save of the interest for investment but also early production and greater market share in high-tech product market.

Table 1 IPC classes of precast technologies of RCI

IPC class	Class description
E02D005/20	Bulkheads, piles, or other structural elements specially adapted to foundation engineering.
E04B001/04	Constructions in general; Structures which are not restricted either to walls, e.g. partitions, or floors or ceilings or roofs.
E04B001/08	
E04B001/21	
E04B001/41	
E04B001/92	
E04B002/00	Walls, e.g. partitions, for buildings; Wall construction with regard to insulation; Connections specially adapted to walls.
E04B002/82	
E04B002/88	
E04B005/02	Floors; Floor construction with regard to insulation; Connections specially adapted therefor.
E04B005/23	
E04C003/20	Structural elongated elements designed for load-supporting.
E04C003/34	
E04C005/01	Reinforcing elements, e.g. for concrete; Auxiliary elements therefor.
E04C005/16	
E04F017/08	Vertical ducts; Channels, e.g. for drainage.
E04G011/04	Forms, shutterings, or falsework for making walls, floors, ceilings, or roofs.
E04G011/36	
E04G011/54	
E04G017/06	Connecting or other auxiliary members for forms, falsework structures, or shutterings

The PCTs developed by RCI is so-called “partial PCT method”, which basically precast the beams and columns first and then cast-in-place beam-column connections, slabs, and other non-critical components. More than 80 patented precast technologies have been developed by RCI. The patents are classified into 20 IPC classes. Descriptions of the 20 classes are shown in Table 1. This research will compare the precast technologies of RCI with other competitors based on the above 20 IPC classes. The USPTO will be employed as the major source for patent search. WIPO and TWPAT will be used as supplements.

4.2 Patent counts analysis (PCA)

The objective of PCA is to predict the trend of technology development. PCA includes the technology life cycle chart and the patent quantity comparison chart.

(1) Technology life cycle chart (TLCC)

Figure 1 show the TLCC of PCT As shown in Figure 1, the number of patents and patent holders has been on a rising curve since 1988, showing fluctuation around 1992 and 2001. After 1998, the number of patent and patent owners has deceased. The decreased precast technology patent application might reflect the recession of PCT development.

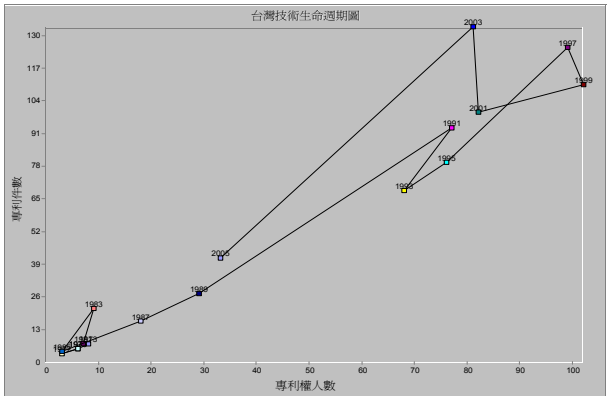

Figure 1 Technology life cycle chart (TWPAT)

While searching USPTO, a similar trend is discovered that the PCT patents declines after 1998 (see Figure 2), showing that the current PCT development has faced a bottleneck.

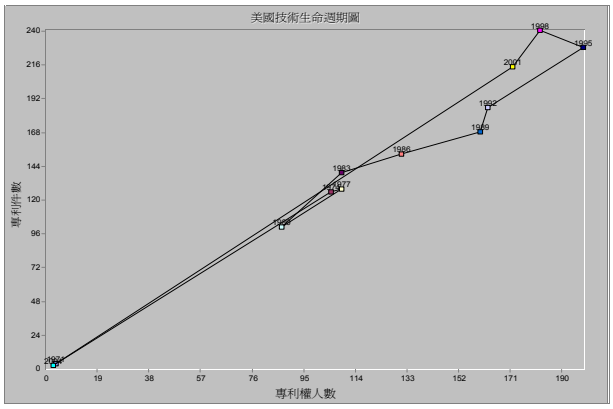

Figure 2 Technology life cycle chart (USPTO)

(2) Patent quantity comparison chart (the application date and issue date)

As shown in Figure 3, the number of PCT patents reached 748 in Taiwan from 1991 to 2005, with the peaks in 1998 of 64 announcements, followed by 62 in 2000. The least number of patents occurred in 1991 & 1994. By the end of 2005, the number of patents had decreased after reaching its peaks in 1998. The curve is skewed toward the left.

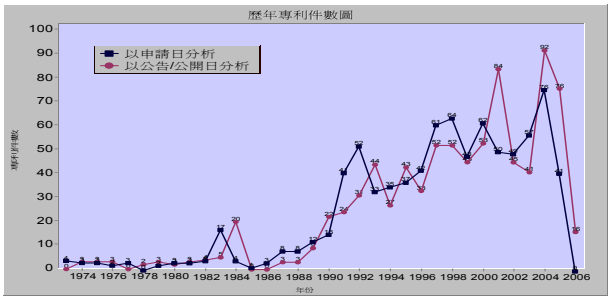

Figure 3 Patent counts comparison chart (TWPAT)

4.3 Country analysis (CA)

As shown in Table 2, the U.S. ranks number one with 661 patents, followed by Canada with 280 and Japan with 86. Taiwan is ranked 11th, the number of patents (21) is far below the top three countries.

Table 2 Assignee country analysis (USPTO)

Country	Patent Counts	Assignee Counts
USA	661	489
Canada	280	219
Japan	86	67
Israel	85	57
Germany	84	65
Panama	60	37
France	53	44
Australia	39	33
W. Indonesia Is.	28	19
Switzerland	27	20
Taiwan	21	18

4.4 Assignee analysis (AA)

The assignee analysis compares detailed data on R&D, citation rate, detailed data on citation, cross-citation, event charts, ranking chart, and competitors.

Table 3 Detailed data on R&D capability (USPTO)

Company	Patent Counts	Activity Years	Number of Countries	Inventor Counts	Patent Age
National Gypsum Company	14	10	1	10	22
Steelcase Development Inc.	13	2	1	41	8
USG Interiors, Inc.	9	6	1	10	6
Fischer/Artur	9	5	2	2	30
Herman Miller, Inc.	8	5	1	14	16
RCI*	51	6	2	5	3

* Data of TWPAT

(1) Detailed data on R&D capability

As shown in Table 3, National Gypsum Company with 14 patents and Steelcase Development Inc. with 13 patents, rank the top two. The "activity-years" refers to the average time from patent filing to the present. The activity years of the National Gypsum Company are 10 years, which is the highest in the table. The number of investors in Steelcase Development Inc. is 40, which shows sufficient R&D researchers in that firm. The average age of patents in Fischer/Artur is 30 years, the highest compared to the others, showing that the effective period is relatively long. Compared with US PCT leading firms, RCI is active recent year in PCT patents. However, both the inventors and patent age of RCI are low. It means that the research capacity and patent effectiveness may not be sufficient.

(2) Citation rate analysis

Citation rate refers to the total number of citations on the patent and/or the number of patents of the assignee. Technology impendence refers to the number of citations on the patent by itself and/or the total number of citations on the patent (by either itself or others). Citation rate indicates the quality of the patents. High citation rate means that the patents of the assignee are cited frequently and of high quality. As shown in Table 4, the citation rate for Herman Miller, Inc. is the highest, at 3.25, followed by and National Gypsum Company, at 2.28. Obviously, the quality of the patent by these two companies is superior to other assignees. RCI's patents seem not significant due to the short age.

Technology independence indicates the technology difference between the firm and others. As the company gains more technology independence, the R&D of the company becomes more independent, and has fewer competitors. As shown in Table 5, the technology independence of some companies is zero; it means that these companies develop patents depending on others.

Table 4 Citation ratio analysis (USPTO)

Assignee Name	Citations	Technological Independence
Fischer/Artur	1	0.556
Herman Miller, Inc.	3.25	0
National Gypsum Company	2.286	0.063
Steelcase Development Inc.	0.385	0
USG Interiors, Inc.	0.778	0.143
RCI*	0	0

* Data of TWPAT

As shown in Table 5, National Gypsum Company, as the technology leader, has 32 citations, of which, only 2 are self-citations, and 30 are cited by others. Thus, the patent quality of National Gypsum Company is relatively high and excellent. On the contrast, RCI has not citations from itself or others showing that its low patent quality.

Table 5 Detailed data of citation ratio (USPTO)

Assignee Name	Self-Citations	Citations by Others	Total Citations
Fischer; Artur	5	4	9
Herman Miller, Inc.	0	26	26
National Gypsum Company	2	30	32
Steelcase Development Inc.	0	5	5
USG Interiors, Inc.	1	6	7
RCI*	0	0	0

* Data of TWPAT

(3) Chronological counts of patents in competitor companies

As shown in Figure 4, National Gypsum Company shows consistently in PCT patent developments, while recently surpassed by Steelcase Development Inc. and USG Interiors, Inc.. The number of patents peaked in 1990s and declined in the last two years. Herman Miller, Inc. is another consistently productive firm of PCT patents.

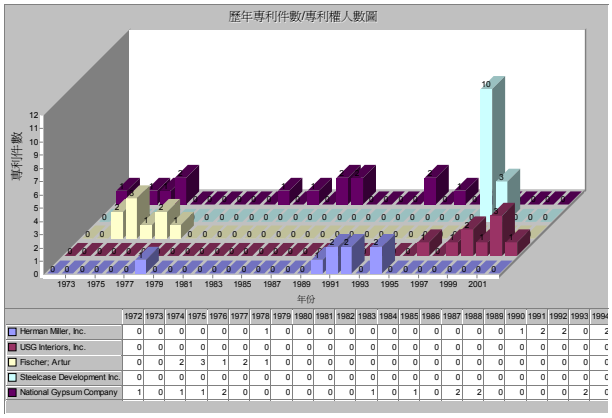

Figure 4 Chronological patents counts/assignees (USPTO)

4.5 Citation rate analysis (CRA)

Citation ratio is the number of citations made by other patents during its valid period; high citation rate indicates high significance of the patent. The technology leading position of the assignee and the patent value are closely related to citation rate. The technology leader has high monopoly power and a low possibility of replacement by others.

By referring to Table 1 and looking into Figure 5 and Table 6, it shows the leaders of PCT patents in USA, and is considered important technology provider to other companies.

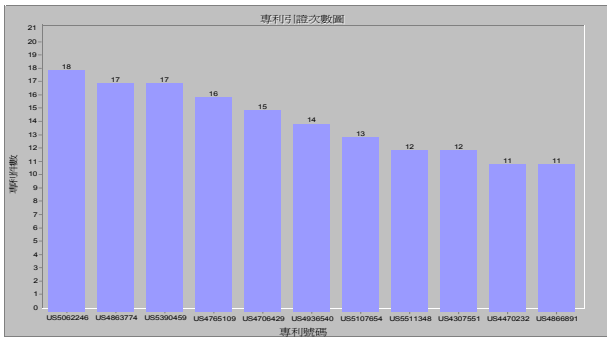

Figure 5 Leaders of important patents (USPTO)

Table 6 Detailed data on citation (USA)

Patent Number	Total Cit. Cou.	Assignee	Self-Cit.	Cit. by Others
US5062246	18	Sykes; Christopher C.	0	18
US4863774	17	Tucker; Richard E.	1	16
US5390459	17	AAB Building System Inc.	0	17
US4765109	16	GSI Engineering, Inc.	0	16
US4706429	15	Young Rubber Company	0	15
US4936540	14	Burdett; Harold D.	0	14
US5107654	13	Leonardis; Nicola	0	13
US5511348	12	Herman Miller, Inc.	0	12
US4307551	12	PPG Industries, Inc.	3	9
US4470232	11	Enterprises Electriques Mors-Jean et Bouchon&&Societe Francaise d_Expositions	0	11
US4866891	11	National Gypsum Company	0	11
US5062246	18	Sykes; Christopher C.	0	18

4.6 International Patent Classification Analysis (IPCA)

In this research, 'IPC patent categorization analysis', 'IPC patent activity, and 'Number of IPC patents of competitor companies' are considered:

(1) IPC patent activity chart

As shown in Figure 6, the highest number of patents in Taiwan is E04B2 (Walls, e.g. partitions, for buildings), reaching its peak at 25 in 1997 & 2000.

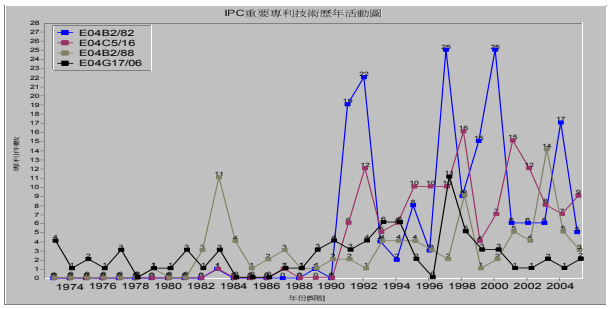

Figure 6 IPC patent activities (TWPAT)

Similar analysis is performed to USA. The results are shown in Figure 7. The highest number of patents in USA is also E04B2, reaching its peak at 47 in 2002.

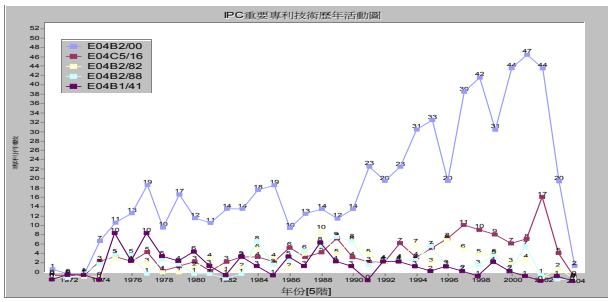

Figure 7 IPC patent activities (USPTO)

(2) Number of IPC patents of competitor companies
As shown in Figure 8, USG Interiors, Inc. and National Gypsum Company are leaders, with highest number of patents, in E04B2 (Walls, e.g. partitions, for buildings). In addition, most IPC patents of the top five companies are concentrated in E04B2 meaning that this is the key area for PCT.

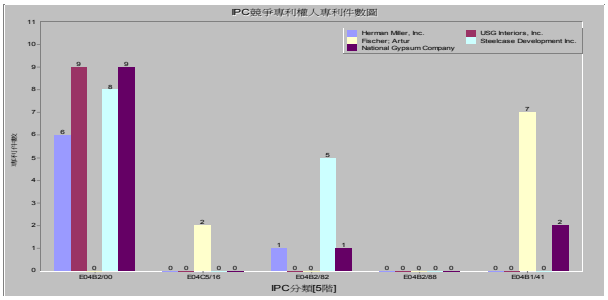

Figure 8 IPC patents of competitor companies (USA)

5. CONCLUSION AND FUTURE WORK

This paper presents the application of patent map analysis (PMA) method to analyze precast construction technologies (PCTs) in USPTO database. The analysis results are used to benchmark the performance of a local PCT specialized firm (RCI) with other PCT leading firms in USA. Some of the PMA techniques are used for comparison between countries, while others are used to provide competitiveness information among the competing companies. After case study, it is concluded that even though the case construction firm is engaged in developing PCT patents. Their quality is still lagging the leading PCT firms in USA. However, PMA shows that the direction of technology innovation of the case firm is on the right track compared with other leading firms in USA. The key issue will be improvement of patent quality and technology independence. With the tremendous investment in technology innovation, the case firm has built solid technological background in PCT domain. From the case study, it is found that the PCT has entered the recession phase of the technology's life cycle. Major investment is required to create radical technological break-through. However, future investments should be planned to avoid patent infringement with the leading PCT firms due to the overlap of the major PCT areas.
Due to time constraint, the research only searched USPTO, TWPAT, and WIPO databases. Future work can extend the search to other databases. Moreover, the patent search of this research is based on the 20 IPC classes identified in Table 1. Future research should be conducted to verify the completeness of the classes conceded above.

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