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Patent analysis for forecasting promising technology in high-rise building construction

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ABSTRACT

For last 15 years, the market size of high-rise building construction has rapidly increased by four times. Many global contractors are investing in the development of high-rise building construction technology, which needs more advanced construction technology than ordinary building construction to secure competiveness in the market. It is significant for contractors to prospect the promising field of technology for strategic investment. Therefore, this study analyzed patents to forecast promising technology fields in future high-rise building construction. 2875 patents related to high-rise building construction that were applied for in the US, Europe, Korea, China and Japan during 1995–2013 were analyzed for market prospect and promising technology. As a result of the market analysis, Korea and China are in the developing phase of the technology market; and in particular, the Chinese market is showing the most drastic growth. On the other hand, the analysis of technology suggests the following technologies offer promising technology: 1) monitoring technology to enhance the efficiency of high-rise building construction; 2) information modeling technology and energy reduction technology in the construction phase based on information modeling technology; and 3) safety management technology based on information modeling technology. This study is intended to provide directions for high-rise building construction technology investment, and objective data for decision making for future global contractors.

1. Introduction

As the population density of cities is continuously increasing, especially in developing countries, the demand for high-rise buildings that can solve high-density pressure in residence and business space is also continuously increasing (Blackman and Picken, 2010). The Council on High-rise buildings and Urban Habitat currently reported that 1040 tall buildings over 200 m exist as of 2015, with an increase of 392% compared to 2000, and the number of tall buildings over 300 m was 100 buildings, which is two times higher than 2010 (CTBUH, 2015). Not only the number of high-rise buildings, but also the building height is increasing, which shows that the scale of high-rise buildings is also increasing nowadays. Hence the market size of high-rise building construction is continuously expanding worldwide, especially in developing countries.

Construction technology is a very significant factor that is required for competitiveness in the high-rise building construction market. New cutting-edge technologies are required in higher building construction due to the limitations in applying existing construction technology to high-rise building construction (Kim et al., 2013). Also, high-rise buildings have evolved significantly in height and design in the last two decades, and this has accelerated the competition of new technologies in high-rise building construction (Abdelrazaq, 2015). In these circumstances, more creative and progressive construction technologies provide competitiveness of construction companies in the high-rise building market, and significant factors for the success of projects. Therefore, construction companies are urged to invest in the development of new construction technology to secure market competitiveness, considering the future prospect of high-rise building construction. Forecasting technology is required for high-rise building construction to establish technology development directions for strategic investment.

Patent analysis is a useful method used to forecast technology innovation patterns and establish technology development strategies (Kim and Lee, 2015). Patents include various and integrated information of researched and developed technologies (Feng and Fuhai, 2012), and can offer mature and objective indicators that reflect technology trends (Chang et al., 2009). Also, potential competitors in the technology market and recent technology trends can be determined from patent analysis, which includes information on the period of technology development and developers (Trappey et al., 2011). For this reason,

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patent analysis can be usefully utilized to establish technology development strategies to set target markets and promising technology of high-rise buildings. However, previous research paper and patent reviews are not focused on the development strategies of high-rise building construction area, and they are not considering the technology markets and technology trend at the same time.

This study performed a patent analysis to forecast future promising technologies of high-rise building construction technology. First, a technology tree of high-rise building construction technology was created to classify technologies and collect patent data by classified technology. Then, patent trends and technology maturity by main markets were analyzed for technology markets. Next, patent trend by technologies and vacant technology were analyzed for promising technology. Lastly, we discussed the future technology of high-rise buildings based on our analysis results.

2. Literature review

2.1. Forecasting construction technology

Various papers have been analyzed to prospect promising, cutting-edge technologies by reviewing technology trends and their requirements. New technologies such as 3D Printing (Wu et al., 2016), low carbon technology (Lai et al., 2016), and action recognition technology (Yang et al., 2016) have been researched in various papers, and technology groups required in development have been researched through professional survey. Several researchers analyzed the current top research of topical areas by analyzing construction field research trends in the American Society of Civil Engineer's Journal of Construction Engineering and Management from 1985 to 2002, to propose topic trends of research that reflect the needs of modern society (Abudayyeh et al., 2004; El Kadiri et al., 2016 and Ibem and Laryea, 2014). Also, publications in the construction & building technology category in the Web of Science database were analyzed (Cañas-Guerrero et al., 2014). Statistical analysis of research trends and recent research themes of publications was performed, and the research aimed to analyze the social influence of journals and influence on national policies and investment.

Previous patents were also analyzed to understand research trends and the current technology level. More than 3000 technology patents are analyzed to propose a technology development roadmap for the research of construction technology in interdisciplinary fields (Kim et al., 2009). This research did not reflect the latest construction technology and research trends, and mainly researched technology groups that are promising in other industrial fields. Other researchers conducted patent analysis only on particular technology groups in the construction fields, such as remodeling technology (Hwang et al., 2005), or modular construction (Lee et al., 2014).

However, the number of paper and patent reviews on high-rise building construction technology was few, and almost all the researches are conducted with qualitative and subjective approaches. In particular, since patents include in-depth information on technology and its market, they become a significant source for technology prospects. Therefore patent analysis regarding high-rise building construction technology is required to establish development strategies for prior occupation in the competitive tall building market.

2.2. Patent analysis methodology

Fig. 1 shows that patent analysis was performed in 4 stages to forecast promising technologies in high-rise building construction. First, technologies of high-rise building construction were classified according to a tech-tree through conferences with experts. The tech-tree is a method that classifies segment technologies by specific functions in tree branch form. Specific technology unit analysis is possible through segmentation of technologies when using the tech-tree in patent analysis and comparison between technology fields with equivalent level units (Lee et al., 2013). In this study, the high-rise building construction field was segmented into 3 levels to compose a tech-tree of each technology. After composing the tech-tree, keywords of each specific technology were deducted to collect data.

Secondly, patent data of each specific technology were collected based on the deduced keywords. Patents of main markets were searched by search engine to derive raw data using the keywords. Effective data was extracted through data filtering, because raw data includes noise data that is unnecessary in analysis. Filtering excludes technology that has low relation to the corresponding technology.

Thirdly, portfolio analysis by market and qualitative level of technology was analyzed to understand the technology market circumstances. First, the market trend was analyzed to understand the trend by markets. Maturity of technology by market was investigated through portfolio analysis that expressed the annual number of applied patents and applicants in time series. Technology maturity can predict the current stage and future direction of the relevant market, and can determine investment in the technology by a decision marker (Trappey et al., 2011). Also, leading countries of technology and future main markets were forecast through comparative analysis of the qualitative level of patents of main market nations.

Lastly, patent trend and vacant technology were analyzed to forecast promising technologies. Patent trends by specific technologies were analyzed to grasp the patent trends and currently developing technology fields. Next, object-solution matrix (OS-matrix) analysis was performed to predict vacant technology. Core data that was most related to technology fields was used in the vacant technology analysis to enhance the accuracy of the analysis in this study. Analysis was conducted by classifying the core data into objects and solutions, and the solutions of vacant technology were analyzed to predict promising technology fields.

3. Patent analysis in high-rise building construction

3.1. Tech-tree of high-rise building construction

All of the high-rise building construction technology groups were deducted through literature reviews, research papers and R&D reports regarding development process of high-rise building construction technology, and 10 types of technology groups are selected considering their frequent, weight and significance. Each construction technology group consists of different kinds of keywords and they are extracted and integrated through keyword analysis of papers, patents and reports.

A committee of high-rise building construction technology experts was organized to create a tech-tree based on the deduced keywords. 5 managers of high-rise building contractors and 14 R&D experts with a career of 10 years or longer were gathered in the expert committee. After in-depth meetings, the expert committee, the committee reclassified the previous 10 types of high-rise building construction technology groups into final 8 types, and classified high-rise building construction technology into 3 subordinate technologies.

Construction technology of high-rise buildings was classified into fast-track construction technology (A), precise construction technology (B), and management construction technology (C). Reducing construction duration is significant to secure the business value of high-rise buildings projects, because the scale is larger than that of ordinary buildings. For this fast-track construction technology that increases the efficiency of construction is required to reduce project duration. Also, the structural safety of high-rise building is very important compared to ordinary buildings, due to the height of building. Therefore, precise construction technology that secures structural safety through accurate construction is required. Moreover, high-rise buildings are used in complex usages, and have large size, in which a great amount of resources is used in various processes. Therefore, management construction technology that can efficiently manage various resources and