The quantity of construction technology innovations in patent database grows at a high speed. More challenging technical problems require the knowledge workers to make full use of the huge existing technology innovation knowledge base to propose new innovative solutions. Hence it is critical to deliver the right knowledge to the right people at the right time. In order to improve the innovation efficiency & effectiveness, this research explores the development of a new patent knowledge management system to satisfy the increasing demand of construction innovations.

Design/methodology/approach

TPKMS development involves the integration of construction patent knowledge management, TRIZ theory, database techniques, and computer programming technology. The contradiction matrix in TRIZ theory serves as the patent knowledge extraction framework while SQL Server 2000 database management system is employed to manage the extracted patent knowledge, TRIZ and user account information. Visual C++ 6.0 is adopted as the development tool.

Findings

The developed system to manage construction patent knowledge integrates the theory of inventive problem-solving (TRIZ) with the database design enabling the system users to be more problem-focused, systematic and efficient. The system provides a heuristic environment to help improve the innovation effectiveness by motivating knowledge workers' innovative thinking. Further development of the system is proposed in the context of big data age.

Originality/value

A new TRIZ-based patent knowledge management system for construction technology innovation was developed.

Keywords: technology innovation, knowledge management, TRIZ, database, construction patents

1. Introduction

As one of the key industries for national economy, construction industry is one of the most knowledge-intensive and challenging industries due to the complicated, uncertain, and dynamic nature of construction operations. In China, it has been facing more intense challenges in recent years due to the competitive construction market, the improvement of the core technology capabilities, and the emphasis of innovation ability. An important indicator of innovation ability in China is the quantity of technological innovation outcomes such as patents, academic papers, and technology innovation products(Chen 2002). Among them, the most critical measure is the quantity of patents since it largely benchmarks an organization's as well as a country's innovation. A patent is a right granted by governments to inventors in order to exclude others from using, offering for sale, or selling the patented invention. The number of global patents increased from 1.52 million in 2007 to 1.80 million

Moreover, continuous improvement of the construction industry depends upon the construction technology innovations (Flint 2002, Mann 2001, Skibniewski and Zavadskas 2013, Chung et al. 2009). However, there are some problems with the construction technology innovations in China such as the low innovation efficiency and the insufficient investment in research and development (R&D)(Liu et al. 2011). With the rapid development of computer and network applications, information technology has become an important tool in managing construction knowledge and technology innovations(Dossick et al. 2010). Although there are platforms to store and index the existing patents, they are more database oriented instead of knowledge oriented and cannot help innovators to make the best use of the available patent knowledge. Consequently, a new patent knowledge management system is desirable to provide innovators with up-to-date patent knowledge to improve their innovative capacity by motivating their creative thinking(Zhao and Zhao 2007).

In the construction industry, different knowledge management systems have been developed for various purposes. For example, knowledge based decision support systems for construction project management (KDSS-CPM) enable professionals and organizations in the construction industry to make better use of the knowledge and experiences from the previous projects(Kanapeckiene et al. 2010). Assistant people-based map experience management (APMEM) system is a project knowledge and experience management system which assists contractors to capture experiences for reuse in future projects(Lin 2009). The Expert System to Control Construction Problems in Flexible Highway Pavements (ES-CCPFHP) aims to help engineers control, analyze complicated problems and recommend effective solutions which are difficult to obtain. In addition, it can effectively archive and distribute expertise among pavement engineers(Mosa et al. 2013). However, the knowledge in the systems are extracted from past project experiences, experts and enable users to gain competitive edge in the market. Due to the protection of intellectual property, the systems are usually not public available and only used by the owners. Furthermore, these platforms only cover the knowledge of construction experience instead of technology innovations. Therefore, from the perspective of patent knowledge management, this research explores how to develop and use a new patent knowledge management platform to promote technology innovations.

Traditionally, construction technology innovations rely on the brainstorming and trial-and-error approach to generate ideas and solutions. It often starts from scratch without adequately utilizing the knowledge generated from previous innovations (Tan et al. 2008, Tan 2006, Tan 2004). Although these classic methods can solve some technical problems creatively, it may be time-consuming and not cost-effective(Fey et al. 1994). The solutions are usually suboptimal such that the technical problems are not settled completely(Moehrle 2005, Savransky 2000, Terninko et al. 1998).

The theory of inventive problem-solving (TRIZ) is employed in this research to tackle the aforementioned problem. TRIZ is proposed by Altshuller. The theory is built on an contradiction matrix table of TRIZ. The improved parameters and worsened parameters among 39 engineering parameters combine with 40 inventive principles to form the contradiction matrix table. Using the table, knowledge workers could identify the most powerful and promising principles for a technical problem where a specific type of contradiction is to be resolved(Altshuller et al. 1999).

Several innovation platforms based on TRIZ have been developed. They cover some basic modules of TRIZ such as contradiction matrix (Wei-Chen 2006). Based on QFD (Quality Function Deployment) and TRIZ, Liao developed a product innovation design system which adopted the structure of quality house, query of contradiction matrix, case browsing etc.(Lu et al. 2006). However, the structure elements, quantitative evaluation of the quality house as well as the function modules need further improvement. The design of the innovation platform includes the mining of information and query application system. The primary function of the platform is to provide information management and query related to the problem through the application of the database(Tian 2007). Liu put forward an online service platform to encourage small and medium-sized enterprises to use patents to shorten the development cycle and improve efficiency during innovation designs(Liu 2007). Based on TRIZ, Zhang developed a platform which provided knowledge workers with guidelines and design directions by using the different function modules according to different problems. Besides, the research verified the effectiveness of the evolutionary theory and the software system through an analysis of a wrench example(Zhang 2009). For mechanical product innovation design, Tang developed a computer aided innovation design platform. It is a four-module system framework including user demand investigation, internal staff survey, contradiction matrix, and product function optimization(Tang 2011). For innovation design of bags, Zhao developed a design system based on VB (Visual Basic) and database technique. The system provided functions such as searching the product characteristics, evolution mode and invention principle, editing system contents etc., which could improve bag designers' efficiency(Zhao 2012). It can be seen that in literature few innovation systems are developed for the construction industry. Most systems focus on the basic contents of TRIZ and fail to integrate with the knowledge base of existing patents. Besides, the function modules of these platforms should also be further improved.

For technology innovation in the Chinese construction industry, some exploratory research has been done by applying TRIZ. For instance, the most often utilized TRIZ parameters and innovation principles have been identified by analyzing construction template and scaffolding patents(Ding et al. 2014, Ding and Ma 2014, Mosa et al. 2013). The research findings demonstrate the applicability of TRIZ in the construction industry innovations and could help the industry to improve the innovation capacity. However, no platforms have been developed yet to apply the findings for future innovations. Therefore, the research and development of a construction technology innovation platform based on TRIZ has strong practical significance. The main contribution of this study is the development of a user friendly patent knowledge management system that enables a heuristic environment to help

2. Development of TRIZ-based patent knowledge management system (TPKMS)

TPKMS development involves the integration of construction patent knowledge management, TRIZ theory, database techniques, and computer programming technology. The contradiction matrix in TRIZ theory serves as the patent knowledge extraction framework while SQL Server 2000 database management system is employed to manage the extracted patent knowledge, TRIZ and user account information. Visual C++ 6.0 is adopted as the development tool.

2.1 Patents collection and analysis

According to international patent classification, the patent data in section E are construction related patents which are collected in this research. Considering the huge amount of patents, this research collected the construction patents category by category in section E. The patent data which have been published are collected from Guangdong Intellectual Property Office which make the patents public available. It should be noted that the patent database is nationwide connected. So all the patent data will be the same whichever local Property Intellectual Office database is accessed. More than 3,800 patents are related to scaffolding, templates, safety net, door and window from 2002 to 2013. A research team was set up to analyze the collected construction patents. To ensure the reliability and validity of the analysis, the following steps are defined for each patent analysis:

1) Each patent is analyzed by two team members. For every patent, the improved parameter and worsened parameter are extracted. By referring to the TRIZ contradiction matrix, appropriate inventive principles which could be applied to the patent at hand are identified.

2) The two analysis results are then compared. If they are inconsistent, a team discussion will be held to handle the discrepancies.

3) The results are input into database after agreement being achieved.

The information of the collected patents is shown in table I including patent categories, the quantities of each patent category, the published year, legal status, and patent type. More than 2,000 patents have been analyzed and input into the database. The patent collection and analysis is still on-going to cover other categories in section E.

Categories	Quantity	Years	P[1]	S[2]
door	1032	2002-2011	I、U	A、P、E
window	659	2005-2011	I、U	A、W、T
scaffold	852	2000-2010	I、U	A、T、W、P
template	1252	2007-2009	I、U	A、P、E
safety net	100	2008-2013	I、U	A、T、W、P、E
Sum	3895	2000-2013	I、U	A、T、W、P、E

Table I. Patent information demonstration

[1]P= patent type; I=invention; U=utility model

2.2 Database architecture design

The first step in the TPKMS development is the design of database architecture. Success of the system depends largely on the patent information and extracted patent knowledge in the database. In addition, new patent knowledge could be added to the database as continuous improvements. Therefore, database design is a critical step in the whole development process.

The collected data are classified into four tables in the database according to the different uses. The four tables are user information table, contradiction matrix table, inventive principle table, and patent knowledge table.

For system security, user account and password are required while logging in the system. Once authenticated, corresponding user permissions will be granted. To fulfill this requirement, user information table should contain user accounts, passwords, and user types. The value of user type is either 1 or 2, 1 representing system administrator and 2 ordinary user. No guest account is allowed in the system. The primary key of the user information table is user name and its structure is shown in table II.

Field Name	Data type	Field size	Null/Not Null	Specification
UserName	varchar	50	Not Null	Primary key, user name
Passwd	varchar	50	Not Null	Password
UserType	int	4	Not Null	User type

Table II. User information

User name and password will be checked first to identify the user and user type. Administrator can use the user management module to add, modify and delete users' information. The use case diagram of the user management module is shown in Figure.1.

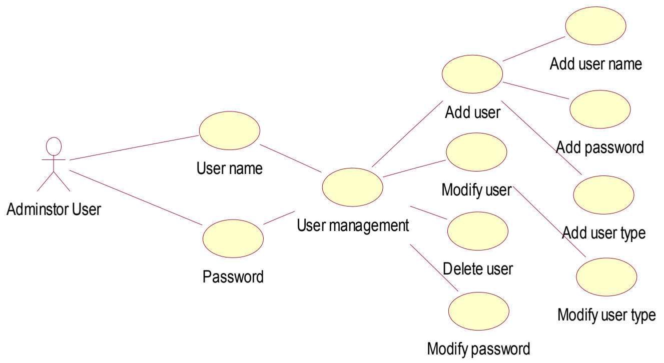

Figure. 1. Use case diagram of user management module

The next table is the contradiction matrix table. It consists of 39 parameters as well as inventive principle index. Recomprincipleindex, prin1, prin2, prin3, prin4, paratoimprove, paratoworsen are covered in the contradiction matrix table as shown in Table III. The prin1

x				
prin1	int	4	Null	Inventive principle 1
prin2	int	4	Null	Inventive principle 2
prin3	int	4	Null	Inventive principle 3
prin4	int	4	Null	Inventive principle 4
paratoimprove	varchar	50	Not Null	Improved parameters
paratoworsen	varchar	50	Not Null	Worsened parameters

Table III. Contradiction matrix

Based on the contradiction matrix table, an inventive principle table is created to provide detailed information of inventive principles to help users understand the meanings of each principle. Table IV shows the structure of inventive principle table.

Field Name	Data type	Field size	Null/Not Null	Specification
principleno	int	4	Not Null	Primary key, principle No.
principlename	varchar	50	Not Null	Names of principles
principledetail	varchar	255	Not Null	Detailed descriptions of principles

Table IV. Inventive principle

According to the patent documentation format, basic information of each patent should include patent number, categories, publication time, patent types, legal status, key technical problems that should be solved, solutions and so on. Meanwhile, the extracted knowledge from each patent according to TRIZ includes improved parameters, worsened parameters and inventive principles. All the information and knowledge are saved in the patent knowledge table. The table primary key is patentID which is calculated by recomprincipleindex multiplied by 100 plus the sequence number of the patents so that it can be used to retrieve the corresponding information and knowledge of the patents. The detailed description of its structure is shown in Table V.

Field Name	Data type	Field size	Null/Not Null	Specification
patentID	float	8	Not Null	Primary key, index number of patent
patentno	nvarchar	60	Null	PatentNo.
classificationno	nvarchar	60	Null	Categories
openyear	nvarchar	60	Null	Publication time
patenttype	nvarchar	60	Not Null	Patent types
lawstatus	nvarchar	60	Null	Legal status
problem	nvarchar	255	Null	Problem description
solution	nvarchar	255	Null	Solution description
paratoimproveno	float	8	Not Null	Improved parameter No.

paratoworsen	nvarchar	60	Not Null	Worsened parameters
principleno	float	8	Not Null	Inventive principle No.
principle	nvarchar	60	Not Null	Inventive principle
solupicturename	nvarchar	60	Not Null	The filename of solution picture

Table V. Patent information and knowledge

2.3 TPKMS Design

Figure.2 shows four important function modules of TPKMS: user management, TRIZ introduction, conflict resolution and case browse. The content of each function module is also presented.

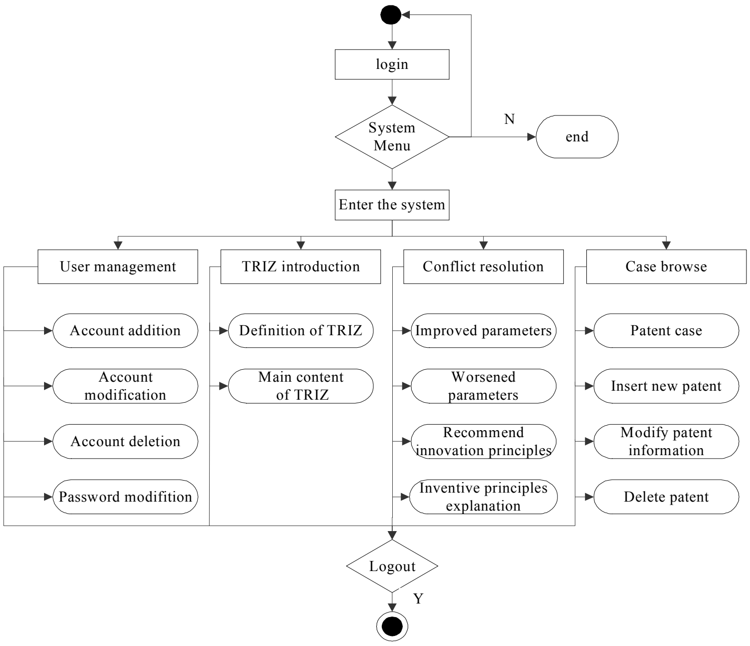

Figure. 2. Framework of TPKMS

After log in and authentication, the main menu is displayed. If a user logs in with a system administrator ID, more authorizations such as account information modification, creation and deletion of user accounts will be granted while ordinary users can only change their passwords. Besides, user name is checked whether there are duplications in the database while a new account is to be created. This is illustrated by the sequence diagram in Figure.3.

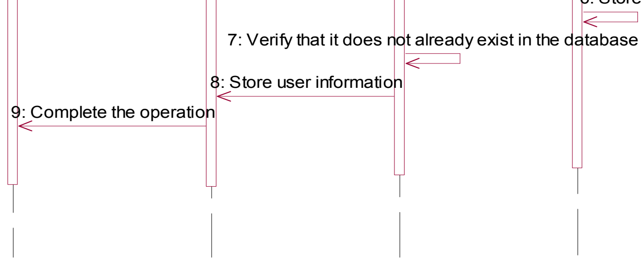

Figure. 3. Sequence diagram of the login process

There is a module for the introduction of TRIZ theory in the TPKMS. The module helps users learn more about TRIZ theory including definition of TRIZ, explanation of system evolution, 40 inventive principles, 39 general engineering parameters and contradiction matrix, and ARIZ(Algorithm for Inventive-Problem Solving), as shown in Figure.4.

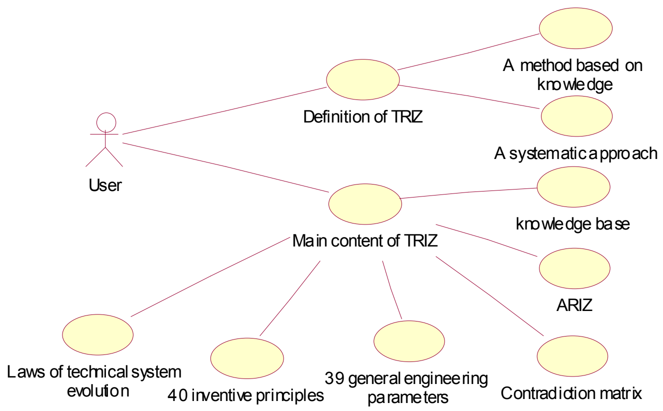

Figure. 4. Use case diagram of TRIZ introduction module

In conflict resolution module, user defines the technical contradictions according to the technical problems to be solved. Then, the system calculates the index number to find the corresponding recommended inventive principles according to improved parameters and worsened parameters related to the user's technical contradictions. Besides, inventive principles are explained in detail to provide a clear picture of how the principles could be applied to solve the contradiction. Moreover, the extracted patent knowledge can be reviewed by users in the patent case browse module. Users' innovative thinking can be motivated through the reference to the detailed patent problem description, solution and schematic diagrams of resolution with recommended principles from TRIZ. Furthermore, users can insert, modify, and delete patent information. A link to full patent documentation is also provided. The flowchart and activity diagram of the contradiction resolution and patent knowledge browse module are shown in Figure.5.

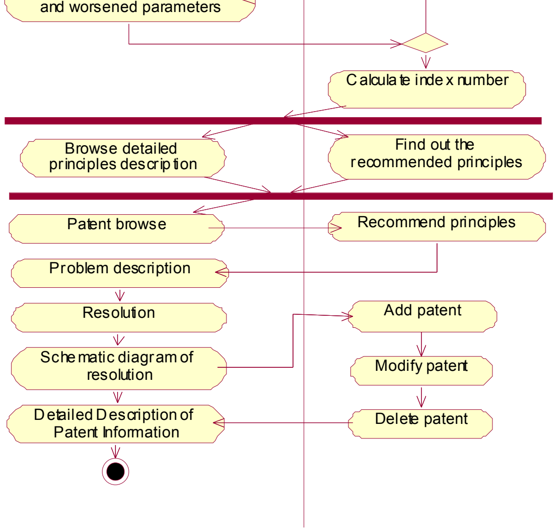

Figure. 5. Activity diagram of the contradiction resolution and patent knowledge browse module

In the following section, the logical relation and composition of the system main frame classes are described. Figure.6 shows the different classes and their corresponding attributes and activities.

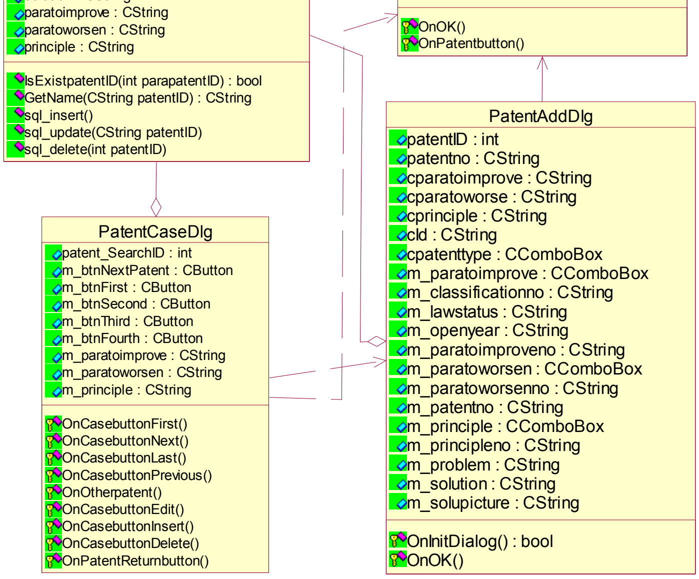

Figure. 6. Class diagram of TPKMS

The classes used in TPKMS are defined as following:

●ConflictDlg: The conflictdlg is the primary class of the TPKMS. It covers the knowledge of TRIZ, such as 39 parameters, 40 inventive principles, and query of contradiction matrix. In the process of inventive principle queries, the system algorithm of query is defined by setting the value of i_SearchNumber. After user chooses the improved parameters and worsened parameters, the function of OnOK( ) automatically generates the i_SearchNumber, which is calculated by multiplying NumberParametersImproved by 100 and adding NumberParametersWorsen. In addition, the function of OnPatentbutton( ) searches for the patents that are related to the inventive principles from the patent information table in the database. The contradiction matrix dialog interface is shown in Figure.7.

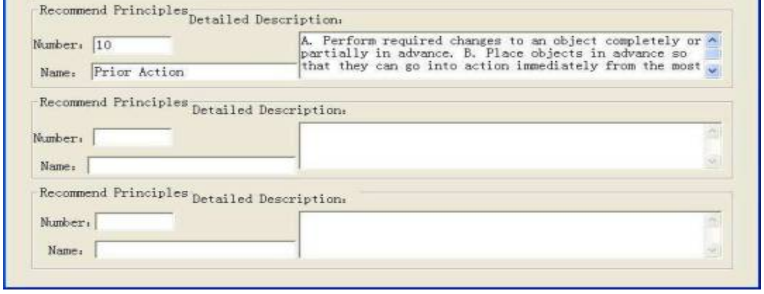

Figure. 7. Contradiction matrix dialogue interface

●Patents and PatentCaseDlg: The attributes and function design of patent class is crucial to the realization of patent queries and operation. These attributes includes the numbering of patent i.e. patentID, the type of patent i.e. patenttype, the patent publication year and so on. Moreover, the problem and the solution in patents are analyzed and summarized by carefully reading the corresponding patent documents based on TRIZ. In order to insert, update and delete patent information, the function of IsExistpatentID( ) search the existing patents to ensure that there is no duplication. After that, a new unique patent number can be generated. The PatentCaseDlg has four buttons for the recommended principles. When the number of recommended principles is less than four, the remaining button will be unavailable and shown in gray. Other related functions are shown in Figure.8.

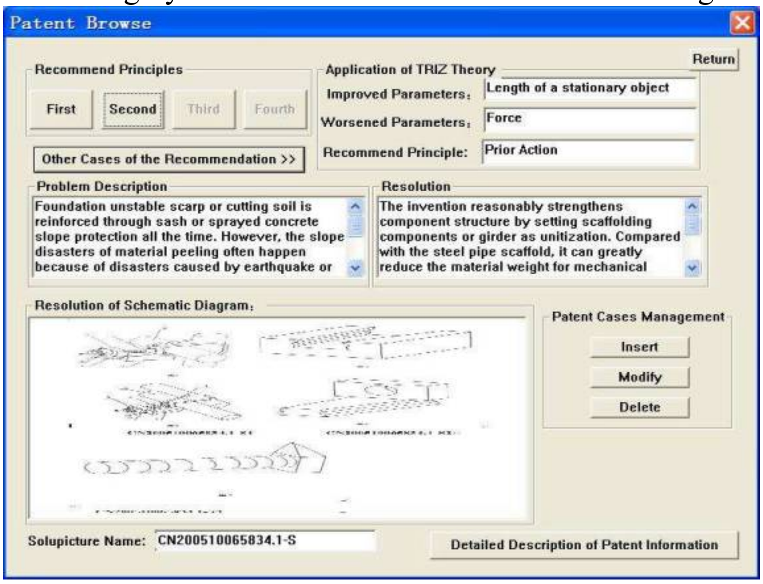

Figure. 8. Patent case browsing

●PatentAddDlg: If users find mistakes or revise patent knowledge, they can add, modify and delete the patent in the system. Figure.9 shows the interface for editing patent information.

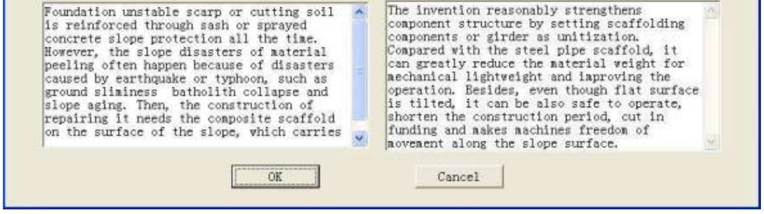

Figure. 9. Edit patent information

The various function modules of TPKMS and their integration must be thoroughly tested to ensure the system working properly. The goal of the test is to verify that TPKMS has reached an acceptable performance level with respect to development requirements such as ease of use, stability, and efficiency. The system modules are tested periodically during the development process to ensure their functionalities. Finally, combined with the module tests, an integrated system test was implemented to identify bugs and then fix them, if any, to ensure the system is running properly.

3. Advantages and limitations of TPKMS

TPKMS has three main advantages. First, it provides an experimental platform for research institutes to conduct innovation related experiments. For example, TPKMS can help researchers explore the process of construction innovations. By observing and recording the subjects' operations on TPKMS, the mechanism of innovation could be revealed depending on the design of the experiment. Second, TPKMS can be used as an assisting tool for enterprise technology innovations. How to improve the capacity of technology innovation by making full use of the existing patent information and knowledge is an important topic of enterprise technology innovation. TPKMS could be used as an assistant during an innovation process in a team or an organization context. It can greatly increase the likelihood of successful innovation while saving time and cost. Third, TPKMS can help new patent applicants find useful knowledge and explore the technological innovations with maximum likelihood of success. Besides, new patent applicants need to review existing patents to avoid duplication. These issues can be solved by using TPKMS.

Current TPKMS has two limitations. First, the users are assumed to have a reasonable understanding of TRIZ. If not, TPKMS cannot be fully utilized. Second, the TPKMS function modules need to be enhanced to provide more functions. For instance, it would be desirable to have statistical functions to analyze the data of construction innovations and reveal patterns.

4. Conclusions

This paper describes the development of TPKMS which is a new construction patent knowledge management system with innovation orientation. TPKMS can be used by knowledge workers to identify and explore the technical problems and the possible inventive principles to solve the problems. Besides, considering the characteristics of construction industry, it is important to manage the patent knowledge effectively so as to construction industry. All the knowledge is extracted from the public available patents based on TRIZ theory. The aim of the system is to help users to make new technology innovations instead of copying or applying the patents. Even the intellectual property holders of existing patents could utilize the system to improve their innovations. Therefore, the TPKMS is complementary to the previous systems and intellectual property is not an issue.

Future research will focus on refining the existing functions and adding new functions to the system. Firstly, the volume of patent knowledge in the construction industry is increasing dramatically in the big data age. Therefore, one research goal is to find the underlying principles based on analysis of the big patent data. So, the challenge for future research is to combine data mining technology with the extracted information from patent data in the database. Secondly, in order to facilitate platform application, the functions of each module should be further improved such as visualization etc. instead of plain text. Last but not least, considering the complicated process of technology innovation, the platform could be integrated with other innovative theories or methods to develop a more efficient tool to motivate knowledge worker's innovative thinking and practice.

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