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Review Article

A Bibliometric Review on Risk Management and Building Information Modeling for International Construction

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International construction is complicated and involves high risks. However, with the development of technological innovation, Building Information Modeling (BIM) emerged and seems to be able to address certain risks. To understand BIM applications in risk management for international construction, a state-of-the-art review is required. Therefore, this paper aims to identify the research trends and opportunities for risk management in BIM-enabled international construction by reviewing 526 peer-reviewed journal articles for the years 2007–2017. Thus five steps of bibliometric analysis were conducted based on the proposed frameworks of BIM risk management in international construction (BIM-RM-INTL). The results show that the popularization of BIM not only attracts all stakeholders' interests but also brings some risks. For example, financial factors are hard to detect and control through BIM, information loss during transmission stands out, and BIM has no unified standards and regulations for international construction. The research has mapped existing research results and their relationships for future risk management in BIM-enabled international construction.

1. Introduction

Although Building Information Modeling (BIM) has demonstrated its significance in construction management and being embraced by increasingly and more clients [1], its application remains in the growth stage [2]. However, international constructions are more complicated than domestic construction projects in contractual terms and are also exposed to greater risk such as cross-cultural differences, multistakeholders, and legal and standard differences [3]. Even though BIM has the capability of dealing with complex construction problems and integration of massive information, reviews of BIM in international construction's risk management still is sporadic. Additionally, for international construction, BIM is great software for improving design process and facilitating on-site communication. However, risks at the project's whole life span are more acute and important to solve. In this regard, the risk-management challenge for BIM-enabled international construction demands for studies and practices that can provide solutions to current problems. Therefore, this study defines BIM-RM-INTL field as BIM-enabled international construction using BIM as a tool for risk management, including traditional construction risks, risks caused by international feature, BIM risks, and so on.

Previous studies mostly focused on the research of international construction risk management, such as political risk management on international construction [4], and management-reserve estimation for international construction projects [5]. Some individuals pay attention to the studying BIM technology development and application in the construction industry [6]. BIM is used in construction design process [7] and BIM 3D/4D/5D technology for cost, schedule, and material management [8]. However, there is insufficient research on risk management of international construction using BIM and BIM-enabled international construction risks.

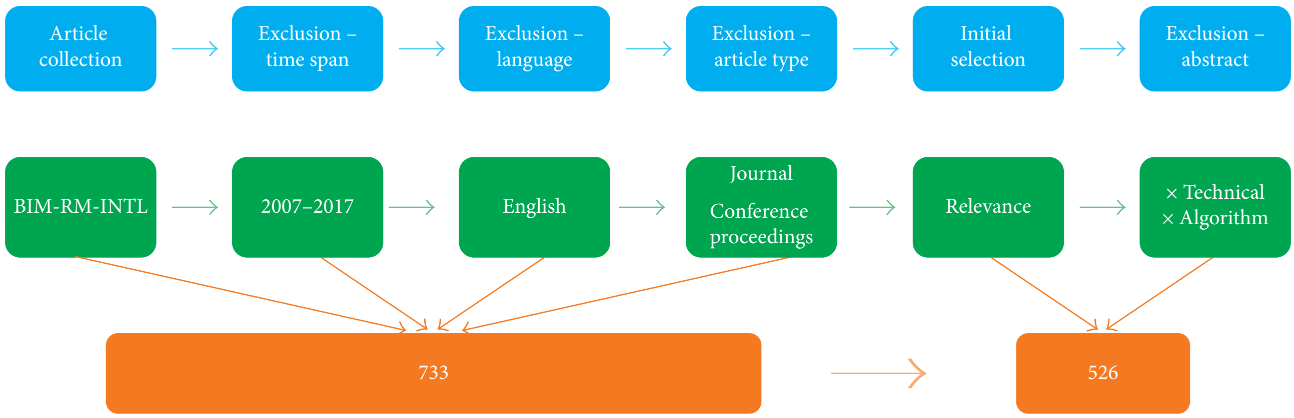

Figure 1: Paper retrieval process.

In order to draw inspiration for future studies that illustrate the gaps and details of current status, this paper aims to (1) collect peer-reviewed articles and conference proceedings in the BIM-RM-INTL field from 2007 to 2017, which could ensure the integrity as well as sufficiency insights into the research area; (2) acquire an overall research status from the perspective of keywords cooccurrence network and time zone network; (3) identify the potential research topics by examining keyword burst detection; (4) analyze the intersections of research groups and patterns through abstract term cluster analysis; and (5) build a framework for BIM-RM-INTL that demonstrates details and gaps of the field so that future researchers can gain a more in-depth understanding of the field. Lastly, based on the studies of Hastak and Shaked [9] and Eadie et al. [10], we proposed a framework that addresses the directions of future studies as a final result of this study. An interview was conducted to fine-tune our findings in this review.

The rest of the paper is structured in the sequence of bibliometric study. Section 2 shows the procedures of this study in detail. Section 3 presents the keyword cooccurrence network that poses the semantic relationships of various research elements, followed by Section 4 in which the keyword time zone analysis displays the past research trends and evolution of research topics over the years. Section 5 shows the burst of keywords and reveals the focus of interdisciplinary fields chronically. Section 6 groups keyword terms into semantic clusters to present relationship of research groups and the intersections. In Section 7, a structural framework is proposed which outlines the distributions of to-be-explored areas as reference for future studies. Finally, Section 8 concludes with the findings and limitations of this study.

2. Research Methodology

2.1. Paper Retrieval. In this study, Web of Science (Clarivate Analytic (2017) *Web of Science Fact Book*. Retrieved May 27, 2017, from: http://clarivate.com/scientific-and-academic-research/research-discovery/web-of-science/) datasets of bibliometric analysis and journals concerning risk management of international construction using BIM were identified and gathered. The paper resources collected from the database are sufficient and highly reliable since papers were picked out after rounds of strict peer-evaluation and selection. Additionally, the abundant quantity of qualified academic papers is adequate to represent the main body of the BIM-RM-INTL field of study.

Considering the probability of downloading unrelated papers or papers with little relevance, it is necessary to eliminate unwanted ones. By reading the abstracts carefully and analyzing the problems articles aim to solve, 526 journals that conform to the criterion were selected. The criterion is described as below. Figure 1 shows the framework of paper retrieval process.

First, three sets of keyword terms were used to triangulate the articles related to risk management, BIM-enabled projects, and international construction. The search strategy was triangulating *("BIM" OR "Building Information Modeling" OR "Building Information Model" OR "Building Information Modeling") AND (risk OR safety) AND (international OR global OR world) AND management*. Then, only journals and some conference papers in English during 2007 to 2017 were saved. Since studies of construction field strongly rely on practice, though study quality is guaranteed in journal alone, may not be in accordance with practice or in the frontier of the field. Furthermore, management methods' implementation and experiences are often communicated in conferences. Thus, some conference papers were included in this study. Since BIM technology, which is what this paper meant to focus on, has only been put into large-scale use within the last decade, previous studies and practices are scarce and of little help. Accordingly, the time span was restricted to 2007–2017. To incorporate high quality into international construction and cross-country findings, this study chose English, the universal language, as the only language papers should be in.

Second, to avoid containing irrelevant papers with titles concerning BIM-RM-INTL in the database, for example, grid construction and biology technology are not relevant but might contain the same term, these journals were eliminated by checking the content of papers through skimming their titles. Then, by reading the remaining abstracts, papers about purely technical issues, such as those solely about the development of software, BIM technology optimization, and risk analysis algorithm, which are not relevant to management field, were deleted.

Since the data analysis implemented in this study relied on title, abstract, and keywords of the paper, the methodology, emphasis of research field, and findings were all included. With the precision of information extracted, the result was high accuracy. According to the criterion above, 526 papers were picked out, and 733 papers were deleted. The selected 526 papers are published in major journals and from international conferences. Figure 2 shows the citation details of the distribution of the 526 bibliographic records from 2007–2017.

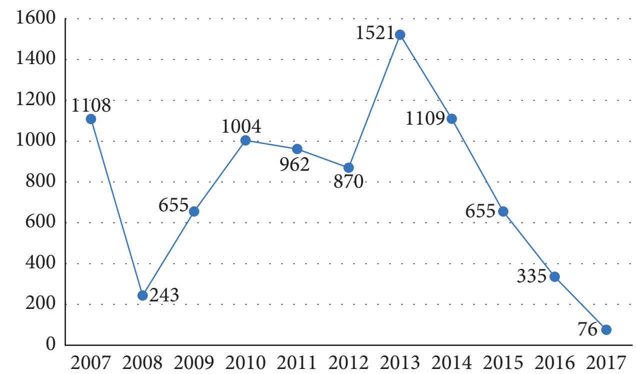

Figure 2: The citation details of the 526 papers in 2007–2017.

2.2. Bibliometric Analysis. Understanding the earlier studies and the trend requires analyzing big amount of paper, extracting information, and building conceptual framework. However, manually reviewing papers at huge quantity is impractical; meanwhile, subjective categorization and clustering are prone to human-related systematic errors or false analysis. Bibliometric approach, functioned by automatic calculation, can remedy this situation. Bibliometric approach is a method that integrates the information of large-scale data; by scientific calculation, it can then map the structure and evolution of knowledge in the database. Through visualizing the results, the relationship of study fields can be easily grasped. The landscape of researches' abundant or rare resources can be depicted clearly. Bibliometric approach helps to outline the framework of current BIM-RM-INTL field of study.

The research area this study examined contains interdisciplinary knowledge as well as large number of specific studies in only one field. BIM technology as a multidimension tool provides great convenience to construction enterprises so that scholars worldwide are studying its function and implementation. Risk management in the construction industry, where the money involved is usually very big amount, is very important for controlling the quality of buildings and ensuring the profits. Many studies have placed emphasis on risk identification and control system. Research on international construction is prevalent with the spread of globalization, and it is becoming more important in China since more enterprises are walking out of mainland China to find opportunities in other countries. Manually analyzing these three fields and their intersection is not practical since the papers and knowledge included are of huge-scale. To better understand the research status of these three fields at the base of large-scale papers extracted, this paper adopted CiteSpace [11] as the tool for analysis. This software was used for links and network building and analysis as well as mapping visualization. All the information was extracted from terms in keywords and abstracts that the authors wrote to summarize their studies.

A publication's keywords and abstracts are what the author considered capable to represent the study. Thus, using terms from keywords and abstracts as analysis units can represent the research framework of BIM-RM-INTL field. Keyword cooccurrence analysis, keyword time zone analysis, keyword burst analysis, and abstract term cluster analysis were adopted in this study to demonstrate research patterns and past trends in BIM-RM-INTL field.

First, keyword cooccurrence analysis based on the mapping results illustrated the network of BIM-RM-INTL field; the links among words represent connection of researches and provide evidence for further cluster analysis. Second, keyword time zone analysis demonstrated the evolution of researches by showing connection lines colored by year and its transition, and highlighting the hotspots in different years. Third, keyword burst analysis gave insight into individual term's strength through the time span, which could provide more specific evidence to time zone analysis and suggest different opinions. Finally, cluster analysis provided evidence about grouping of research patterns and intersections, which allowed framework building accordingly.

Mean silhouette value measures the homogeneity of clusters while modularity Q represents the strength among node links. High mean silhouette value indicates strong homogeneity inside a cluster. High-modularity Q value stands for dense connections between nodes within modules and sparse connections between nodes in different modules. A convincing semantic mapping requires mean silhouette value to reach 0.7 [12] and modularity Q to 0.3 [13]. This would be the criterion for the credibility of figures in this study.

3. Keyword Cooccurrence Analysis

The keyword cooccurrence network is demonstrated as Figure 3. The overall network shows the research centrality and edges as well as the evolution of researchers' concerns through time. Nodes in the map stand for terms that can represent one of the basic concepts of each article. The radius and color of each node demonstrate the link strength of it in each year. Most frequently linked nodes were tagged by the representing word. Lines that connect nodes indicate the year that the two words first being used together in one article. The line weight indicates the link strength through years. The thicker the link, the stronger the relationship. The color of both nodes and lines, in all, clarifies the old and new areas in this field of study. Color transition from cool tone to warm tone signifies the time span from past to present.

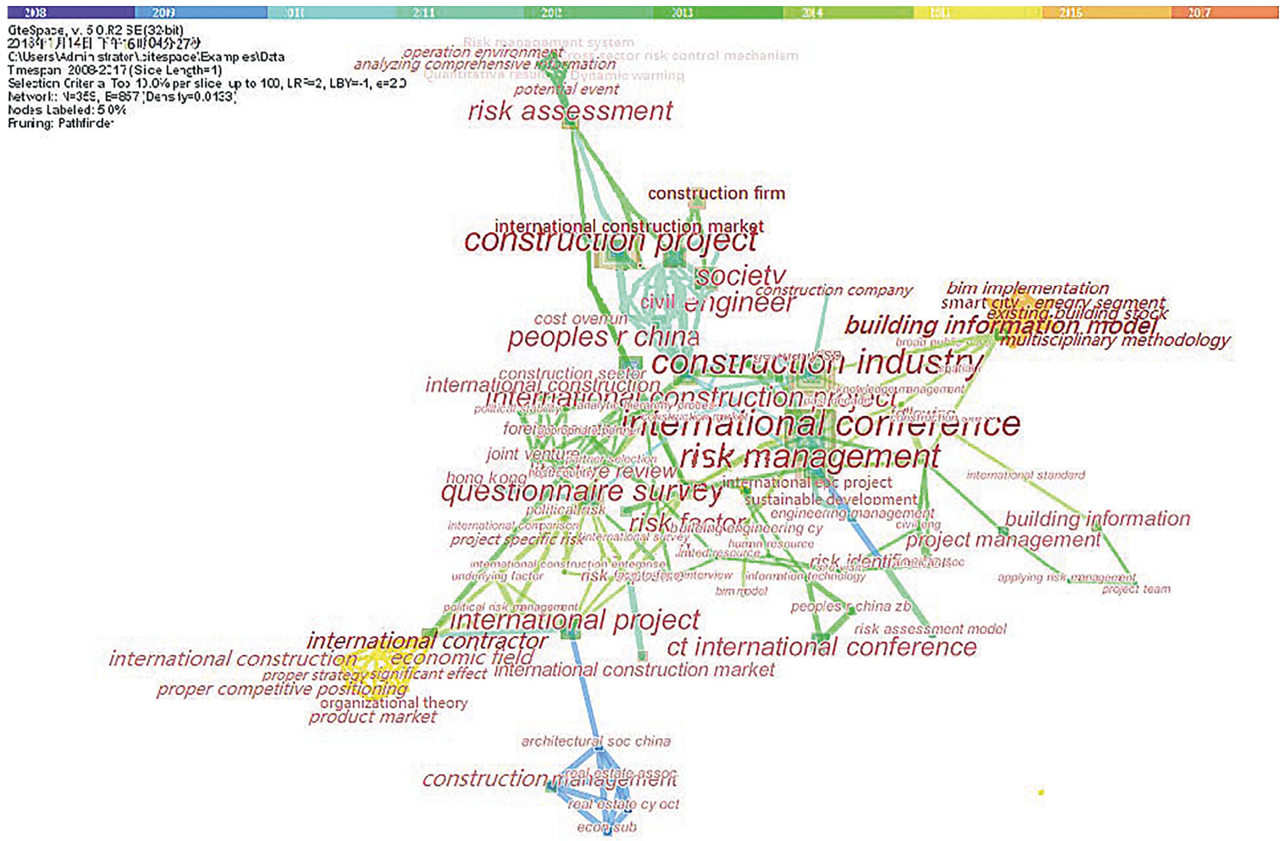

Figure 3: Keyword cooccurrence networks.

As the selection criterion went as "10.0% per slice (one slice equals to one year), up to 100," Figure 3 shows the very detailed mapping of BIM-RM-INTL field of knowledge. Although this figure can delicately demonstrate the relationships among different concepts, it shows that the silhouette value, 0.1945, did not reach the standard for cluster analysis, which will be applied in Section 6. Thus, to create a more convincing mapping for cluster analysis, this study narrowed down the percentage terms that were extracted for the use of analysis to 1.0%. As shown in Figure 3, modularity Q (0.6354) and mean silhouette (0.7005) both reached the standard. However, there is a price to take—lack of content in the mapping. Thus, in order to take advantage of both figures, this study adopts Figure 3 for keyword cooccurrence analysis, seeking detailed link analysis and adopts Figure 4 for further cluster analysis, ensuring the accuracy of results.

BIM, comparing to traditional construction project and risk management, is a new field of study, and studies about BIM are new-rising as well. Though the concept was mentioned at late 70s and has been put into use for years, the low popularity, high qualification, and immature standards made this field still thriving. China imported BIM technology since 2003 [14], but no law or professional standard has been established to date. BIM could bring instant benefits to all parties concerned in a project [15]. Since the implementation of BIM technology and construction policies concerning BIM are both at early stages, educational programs designed for preparing skilled BIM students or workers are evolving [16]. Training of professionals could clear barriers through BIM implementation and improve the abilities of professionals [17]. Advantages of BIM have been studied thoroughly, and the instant benefits contractors experienced have been categorized in detail [18]. The process of facilitating BIM adoption and the latent challenges are being reciprocally studied through years [19, 20]. In practice, enterprises intend to advance implementation theories so as to use BIM-based tools to its full gear, which advances the project's functionality [21]. While some features of BIM can help solve project risk, it is not possible to conduct comprehensive risk management.

Culture poses a salient concept in keyword cooccurrence network since variation in value system and transaction practices normally serve as the barriers of project delivery [22]. To better accomplish projects in international construction, one must understand the cultural background. Different cultures might have different acceptance towards new technology, and different attitudes and habits in dealing with people and participating in projects [23]. Immature cooperation culture might lead to difficulties to life cycle BIM implementation as well [24]. Stakeholders may resist sharing information, particularly costing or scheduling information that may be used against their liability in breaching the contract. Project managers' lack of knowledge in BIM leads to low efficiency in BIM implementation as well as the lack of competencies in job field personally [1]. If stakeholders overlook the variations in regulations, they might encounter troubles in building process.

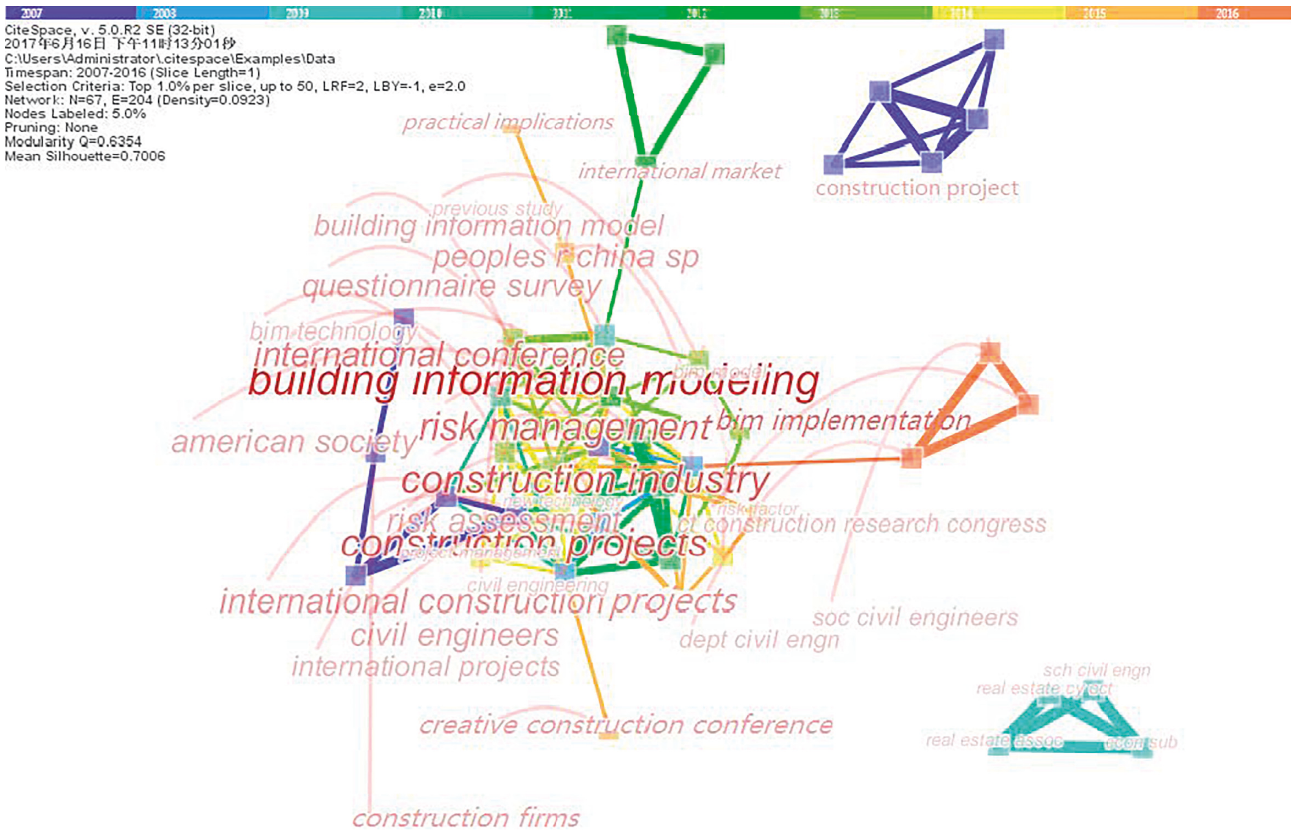

Figure 4: (Extracted) keyword cooccurrence networks.

In the international sector, "political issue" has strong link with it. Political issue is a key factor in which the project can be carried out successfully since international construction is very social stability. Partner selection, on the other hand, concerns subjectively choosing partners. Proper choice of local joint venture partner plays an important role in reducing political visibility [25]. Reliable stakeholders can help conduct the project better in a foreign country for the firm but the opposite case might have negative impact on progress [26].

Different from partners, international contractor means an aspect related to law and new ways of risk allocation [27]. Business issues, including marketing, proper strategy, and proper competitive positioning are included [28].

It could be easily determined that the most popular method of analyzing risks is questionnaire survey. It can be used in deciding risk factors [29], risk impacts [30], international construction comparison [31], and so on. Since the construction industry relies heavily on practices, by choosing experienced experts through scientific approaches, deciding risk categories and their impacts by expert interview is the most reliable. Researches about risk exposure are about to mitigate negative impact by knowing under what circumstances the constructions are prone to risks most likely to happen [32]. By reducing such situations, risks can be avoided or reduced. Risk assessment, which is conducted throughout a project, greatly influences the process and outcome. Different risks, concerning cost, social issues, asset, and social environment, are being considered in great amount of papers. Risk management methods like dynamic analysis [33], quantitative risk assessment model [34], and fuzzy theory [35, 36] are being studied.

Risk assessment part is separated from risk management in Figure 4, which is not same as how our conceptual framework works. The reason can be that assessment process focuses more on dividing construction phases and give in-depth study about each stage and aspect of a project instead of being integrated in risk management field.

4. Keyword Time Zone Analysis

Keyword cooccurrence network is a static figure even though initial year of links between words is represented by different colors. Time zone analysis arranges terms in a chronological manner that shows the trends and interactions among keywords. As shown in Figure 5, the colors of these lines are showed when a connection has been made for the first time, and the lines that connect nodes are cooccurrence links between different keywords. According to the complete result shown in the software, this paper did insight investigations.

In 2007, the main research focus on concepts relating to "risk assessment," "risk management," "international construction projects," "risk factor," and so on. It could be seen on the figure that in 2012, with the rise of BIM technology, the field of civil engineering and risk management started to establish links with BIM. Since BIM technology integrates information in a nD model (nD model means all the

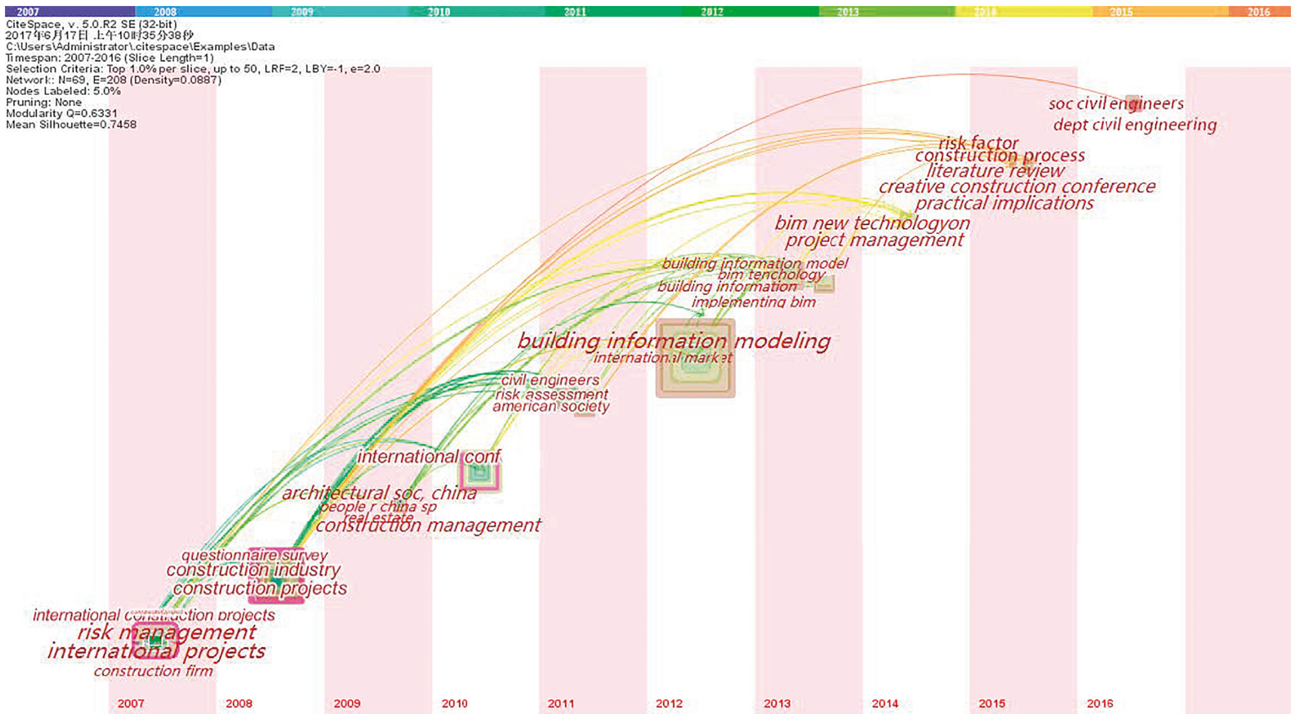

Figure 5: Time zone.

dimensions of BIM technology, e.g., 2D, 3D, 4D, 5D, 6D, . . .) [37], for risk management which requires detailed information in every stage, BIM stands as a future processor for risk management [38]. This link demonstrates their relationship. Sustainable development, involving the demolition and refurbishment of buildings as well as green building and so on, emerged in 2014. As a new practice, in order to assess the risks and possible barriers, a lot of risk management issues and information management methods were discussed [39]. BIM also played an important role in developing sustainable building. 2015 is an important year of risk management studies. Theoretical research about risk assessment, identification, and others established strong links with practical implication, especially for risks that are more subjective and related to human reasons [40]. As such, fuzzy approach was widely adopted for semantic analysis on human factors in risk management [41]. Furthermore, international constructions also had strong links with it. The studies about integration of BIM, international projects, and risk management involved practical uses. For instance, asset management through knowledge management was broken down to issues like liability, authenticity of BIM users, and development of new ways of collaborations for practical instructions. The usage of BIM started to be expanded in 2015 when project cost, in-depth design, and safety issues were widely discussed, and all of them were closely connected to BIM [39]. Researchers have been relating topics like spatial conflicts and site safety management to BIM. In 2016, BIM started to be integrated with risk management in a project's life cycle [42]. PMBOK breaks down risk management into three phases: risk identification, risk analysis, and risk management [43]. A project's life cycle has been separated into design, construction, operation, and demolition. Secondary phases have been identified as well. The relationship between risk management stages and construction project's life cycle is being studied. For example, during the operation stage, existing modelling conditions which involve laser scanning, image, and data processing have been deployed to manage the construction quality (its risk intervention phase) [44]; in the design stage, BIM can provide detailed data for optimization of management resources, for example: it helps quantity take-off, project cost estimation, information records of spare parts, labour, and machinery (it's risk identification and intervention phase) [45]; to reduce safety risk, BIM can provide a virtual construction platform and safety simulation environment so as to enable all the parties to develop a better construction safety plan (it's risk identification and intervention phase) [46], and so on.

5. Keyword Burst Analysis

Time zone analysis gives insights into trends and evolution of researchers' interests, but still it is unable to explain the centrality of words. Keyword burst analysis, accordingly, stands out to indicate words, which possess impressing link strength, its centrality, and active years. These words stand out to be representative of particular fields of study so that the performance of them can display attraction towards researchers during a certain period of time. However, there are words that cover too big the scale that they lack the ability to certain statements or similar terms were identified in the same figure. In Figure 6, *international construction projects*, *civil engineers*, *building information modeling*, and *BIM*

Terms	Year	Strength	Begin	End	2007 - 2016
International construction projects	2007	4.2081	2007	2010	
International projects	2007	4.6456	2007	2011	
Peoples r china sp	2007	5.3905	2009	2013	
Risk management	2007	6.9822	2010	2014	
Civil engineers	2007	3.379	2011	2013	
American society	2007	3.379	2011	2013	
Risk assessment	2007	3.379	2011	2013	
Building information model	2007	3.0395	2013	2016	
BIM technology	2007	3.135	2013	2014	
Building information modeling	2007	2.7566	2013	2016	

Figure 6: Keyword burst 2007–2016.

technology are the foundation of the study, on which the research structure was built. Different researchers are using different terminologies in their papers. For example, international projects are described as "international construction project" or "international project," respectively. BIM terminology also appears as "building information model," "BIM technology," or "building information modeling," so in the keywords burst results, these terms are duplicated.

(i) "International construction projects" and "International projects" as a prevalent concept due to the internationalization progress remained popular during 2007 to 2011. In the past 30 years, with the development of economy, many countries began to build international construction projects. According to ENR THE TOP 250 data, international engineering contractor revenue $310.3 billion in 2007 increased to 544.3 billion in 2014. With the increase of international constructions, the research on international constructions has gradually increased. Therefore, during this time, international constructions were being widely studied.

(ii) "Peoples r China sp" is the abbreviation of "People's republic of China" in CiteSpace, whose frequency could be related to studies by Chinese researchers. As an important emerging country, whose construction field is thriving rapidly, its importance burst out was in 2009–2013. During this time, papers published by Chinese researchers were abundant, and the amount of case studies based on Chinese practices is huge [47]. Since 1997, China has been putting the national strategy—*Go Globally*—into practice. However, at that time, Chinese construction industry was not well developed, and there's a great gap between Chinese and the global standard of construction projects' quality [48]. Since the great development in the real estate field, Chinese construction companies start to expand internationally. Along with it is the burst of researches in this field. It is clear that, in the construction field, China is becoming an increasingly important figure.

(iii) Risk management: risk management has undergone decades of development, but due to the prevalence of risks and the specialization of risk management in the industry, this topic has become popular in recent years. Risk management includes risk identification and risk assessment process, through which risk management can increase the probability and impact of opportunities, while decreasing the probability and impact of the threats to the projects.

(iv) Civil engineering is the main research field of international construction and BIM, so these topics are inseparable with development in civil engineering.

(v) As a pioneer in new technology and management fields, the US' cases are being widely studied and imitated around the world. Experiences of implementing BIM, including the problems teams encountered as well as the benefits, are of high value for other construction projects [49]. The regulations, culture, and atmosphere of *American society* have caught researchers' attention for better understanding how projects have worked with a certain background. At the same time, how organizations adjusted to the advancement of technology is important for future projects [23]. By studying American's cases and analyzing similarities and differences between social statuses, one could better conduct projects with new approaches in his own country.

Figure 7: Cluster map.

6. Cluster Analysis

Scrutinizing the information keywords could bring is essential for understanding the trend of BIM-RM-INTL field. However, keywords are too detailed and sporadic to clarify major areas and research structures. Cluster analysis, through mathematical and statistical calculation of text data (which was refined to keywords and abstracts in this study), is able to summarize the latent semantic themes and their overlaps [50]. Through multidimensional cluster analysis to investigate merge concepts with strong inner relation, researchers could understand the prevalent thoughts in the field and its frontier. Cluster analysis employs a set of algorithms to attraction and repulsion of word links and then terms the cluster groups. Each cluster reserves and represents a certain amount of the overall observed terms [51].

CiteSpace allows researchers to decide what kind of algorithm they would like to use to name the clusters. For instance, name by the term of highest frequency or highest centrality. To fully understand the cluster and its implication of connection among groups, this study adopts three naming regulations: by highest term frequency; log-likelihood ratio; and mutual information. Figure 7 shows clusters that are numbered in descending order of cluster size and that the naming of clusters is done automatically by CiteSpace default calculation.

6.1. Cluster 0: Perfecting Engineering Guarantee System—Risk Assessment. Engineering guarantee is often seen in ensuring project's schedule and contract behaviors. The construction of this system can better integrate credit system, financial security, and project management by importing a third party. This technique was firstly used in developed countries, which was imitated and expanded in other countries nowadays. This cluster is closely connected to *International Projects* and *Emerging Countries*, which indicates the importance of it in construction delivery and the in-depth research developing countries have on it. International project general FIDIC contract is also a regulation to guarantee clause

Risk assessment is aimed for the uncertainties at different stages from different aspects and their impact on international construction. Through the risk assessment, result can undertake preventive measures and guarantee the project process.

6.2. Cluster 1: Remote Construction Projects. This cluster shows the management of international construction using BIM; this could be proved by the closeness between it and *International Projects*. Remote construction project is based on the development of information technology and Internet building so that supervision and management in homeland country become available. Due to the digital feature of BIM technology, design process, construction progress, safety management, and other issues became possible. Using BIM to supervise construction could ensure that the project goes as planned and the ability to grasp the construction drawbacks and quality defects. Efficiency and quality of international construction are promoted.

6.3. Cluster 2: Emerging Countries. As the main body of construction field, emerging countries are very important to BIM-RM-INTL, and they are supposed to be the pusher of

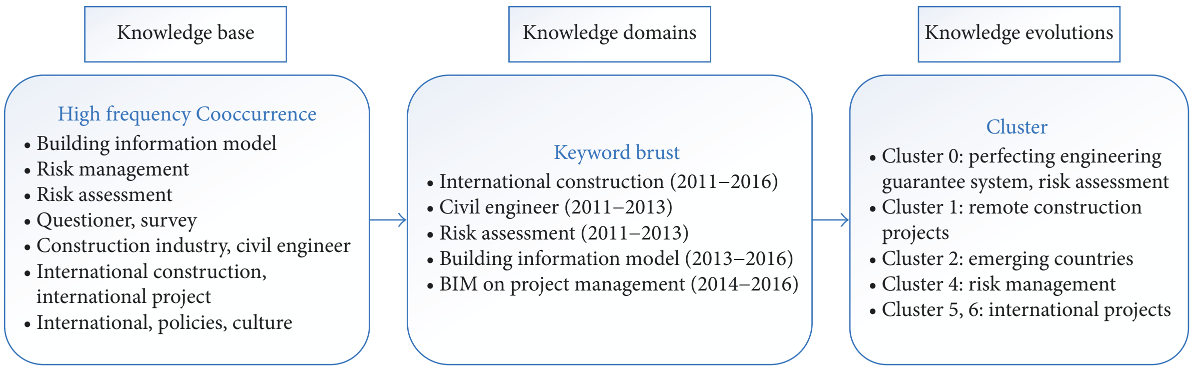

Figure 8: BIM-RM-INTL current research map.

development and practitioners of new technologies. Thus, from the figure, we can see that *Emerging Countries* appears as a sole cluster, and its position is very close to *Risk Assessment* and *Remote Construction Projects*, which indicates the relationship among them. In countries where construction field is well developed, they would choose to construct in other countries so that the productivity actually shifted. Nowadays, more and more engineers in emerging countries are supposed to receive trainings about new technologies and possess the ability to use them. Educated engineers could have the capability of integrating new technologies and the process of project management so that the sudden barriers brought out by implementation of BIM could be diminished [20].

6.4. Cluster 3: Ripple Effect Analysis. Ripple effect analysis is mainly used for complex information models. From researches in 80s analyzing the maintenance of information models [52] to developing the ability of BIM to analyze and predict the effect on whole of a small change in factors nowadays [53], ripple effect analysis is the foundation for information systems. At the location where it is near *International Projects*, *Risk Management*, and *Remote Construction Projects*, it is easy to see the importance of BIM in BIM-RM-INTL field [21].

6.5. Cluster 4: Risk Management. Risk management is a grand field; PMBOK separates it into a few steps: risk identification, risk analysis, and risk management. According to our search strategy, risk management should have close relation to construction projects. Nevertheless, from Figure 7, risk management is very far from BIM and international construction. Meanwhile, risk assessment includes risk identification, and when it is separated from risk management, it becomes an independent cluster, which has intimate relationship with international construction and information technologies. For risk management, choosing partners and contractors at bidding phase, as well as changing the positioning of a project, is so important that researchers put great efforts on this topic [54]. Investigation on risk analysis and risk intervention is a sole group; further research could put emphasis on connecting it with international construction practices.

6.6. Clusters 5 and 6: International Projects. The abundant knowledge and wide range of international projects made it two clusters. Due to the limitation of CiteSpace function, we cannot identify the differences between these two. Thus, this study considers them one big cluster.

One of the features of international projects is remote construction; this has already been discussed in Cluster #1. International projects also have close connection with ripple effect analysis, which proves that informational control is also important for international projects. The global feature of this cluster made the content colorful. Some major problems, like market entry modes and how to cope with political changes, are being widely discussed by researchers. In the bidding process, fragile parts in international construction should be considered in prior to other factors [55].

7. Framework Development and Discussion

The framework is used to identify research gaps in current studies. First, based on the bibliometric approach, results establish the BIM-RM-INTL current research map, shown in Figure 8.

BIM, international construction, and risk management have separate research. For development of the future framework of BIM-RM-INTL, in this paper, analysis of the research topics is given in details.

In risk management, there are lot of researchers who have used methods such as the hierarchy risk tree and expert interview to conduct risk identification and categorization. Traditional international construction risks fall into three levels: macro (nation-wide), market, and projects according to Hastak and Shaked [9] research. More detailed risks, like economics, scheduling, quality, and safety, were listed in the inferior level. Liu et al. [56] and Zhao et al. [57] identified risks on international construction, particularly on macroeconomics risks, social risks, political risks, legal risks, contract problems, client-related risks, design problem, safety risks, procedure complexity, technical problems, material and equipment problems, project team risks, and cost overrun risks [6]. In this paper, through the literature, analysis identifies the most common risks in international construction. The political risks, legal risks, social cultural risks, economic (cost) risks, management risks, technical risks, partners' risks, and contract risks are also highly

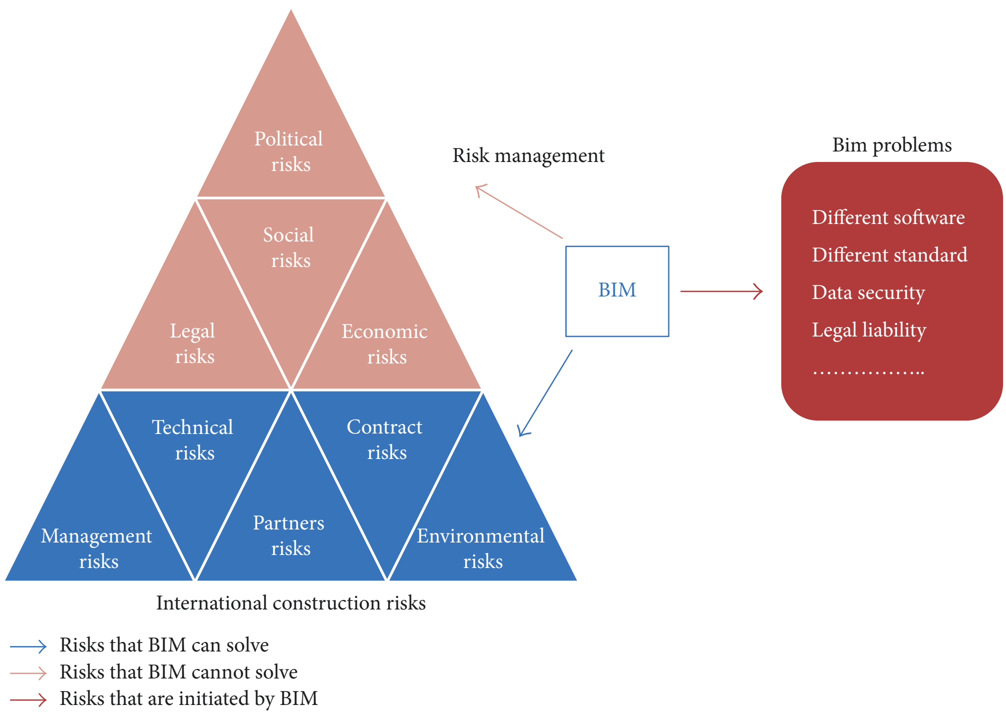

Figure 9: The proposed framework for future studies in BIM-RM-INTL.

mentioned by the academic publications for international construction risks.

BIM is a new development technology in construction industry, as shown in Figure 5. BIM function of 3D–5D can be used for design and construction stage. In design stage, BIM 3D can check collision, solve the conflict of spatial relations and design errors, and also optimize the design steps [58]. In construction stage, BIM is able to provide information, schedule and cost and bill of quantities for construction simultaneously. For minimizing risks of improper planning and cost overrun risks, a 5D automated cost-estimating model has been developed to provide a more accurate cash flow forecast that allows stakeholders make appropriate decisions for different design and payment scheme alternatives in construction projects. 4D can intuitively reflect the construction interface and construction sequence. Thus, the construction coordination between the contractor and the professional construction company becomes clear and it functions in analyzing the workplace [59]. Especially, safety control technologies like laser detection and potential danger prediction by BIM have been developed and put into use. The schedule is normally being updated through the construction process; the merge of Microsoft Project (or other scheduling document formats) and BIM is quite prevalent nowadays. The performance of quality control, hard to count and hard to deal with practically, in BIM is limited to possible defects prediction. Interoperability among different software and information flow control is experimented to be controlled by BIM. However, different standards of software in different countries are beyond the reach.

Since various factors, which are too vague to be quantified, may influence the administration decisions and communication, it is not possible to use digital analysis. On the global scale, common international construction risks that take political status, economic stability, and social cultural differences into consideration are even harder to quantify. Political status is unpredictable and its effect on social stability is huge. Economic unison, which could be understood as steady exchange rate and acceptable inflation, is hard to predict as well. Economic factors are prone to political changes, not just within the country but also the relationship of the local country with others. Social factors are also so subtle that differences in the way people behave and think in social activities are impossible to be fully concluded. Social scientists are still working very hard on cross-culture communication, not to mention quantifying it into a building model by using methods such as the fuzzy approach. Thus, the international risks require more intelligence in assessing the social environment and investment risks, not technological interference.

As discussed above, new technology could bring new problems to life, as shown in Figure 9. In order to prevent vicious cycle due to the lack of ability to control risks, this study suggests the current research status and future possible topics in a framework. Though bibliometric approach could provide insights into the current research area, it might have differences with the real life experiences since some problems in practice are not listed and the theoretical conclusions might not apply. Thus, in order to keep the results of this study accurate, we interviewed a few experts in this field to check the findings. These experts are contractors for international highway projects, and they have extensive experience in international project and have been advocating the implementation of BIM management for many years. Interviewed experts include the chief executive of BIM who has 7–12 years of working experience. BIM software development company, the main researcher, has 10 years of work experience. The college professor who has mainly studied and implemented the BIM project has 15 years of experience. Through the interview, we got to know some important risks that bibliometric did not present: (1) network at construction site is very poor, the interaction of information is very untimely, and the process of remote control is very challenging; (2) renting of facilities is complicated, but buying new facilities costs too much money to cover; (3) constant supervision is not practical for home contractor and it's hard to control construction quality; and (4) though watch dogs have been installed, since the current technology cannot directly extract information of safety behaviors through video, contractor still needs people to do the task and BIM's performance has not been in full use. Meanwhile, many conclusions discovered by bibliometric approach have been proved: since the popularization of BIM concerns interests of all stakeholders, some management issues could not function as planned. For example, contractors or subcontractors will not put construction defects into BIM since it might influence the possibility of compensation; financial factors are hard to detect and be controlled by BIM and contracting is still the most important way to control this risk; information loss during transmission stands out and this situation deteriorates when construction groups changes frequently; and only few countries have built up BIM models with their standard and regulation implemented and it's hard to conduct BIM building in most countries due to the variety of building standards, and so on.

Current studies include the following concepts: life cycle risk management is put into BIM to better gain control of it [37]; remote construction projects have been suggested for construction enterprises who have strong administration in home country or are concerned in design disputes; and through the interview, we can also can know new risks brought up by BIM implementation, since not sufficient examples existing, could only be estimated by experts or experienced professionals, and the risk could be possibly underestimated. The concept of smart city has been studied and the integration of construction, transportation, landscape, and others elements underway [60].

Future BIM-related problems would be based on how to better conduct construction works in different places that have different standards by BIM. Different construction approaches could be demonstrated by BIM on how to standardize modeling methods among different groups or countries and how to precise BIM-enabled international projects risks. These topics may require further study later. To help international contractors, apply BIM technology in controlling and preventing risks.

8. Conclusion

This article was based on 526 papers collected from Web of Science, that are related to BIM-RM-INTL. The papers were limited to those written in English and published during 2007 to 2017 in journals or from conferences in order to cover all possible directions as well as confirming the quality and relevance of papers to the best. A series of bibliometric approaches was adopted to analyze the development track and trend in this overlapping field. The title, keywords, and abstract were used to represent the research. They were analyzed in terms of keyword cooccurrence, time zone leaps, and frequency strength of keywords and semantic grouping of abstract terms. First, the keywords were determined to construct a static network that indicates interrelationships among concepts. Second, cooccurrence of keywords demonstrated on a time span clarified the changes in study interest chronically. Lastly, the abstract term analysis revealed seven groups that represent research themes.

Regarding the theoretical contribution, this article has identified risks on international construction. By scrutinizing the risks and BIM risk management of their characteristics, this article built up a framework, which shows in figure current research field, and suggests future research directions. Traditional risk analysis, international construction analysis, and BIM implementation analysis put much focus on experience and practical problems that the research individual has observed. This paper has mapped existing research results and their relationships, which can be used as an indicator of possible research area as well as instructor towards problem solving. The collection of papers and scientific algorithm ensure the accuracy of the representation of previous works and reliability of the framework.

Regarding the practical contribution, many conclusions made by bibliometric approach have been proven: the legal system and standards in each country is different which in a BIM-enabled international project can easily lead to conflicting information and information loss risk hence affecting project collaboration. Therefore, the framework, a possible topic, "How to better conduct construction works in different places that have different standards by BIM" is an important problem in the actual project. Since the popularization of BIM concerns interests of all stakeholders, some management issues could not function as planned. For example, contractors or subcontractors will not put construction defects into BIM since it might influence the possibility of compensation. In addition, construction enterprises can effectively use the functions of BIM to reduce project risk.

This article has certain limitations. There may be some other articles in other academic databases that we did not consider in this study. Moreover, the proposed research framework was only developed from a conceptual point of view according to the bibliometric analysis. The framework should be further analyzed and validated with empirical data from a quantitative point of view, especially on how risks impact project goals, and how precisely BIM enabled international projects risks and construction goals. Nevertheless, this study has mapped the relationships between existing research and future needs for risk management in BIM-enabled international construction based on the high-quality database. The results also provide insful implications for both industry and academia.

Disclosure

The authors declare that they have no financial and personal relationship with anyone or any entity whose interest could positively or negatively influence the content of this paper.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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