State-of-the-Art Review

Risk Identification and Common Risks in Construction: Literature Review and Content Analysis

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Abstract: This paper examines common risk identification tools and techniques, risk classification methods, and common risks for construction projects. A systematic review and detailed content analysis of 130 selected articles from well-regarded and relevant academic journals published over the last three decades was conducted. The findings of the content analysis showed that the majority of the selected articles identified risks for construction projects—mainly infrastructure projects—in Asia and Europe, and in most cases the identified risks were either classified based on their nature or listed without any categorization. For identifying risks, combinations of different information-gathering techniques were predominantly used in the selected articles, whereas diagramming and analysis-based techniques were seldom used. The most frequently identified risks were unpredicted change of inflation rate; design errors and poor engineering; and changes in government laws, regulations, and policies affecting the project. This paper addresses the lack of a systematic review and content analysis of published articles related to risk identification, and it provides researchers and industry practitioners with data on the most common risks affecting construction projects. **DOI: 10.1061/(ASCE)CO.1943-7862.0001685.** © *2019 American Society of Civil Engineers.*

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Introduction

Studies confirm that construction is a highly risk-prone industry because of certain distinctive characteristics of construction projects (El-Sayegh and Mansour 2015; Zeng et al. 2007). Construction projects are characterized by their varying degrees of uniqueness and complexity, the active involvement of multiple stakeholders, capital intensiveness, dynamic environments, long production durations, and exposure to external environment and weather conditions (Taroun 2014). Such characteristics contribute significantly to the existence of high uncertainty and risk in construction projects. Risks and uncertainties are indeed inherent in every construction project from initiation through to completion—and even during the operation phase of the constructed facility—regardless of the size, nature, complexity, and location of the project. Failure to deal sufficiently with potential risks and uncertainties throughout the project life cycle can often have detrimental consequences on project objectives. Risk management, therefore, should be applied as an integral part of project management for the successful delivery of construction projects in terms of time, cost, quality, safety, and environmental sustainability (Zou et al. 2007).

There are several definitions of risk in the literature, and the definitions vary based on the industry and context in which they are used. Risk is often defined in terms of uncertain events and their impact on project objectives. The Project Management Institute (PMI 2013) defines risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives." Although risk and uncertainty are considered distinct terms and concepts by some authors, others consider them to be synonymous. The International Organization for Standardization (ISO) defines uncertainty as the "state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood" (ISO 2009). In this paper, risk is considered a concern if and only if an event or its effect is associated with a certain degree of uncertainty. According to Al-Bahar and Crandall (1990) and Lam et al. (2007), risk is characterized by three components: the risk event (what might happen to the detriment or in favor of the project), the uncertainty of the event (the chance of the event occurring), and the potential loss or gain (the consequence of the event happening).

The identification of possible sources of risk is an essential stage in the risk management process because it allows project parties to discern specific instances of uncertainty; thereby, the potential impact of these uncertainties can be analyzed and appropriate strategies for mitigating their effects can be developed (Zayed et al. 2008). Furthermore, structured and detailed risk identification provides a basis for later stages and ensures risk management effectiveness (Banaitiene and Banaitis 2012). Published literature is one of the main sources of information for identifying risks (both positive and negative) in construction projects. Researchers have previously identified numerous risks affecting construction projects, and these identified risks have been used for risk assessment, analysis, and modeling purposes. Although much effort has been expended on identifying risks from the literature, existing literature reviews are not exhaustive, they lack systematic analysis, and they are limited to only a few papers. Moreover, a detailed content analysis has not been done on articles that deal with risk identification tools and techniques, classification methods, and common risks in construction management. The objectives of this paper are threefold. The first objective is to address the lack of a systematic review and content analysis of published articles related to risk

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identification in construction, identify research gaps, and suggest directions for future research. The second objective is to perform a critical examination of common risk identification tools and techniques and risk classification methods employed in construction risk management processes. The third objective is to identify, systematically categorize, and prioritize potential risks affecting construction projects through an extensive review and detailed content analysis of articles published in academic journals specializing in civil engineering, construction engineering and management, and project management.

The rest of this paper is organized as follows. In the second section, an overview of the risk identification process is provided, along with a review of the tools and techniques used for risk identification and the methods employed for risk classification in construction projects. Also, a summary of previous reviews conducted on risk-related topics is presented. In the third section, the research methodology adopted in this paper is briefly discussed. In the fourth section, the results of the content analysis of the common risk identification tools and techniques, risk classification methods, and common risks in construction projects are presented. Conclusions and future work are discussed in the final section.

Background and Literature Review

Risk Identification Process

Risk identification is the process of systematically and continuously identifying possible risks and their potential consequences on a project using different risk identification tools and techniques, classifying the risks into different categories, identifying their root causes, and documenting the characteristics of each risk (Al-Bahar and Crandall 1990). In some cases, primary risk responses may also be identified at the risk identification stage. Risk identification is the first and possibly the most important stage in the risk management process because subsequent stages can only be performed on potential risks that have been identified (Banaitiene and Banaitis 2012; Hwang et al. 2013; Zayed et al. 2008). The risk identification process should equally focus on the identification of positive risks or opportunities, which have beneficial effects on project objectives (Hillson 2002). However, common practice is to concentrate more on the identification and management of negative risks, and opportunities tend to be overlooked or addressed reactively (Hillson 2002). Risk identification is an iterative and continuous process. It should be carried out rigorously on a regular basis throughout the project life cycle because new risks may appear and previously identified risks may cease to exist (PMI 2013). El-Sayegh (2008) pointed out that attempting to identify all potential risks for a construction project is laborious, counterproductive, and impractical. Hence, the focus should be on the identification of the most critical and frequently occurring risks.

Risk identification is a process of discovery, and thus it calls for creative thinking, imagination, and leveraging project team experience and knowledge (Chapman and Ward 2003). According to Mojtahedi et al. (2010) and PMI (2013), the identification of risks in construction projects requires the participation of project stakeholders, project team members, the risk management team (if assigned), subject matter experts who are not members of the project team, project managers of other projects, and risk management experts, depending on the type of project. Involving the project team in the risk identification process can develop and maintain a sense of ownership and responsibility for identified risks and their respective response strategies (PMI 2013). In addition to the involvement of combinations of experts and stakeholders, inputs and sources of information such as historical project data, published literature on risk, standard checklists, risk breakdown structures, and risk registers facilitate the identification of risks and contribute to the comprehensiveness of the risk identification process. Tools and techniques and classification methods involved in the risk identification process for construction projects are discussed in the following subsections.

Risk Identification Tools and Techniques

In the literature, risk identification is one of the most widely studied stages of risk management. As a result, a wide array of tools and techniques exist for risk identification. These tools include documentation reviews; information-gathering techniques (brainstorming, the Delphi technique, interviewing, root cause analysis, questionnaires, and risk workshops); checklist analysis; assumption analysis; diagramming techniques (cause-and-effect diagrams, system or process flow charts, and influence diagrams); strengths, weaknesses, opportunities, and threats (SWOT) analysis; expert judgment; fault tree analysis; decision tree analysis; and failure mode and effect analysis (Grimaldi et al. 2012; Marle and Gidel 2014; PMI 2013). Hillson (2002) suggested that an appropriate combination of tools and techniques should be employed in risk identification because there is no single "best method." The selection of appropriate tools and techniques for risk identification requires taking into account criteria such as project phase; complexity of the project; availability of skilled personnel familiar with the risk identification tools and techniques; risk maturity of the organization; the approach (analogical, heuristic, or analytic) to be applied for risk identification; and simplicity of use, interaction considerations, and completeness of the tools and techniques (Grimaldi et al. 2012; Marle and Gidel 2014). Despite the availability of several risk identification tools and techniques, only a few are frequently used in the construction industry. Based on an investigation conducted by Lyons and Skitmore (2004), brainstorming, case-based approaches, and checklists are the most commonly used risk identification techniques. Irrespective of the tools and techniques used to identify risks on a project, the main outputs of the identification process are presented in the risk register. The risk register contains detailed information on the identified risks, and it can help the project team assess, review, track, mitigate, and control project risks periodically throughout the project life cycle. Additionally, a well-documented risk register can be a useful reference for future risk identification and the main source of information for developing a risk knowledge database.

Risk Classification Methods

Risk classification (or categorization) is an integral part of risk identification. It helps the project team structure the diverse and varied risks that may affect a construction project. The structured classification of risks contributes to the effectiveness and quality of the risk identification process and creates a better understanding of the nature of risks and their sources (Bu-Qammaz et al. 2009). Moreover, a logical and structured classification of risks assists in the reduction of redundancy and ambiguity in the risk identification stage and provides for easier management of risks in the later stages of risk management. In the literature, various approaches have been recommended for classifying risks on construction projects. Some of the approaches adopt a broad categorization, whereas others use categories that are more detailed. Risks can be categorized based on their source, nature, occurrence at different stages of the project, impact on project objectives, the party who might be the originator of the risk, and a three-level metaclassification approach (macro-, meso-, and micro-level).

Using the initial source of risks as a basis, Al-Sabah et al. (2014), El-Sayegh and Mansour (2015), and Tah and Carr (2000) classified risks into two main categories: internal risks (those that are project-related and that usually fall under the control of the project management team) and external risks (those risks that are beyond the control of the project management team). Each author partitioned these main categories (internal and external) into detailed subcategories according to the nature and type of the projects. Several researchers, including Boateng et al. (2012), Elbarkouky et al. (2016), and Tavakolan and Etemadinia (2017), used the nature of risks as the criteria for classifying risks into distinct groups. For example, Tavakolan and Etemadinia (2017) classified risks into nine groups: financial, contractual, design, health and safety, management, construction, social/political, external, and procurement/supply. Goh et al. (2013), Lee and Schaufelberger (2014), and Li and Zou (2011) categorized risks based on the project stage at which the risks would occur. For example, Goh et al. (2013) categorized risks into five groups: planning, design, procurement, construction, and hand over stage risks. Zou et al. (2007) categorized risks into five groups based on their respective impact on project objectives: cost-, time-, quality-, environment-, and safety-related risks. Such categorization may result in redundancy because a single risk may have an impact on more than one project objective. According to the party who might be the originator of the risk, Wang and Yuan (2016) classified risks into five groups: client-, designer-, contractor-, subcontractor-, and authority-related risks. Bing et al. (2005) and Hwang et al. (2013) adopted a three-level metaclassification approach and grouped risks into macro-level risks (risks beyond the system boundaries of the project), meso-level risks (risks within the system boundaries of the project and directly related to the nature of the project), and micro-level risks (risks that are project party-related, that is, risks associated with the relationships between the parties involved in the project).

According to Ebrahimnejad et al. (2010), the classification of risks based on either the source or the nature of those risks are the most widely used methods for risk identification on construction projects. Risk classification methods selected for construction projects may differ based on the type of project, the type of procurement method employed, and the project party conducting the risk identification and assessment. Regardless of the categorization scheme adopted, the various categories of risks are organized and presented using a risk breakdown structure (RBS). According to PMI (2013), an RBS is defined as "a hierarchically organized depiction of the identified project risks arranged by risk category and subcategory that identifies the various areas and causes of potential risks." RBSs show the risk categories and subcategories within which risks may arise as well as the risks at the lowest level for risk identification, assessment, mitigation, and reporting purposes.

Previous State of the Art Reviews Conducted on Risk-Related Topics

Despite the abundance of published articles focusing on risk-related topics in construction, only a few are dedicated to bibliometric or content analysis. Edwards and Bowen (1998) carried out an analytical review of construction and project risk management literature published between 1960 and 1997 to identify gaps in research and practice and to determine potential areas for future research. Taroun (2014) presented a review of risk modeling and assessment literature published between 1983 and 2012 in academic journals specializing in the construction industry, project management, risk analysis, and management science. Islam et al. (2017) provided a comprehensive review of current research trends and application areas of fuzzy and fuzzy hybrid methods applied in the risk assessment of construction projects based on content analysis of 82 articles published between 2005 and 2017 in leading construction and engineering management journals. Yu et al. (2018) conducted a systematic review of 37 articles published in construction management journals between 1991 and 2015 to study research trends and identify critical risk factors of transnational public–private partnership (TPPP) projects.

The studies by Edwards and Bowen (1998), Taroun (2014), and Islam et al. (2017) focused on either the entire risk management process or specifically on risk modeling and assessment. Although Yu et al. (2018) reviewed the identification of critical risk factors in previous studies, their review was limited to a particular type of project (i.e., TPPP). This paper specifically focuses on the risk identification process and common risks in construction and addresses the lack of a systematic review and content analysis of literature on these topics. The scope and objectives of this paper are different than the aforementioned studies, thereby resulting in new findings.

Research Methodology

A three-stage process (Fig. 1) was adopted in this paper to achieve the research objectives. These stages are described in the following subsections.

Journal Selection

In Stage 1, journals that have an important impact and prominent position in the research community of construction engineering and management were selected. The selection of journals was based on purposive/selective sampling (Xiong et al. 2015); that is, those journals extensively used to conduct literature review and content analysis specifically on risk-related topics in construction engineering and management by different authors (Islam et al. 2017; Taroun 2014; Yu et al. 2018) were considered. Also, the 2016 Scopus journal metrics (CiteScore) and the research conducted by Wing (1997) on the ranking of construction management journals were referred to when choosing the journals. Journals that have a CiteScore of 0.70 and above based on the 2016 Scopus journal metrics were considered. Only those journals that published at least three papers related to the topic of this study between 1990 and 2017 were chosen. The following 14 journals were selected: *Expert Systems with Applications* (ESA), *Automation in Construction* (AC), *International Journal of Project Management* (IJPM), *Building and Environment* (B&E), *Journal of Construction Engineering and Management* (JCEM), *Journal of Computing in Civil Engineering* (JCCE), *Journal of Management in Engineering* (JME), *Journal of Infrastructure Systems* (JIS), *Construction Management and Economics* (CME), *Journal of Civil Engineering and Management* (JCiEM), *Engineering, Construction and Architectural Management* (ECAM), *Canadian Journal of Civil Engineering* (CJCE), *International Journal of Construction Management* (IJCM), and *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A:Civil Engineering* (JRUES). The selected journals were ordered from high to low based on their CiteScore. Even though the last journal in the list (JRUES) is not included in the Scopus database and does not have a CiteScore, it was selected for this research because of its relevance.

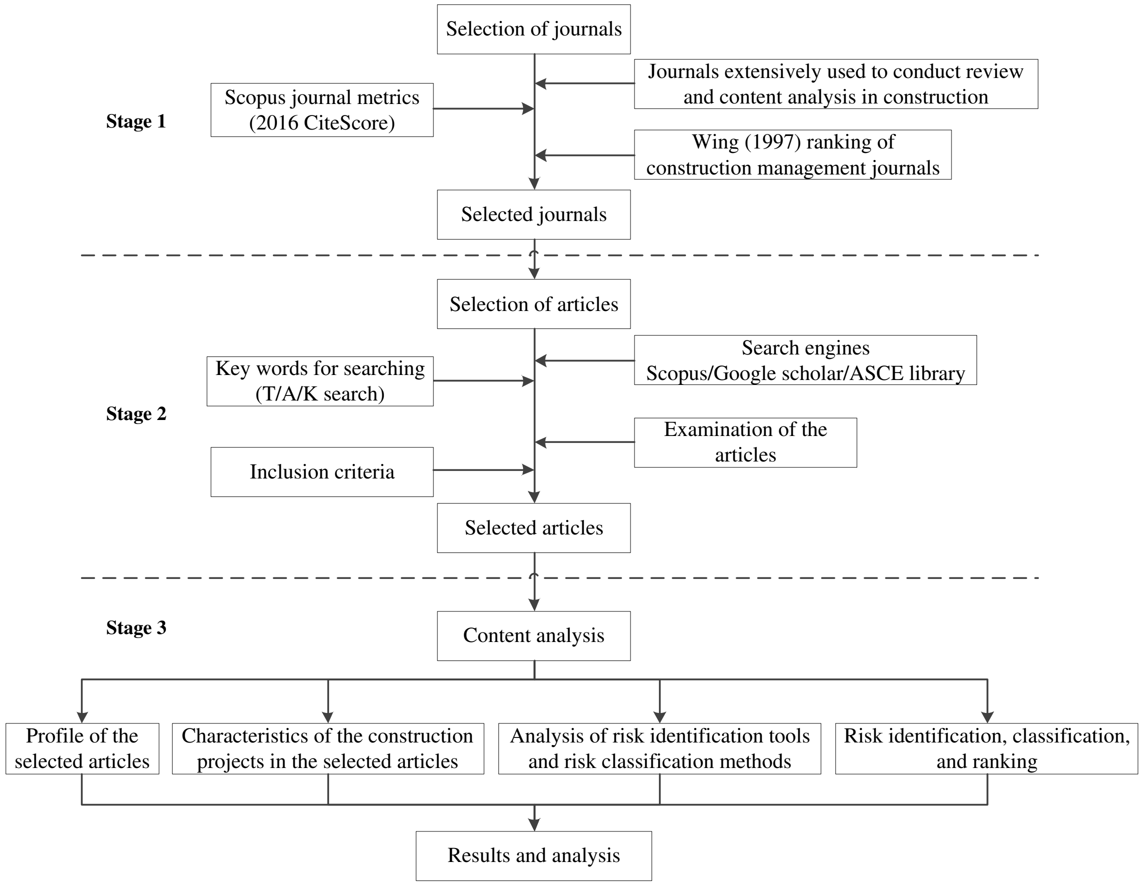

Fig. 1. Research methodology for article selection and content analysis. T/A/K = title, abstract, and keyword search.

Article Selection

In Stage 2, searches for relevant articles were performed using Scopus (Elsevier's abstract and citation database), Google Scholar, and American Society of Civil Engineers (ASCE) library search engines. Keywords used for searching the articles included risk identification, risk assessment, risk analysis, risk management, construction risk, project risk, uncertainty analysis, and project uncertainty. The keywords were selected from previously published articles (Islam et al. 2017; Taroun 2014) that conducted a review on risk-related topics, and they were based on an initial examination of common keywords used in risk management-related articles published in the construction domain. The search was conducted using the title, abstract, and keyword (T/A/K) field of the aforementioned search engines. The search was restricted to articles published from 1990 to 2017 (inclusive). As a result, 484 articles were initially retrieved from the selected journals. The contents of the articles were further examined, and the number of articles was reduced to 130. The following inclusion criteria were used to select the articles: (1) the article should be specifically related to risks in the construction industry; (2) the article should mention, discuss, or list potential risks affecting construction projects in the main text, tables, or figures; (3) the article should use at least one technique for identifying risks; and (4) the article should use a specific classification method for categorizing risks or simply mention, discuss, or list the risks in the main text, tables, or figures.

Content Analysis

In Stage 3, once the articles were identified, detailed content analysis was carried out in order to (1) profile the selected articles based on type of journal, and year of publication, and the number of authors per article; (2) characterize the construction projects considered for risk identification in the selected articles based on region and type; (3) examine common risk identification tools and techniques, risk classification methods, and category names used for classifying risks in the selected articles; and (4) systematically identify, categorize, and rank common construction project risks identified from the selected articles. Content analysis is a research technique for determining major facets of and valid inferences from written, verbal, or visual communication messages, either qualitatively or quantitatively, depending on the nature of the project and the issues to be addressed in the research (Chan et al. 2009; Krippendorff 2013). Content analysis is a powerful technique for collecting and organizing information and for examining trends and patterns in documents (Krippendorff 2013). Qualitative content analysis focuses on grouping data into categories, whereas quantitative content analysis determines the numerical values of categorized data (i.e., frequencies, ratings, and rankings) by simply counting the number of times a topic is mentioned (Chan et al. 2009). In this paper, a combination of both qualitative and quantitative content analysis was adopted.

Results and Discussion

The complete list of selected articles used for the content analysis is provided in Table S1 (see Supplemental Data). The percentage values indicated in the discussion, figures, and tables were determined based on the number of references over the total number of articles considered in the content analysis (i.e., 130 articles).

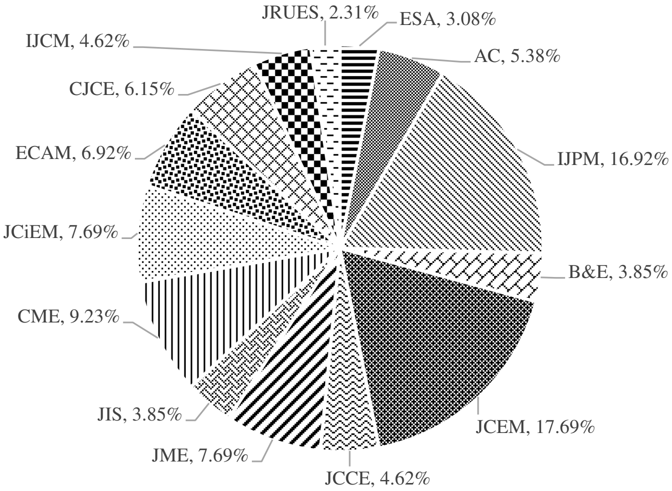

Fig. 2. Percentage of the selected articles published in each journal.

Profile of the Selected Articles

The selected articles considered for content analysis were profiled based on journal and year of publication. Fig. 2 depicts the percentage of the selected articles published in each journal. Close to 60% of the selected articles were published in five journals: JCEM (17.69%), IJPM (16.92%), CME (9.23%), JME (7.69%), and JCiEM (7.69%). The remaining 40% of the selected articles were published in the other nine journals. The number of selected articles by journal and year of publication is shown in Fig. 3. The selected articles were published between 1990 and 2017; among these, 109 articles (73.84%) were published between 2005 and 2017. The number of selected articles published in the span of 2010–2014 is considerably greater than any other publication period.

Profile of the Projects in the Selected Articles

The construction projects considered for risk identification in the selected articles were profiled based on type and geographical region. The selected articles encompassed risk identification on various construction projects located in different geographical regions. The various construction projects in the selected articles were grouped into five categories according to the type of construction work: building projects (residential, office, commercial, mixed development, hospitals, etc.), infrastructure projects (highways, mass transit systems, tunnels, bridges, drainage systems, sewage treatment plants, etc.), power and energy projects (hydroelectric plants, solar energy, wind power, nuclear energy, etc.), heavy industrial projects (chemical, refineries, oil sands installations, etc.), and multiple combinations thereof. As shown in Table 1, most of the construction project types considered for risk identification in the selected articles were infrastructure projects (41.54%), followed by a combination of two or more project types (37.69%), and building projects (11.54%).

A higher percentage is attributed to articles related to infrastructure projects because a wide range of projects are subsets of this project category. Moreover, infrastructure development plays a key role in the economic growth and social development of both developed and developing countries. As a result, infrastructure projects are high on governments' agendas and often have large budget allocations (Yu et al. 2018). Large infrastructure projects often suffer from cost overruns, delays, failed procurement, and lack of availability of finances, which contribute to the existence of a wide variety of risks and uncertainties (Vickerman 2007; Yu et al. 2018). Hence, it is important to identify and manage risks for successful completion of infrastructure projects.

The majority of the selected articles dealt with risk identification of construction projects located in Asian countries (56.92%), of which 39.19% were in China and 13.51% were in Iran; followed by European countries (16.92%), of which 50.00% were in Turkey and 27.27% were in the United Kingdom. The geographical distribution of the projects used in risk identification in the selected articles reflects the growing demand for research on risk-related topics in those regions. Construction companies in developed countries apply systematic risk management, have better risk management maturity, and benefit from well-established risk management standards compared to construction companies in developing countries (Hosseini et al. 2016). The risk management practice in developing countries has been found to be inadequate, unstructured, and inconsistently used (Choudhry and Iqbal 2013; Hosseini et al. 2016; Tadayon et al. 2012). For example, an empirical study conducted on risk management practices by Tang et al. (2007) revealed that the risk management systems applied in the Chinese construction industry tend to be "informal, which are inadequate to manage project risks." The rapid economic growth of China has contributed to large expenditures in infrastructure development, thus creating one of the largest construction markets in the world (Tang et al. 2007). A higher percentage of the projects in the selected articles

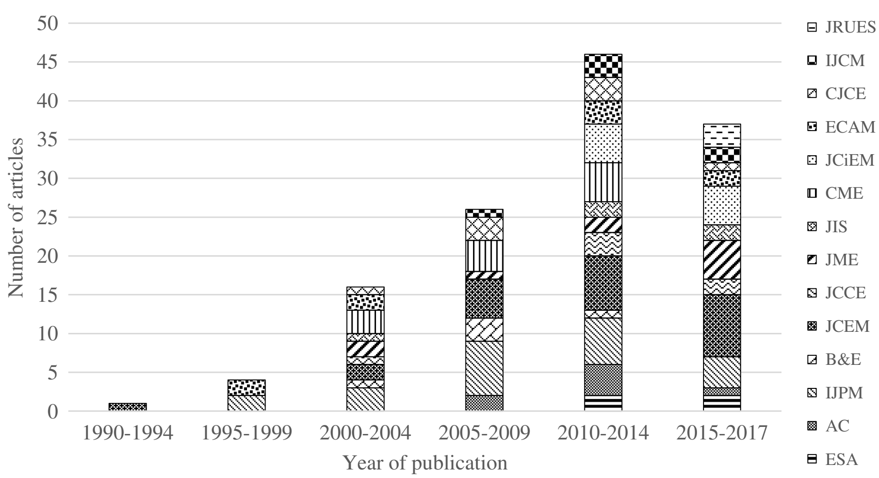

Fig. 3. Number of selected articles by journals and year of publication.

Table 1. Profile of the projects in the selected articles

Feature	Category	Number of articles	Percentage of articles
Project type	Building projects	15	11.54
	Infrastructure projects	54	41.54
	Power and energy projects	9	6.92
	Heavy industrial projects	3	2.31
	Combination of two or more project types	49	37.69
	Total	130	100.00
Geographical region of projects	Africa	4	3.08
	Asia	74	56.92
	Australia	6	4.62
	Europe	22	16.92
	North and Central America	9	6.92
	South America	1	0.77
	General[a]	14	10.77
	Total	130	100.00

[a]The geographical regions of the projects are not stated in the selected articles, or the projects are located in more than one geographical location.

Table 2. Risk identification tools and techniques used in the selected articles

Category	Number of articles	Percentage of articles	Rank
Combination of tools and techniques			
Single tool or technique	35	26.92	2
Two tools and techniques	69	53.08	1
Three or more tools and techniques	26	20.00	3
Total	130	100.00	—
Tools and techniques regardless of being used alone or in combination			
Checklist	3	2.31	10
Documentation review	13	10.00	6
Brainstorming	5	3.85	7
Delphi technique	5	3.85	7
Expert interview	38	29.23	3
Questionnaire survey	61	46.92	2
Risk workshop	4	3.08	9
Literature review	87	66.92	1
Influence diagram	1	0.77	11
Expert judgment/panel	21	16.15	4
Past projects/historical project data	21	16.15	4
Combination of two or more tools and techniques (top 3)			
Literature review and questionnaire survey	28	29.47	1
Literature review, expert interview, and questionnaire survey	15	15.79	2
Literature review and expert interview	9	9.47	3

were therefore focused on Asian countries (mainly China) as opposed to Europe and North America, to highlight the growing demand for research on risk-related topics in countries like China.

Risk Identification Tools and Techniques Used in the Selected Articles

A wide variety of tools and techniques were used for risk identification in the selected articles (Table 2). In the selected articles, the use of combinations of two risk identification tools and techniques (53.08%) was more popular than the use of a single tool or technique (26.92%) and a combination of three or more tools and techniques (20.00%). The three most frequently used risk identification tools and techniques, regardless of whether they were used alone or in combination, were literature review (66.92%), questionnaire surveys (46.92%), and expert interviews (29.23%). Detailed analysis of the selected articles that used a combination of two or more tools and techniques indicated that the use of a literature review combined with a questionnaire survey was the most prevalent (29.47%), followed by a combination of literature review, expert interview, and questionnaire survey (15.79%), and a combination of literature review and expert interview (9.47%). The findings of the content analysis indicate that information-gathering tools and techniques (e.g., literature review, questionnaire survey, expert interview) were more widely used than diagramming tool and techniques (e.g., influence diagrams, cause-and-effect diagrams, and system or process flow charts) for risk identification. Diagramming tools and techniques were rarely used in the selected articles because most articles focused only on the identification of risks and their impact on the project objectives without considering the root causes of risks and their interdependencies. None of the analysis-based tools and techniques (e.g., fault tree analysis, decision tree analysis, or failure and mode effect analysis) was used in the selected articles, perhaps because analysis-based tools and techniques are more often used in risk analysis, even though they are also applicable for risk identification.

Of the information-gathering tools and techniques, literature review is predominantly used in the selected articles mainly because it is easily implemented and helps to assess knowledge and historical information accumulated from previous projects. Since most risks in literature are identified for a specific context, the user should consider risks that do not appear in the literature but are highly relevant to a specific project. A questionnaire survey helps to capture the perception of large (diversified) groups and encourages broad thinking to identify risks. The success of a questionnaire survey depends on the quality of the questions, mode of questionnaire administration, sample size, burden on respondents (length of questions), response rate, and quality of responses (Rostami 2016; Baumann et al. 2016). Expert interview is an interactive method that makes use of the experience of project managers, subject matter experts, and experienced project participants to identify potential risks through structured questions. The results of an expert interview depend on the experience and expertise of each interviewee and the quality of the interview process. Contrary to the other two information-gathering tools and techniques, an expert interview is resource-intensive and time consuming (Rostami 2016; Baumann et al. 2016). Tools and techniques that employ diversified groups of subject matter experts are better for risk identification than tools and techniques that rely on an individual assessment (Baumann et al. 2016). According to Hillson (2002), an appropriate combination of tools and techniques (especially those that complement each other) guarantees better results in identifying potential risks because there is no single best risk identification tool or technique.

The review conducted on the selected articles reflects that there is a lack of guidelines and systematic criteria for selecting appropriate risk identification tools and techniques for construction projects because the selected articles did not provide such guidelines or provide a rationale for selecting a specific risk identification tool or technique based on specific criteria. Also, studies that focus specifically on systematic approaches/models for evaluating the maturity level of risk identification practices are scarce in the selected articles. Groups of experts with different levels of knowledge, experience, and expertise are often involved in risk identification processes. However, the group-based risk identification tools and techniques used in the selected articles do not take into account the expertise level of experts in risk management. In most of the selected articles, the experts are assumed to have equal weights,

Table 3. Risk classification methods and level of RBS used in the selected articles

Category	Number of articles	Percentage of articles	Rank
Risk classification methods			
Classification based on initial source of risks (internal and external)	20	15.38	3
Classification based on nature of risks	50	38.46	1
Classification based on occurrence of risks at different stages of the project	8	6.15	4
Classification based on impact of risks on project objectives	3	2.31	6
Classification based on the project party who might be the originator of the risk	2	1.54	7
Three-level metaclassification	8	6.15	4
No classification (just listing of risks)	39	30.00	2
Total	130	100.00	—
Level of risk breakdown structure (RBS)			
Three levels	28	21.54	3
Two levels	63	48.46	1
Single level (just listing)	39	30.00	2
Total	130	100.00	—

or the weights of experts are simply determined based on experts' years of experience, which calls for further research on methods of distinguishing experts based on a more comprehensive set of qualifications.

Risk Classification Methods Used in the Selected Articles

Table 3 presents the risk classification (categorization) methods adopted in the selected articles. A majority of the selected articles (38.46%) classified risks based on their nature. Classification based on the initial source of the risk (internal or external) was the second most favored classification method and was used in 15.38% of the articles. Classification based on the occurrence of the risk at different stages of the project (6.15%) and three-level metaclassification (6.15%) were considerably less common in the selected articles. Classification based on the impact of risks on project objectives (2.31%) and classification based on the project party who might be the originator of the risk (1.54%) were very rarely used in the selected articles. A considerable proportion of the selected articles (30.00%) did not use any of the classification methods; rather, the risks were simply listed. A large proportion of the selected articles (48.46%) used a three-level RBS composed of main category, subcategory, and risks at the lowest level. Another 21.54% of the articles used a two-level RBS (i.e., main category and list of risks), and 30.00% of the articles just listed the risks without categorizing them. Further analysis carried out on the categories (main and sub) indicated that numerous category names have been adopted in the selected articles for classifying risks based on their nature. The top 20 risk category names used in the selected articles for classifying risks based on their nature are shown in Table 4, which was later used as the basis for the proposed classification method adopted in this paper. The most popular category names used in the selected articles were economic (24.62%), political (24.62%), construction (22.31%), financial (21.54%), and management (20.00%).

The review of existing classification methods in the selected articles reveals that there is no standard or consensus on how to categorize risks in the construction industry. In addition, there is a lack of clarity and consistency in the definition of risk categories. The categories in most risk classification methods adopted in the selected articles do not capture the broad variety of risks. Furthermore, the available classification methods are suitable for specific project types or project stakeholders. These limitations highlight the need for a structured and comprehensive risk classification method. Therefore, a comprehensive and structured classification method is proposed in this paper based on the existing category names in the selected articles (Table 4), as discussed in the next section.

Identification, Classification, and Ranking of Common Risks from the Selected Articles

In this paper, the risks identified from the selected articles were categorized based on their nature because it is the most widely used classification approach in the selected articles. The risks identified from the selected articles were grouped into 11 categories: management, technical, construction, resource-related, site conditions, contractual and legal, economic and financial, social, political, environmental, and health and safety. These category names were chosen from the top 20 category names identified from the selected articles (Table 4). Some of the category names had to be combined to avoid redundancy in risk identification and categorization (e.g., economic and financial, contractual and legal). In the case of category names that were commonly used interchangeably, the one that was more general and inclusive of the other was used (e.g., the category name "technical" was chosen over "design" and "engineering," and the category name "resource-related" was chosen because it incorporates "material," "labor," "equipment," and "subcontractor"). Such classification is intended to illustrate the diversity of risks and thereby assist in examining the full breadth of exposure to possible risks so that project parties do not focus on specific risks and overlook others (Al-Bahar and Crandall 1990; Bu-Qammaz et al. 2009). Since the proposed classification method is comprehensive, it can be adopted for classifying risks for

Table 4. Top 20 risk category names used in the selected articles for classifying risks based on their nature

Category name	Number of articles	Percentage of articles	Category name	Number of articles	Percentage of articles
Economic	32	24.62	Legal	15	11.54
Political	32	24.62	Site conditions	13	10.00
Construction	29	22.31	Market	10	7.69
Financial	28	21.54	Natural	9	6.92
Management	26	20.00	Health and safety	8	6.15
Environmental	23	17.69	Labor	8	6.15
Design	23	17.69	Equipment	7	5.38
Contractual	22	16.92	Resources	7	5.38
Technical	19	14.62	Acts of god	7	5.38
Social	18	13.85	Geological	7	5.38

Table 5. Number of identified risks in each category in the selected articles

Risk category	Number of identified risks	Percentage of identified risks
Management	72	12.61
Technical	63	11.03
Construction	59	10.33
Resource-related	68	11.91
Site conditions	38	6.65
Contractual and legal	65	11.38
Economic and financial	67	11.73
Social	38	6.65
Political	46	8.06
Environmental	24	4.20
Health and safety	31	5.43
Total	571	100.00

different types of construction projects and project stakeholders. Broader and comprehensive categorization facilitates both risk identification processes and subsequent risk management processes. Grouping risks of similar nature is essential to avoid duplication, identify risk interdependencies and interactions, and identify root causes of risks. Moreover, such categorization helps to identify effective risk response strategies and allocate risks to the most appropriate contracting party.

Each of the risks identified from the selected articles were placed in a unique category. Because of the categorization method adopted in this paper, identified risks may fall under a different category than their original category in the selected article. A total of 571 risks were identified after conducting an extensive review and content analysis on the selected articles. Table 5 shows the number of risks identified under each category.

The risks in each category were ranked solely based on their frequencies, that is, the total number of references (hits) each risk had (Table 6). The frequencies reflect how common the risks are in the construction industry or how frequently they are identified in the selected articles. The ranking does not show the probability of occurrence, impact, or severity of the identified risks on project objectives. The probability, impact, and severity of risks are very project- and context-specific and cannot be generalized. The top 10 risks in each category are shown in Table 6.

Management risks are those risks related to the management skills and experience of the project team and project parties, the availability of project management professionals, and the relationships and coordination among project parties (Ling and Hoi 2006). As shown in Table 6, the most frequently mentioned management risks in the selected articles were poor coordination among various parties involved in the project (22.31%), lack of experience and project management skills of the project team (20.00%), inadequate or poor project planning and budgeting (18.46%), unavailability of sufficient professionals and managers (17.69%), and poor communication among various parties involved in the project (17.69%). Technical risks are risks associated with the technical aspects of the project, such as design, specifications, engineering, and technology (El-Sayegh and Mansour 2015). Among the technical risks identified from the selected articles, design errors and poor engineering (46.92%) and unanticipated engineering and design changes (36.92%) were the most prevalent, followed by unclear and inadequate details in design drawings and specifications (16.92%) and inadequate study and insufficient data before design (16.92%). Construction risks involve issues or concerns associated with construction methods, work tasks, delays and interruptions in construction, cost overruns, and quality of construction (Shrestha et al. 2017). The three most common construction risks identified from the selected articles were poor workmanship and construction errors leading to rework (38.46%), delays and interruptions causing a cost increase to the work package/project (27.69%), and an unreasonably tight project schedule causing a cost increase to the work package/project (11.54%).

Resource-related risks are risks associated with the suitability, condition, availability, quality, and procurement of construction materials and equipment and the availability, skill level, and performance of labor and subcontractors. As shown in Table 6, unavailability of a sufficient amount of skilled labor in the project region (40.77%), unavailability or shortage of expected materials (36.92%), unavailability or shortage of expected equipment (23.85%), and delay in materials delivery (20.77%) are very common resource-related risks in the selected articles. The site conditions risk category includes those risks related to the construction project site, including uncertainty regarding subsurface conditions, underground utilities, archaeological finds, accessibility of the site, availability of supporting infrastructure, and security and traffic conditions at the site (El-Sayegh and Mansour 2015). The top three site condition risks identified from the selected articles were unpredicted adverse subsurface conditions (41.54%), differing and unforeseen site conditions (26.92%), and lack of readily available utilities on site and unavailability of supporting infrastructure (15.38%).

Contractual and legal risks arise from poorly tailored contracts, inappropriate distribution of responsibilities, conflicts in contract documents, inadequate claim administration, disputes and litigations, third-party liabilities, immature laws, and complexity in the legal environment (El-Sayegh and Mansour 2015; Shrestha et al. 2017). The most frequently mentioned risks belonging to this category in the selected articles were contradictions and vagueness in contract documents (31.54%), changes in project scope (16.92%), immaturity and/or unreliability of the legal system (16.15%), and delays in resolving contractual disputes and litigations (15.38%). The economic and financial risk category includes risks related to inflation, fluctuations in exchange rates, changes in price, tax rates and economic policies, and also risks arising from financing structures and the financial market as well as challenges in financing the project (Iyer and Sagheer 2010; Shrestha et al. 2017). The most common economic and financial risks in the selected articles were unpredicted changes in the inflation rate (49.23%), project-funding problems (36.92%), fluctuations in currency exchange and/or difficulty of convertibility (33.08%), and unpredicted changes in interest rates (25.38%).

The social risks category involves risks associated with cultural and religious differences, crime and lack of security on project sites, issues or concerns related to social and cultural impacts of the project on the community, and public objections to projects (El-Sayegh 2008; Nielsen 2006). Among the identified risks belonging to this category, the most common were land acquisition and compensation problems (21.54%); public opposition to the project (17.69%); and differences in social, cultural, and religious backgrounds (16.15%). The political risks category includes risks that are dependent on political and regulatory situations as well as the stability of the country where the project is taking place (El-Sayegh and Mansour 2015). Changes in government laws, regulations, and policies affecting the project (46.15%) was the most frequently mentioned political risk in the selected articles, followed by political instability of the government (26.15%), delay or refusal of project approval and permit by government departments (24.62%), and outbreak of hostilities (i.e., wars, revolution, riots, and terrorism) (20.00%).

Table 6. Top ten risks in each category identified from the selected articles

Description of risks	Number of articles	Percentage of articles	Rank
Management			
Poor coordination among various parties involved in the project	29	22.31	1
Lack of experience and project management skills of the project team	26	20.00	2
Inadequate or poor project planning and budgeting	24	18.46	3
Unavailability of sufficient professionals and managers	23	17.69	4
Poor communication among various parties involved in the project	23	17.69	4
Poor site management and supervision by the contractor	16	12.31	6
Poor relationships among various parties involved in the project	16	12.31	6
Inadequate project organization structure	15	11.54	8
Poor project quality management, including inadequate quality planning, quality assurance, and quality control	14	10.77	9
Poor capability of owner in project management	12	9.23	10
Technical			
Design errors and poor engineering	61	46.92	1
Unanticipated engineering and design changes	48	36.92	2
Unclear and inadequate details in design drawings and specifications	22	16.92	3
Inadequate study and insufficient data before design (errors in feasibility studies)	22	16.92	3
Unproven or immature engineering techniques	16	12.31	5
Delay in design (design process takes longer than anticipated)	14	10.77	6
Incomplete design	10	7.69	7
Technology changes	8	6.15	8
Complexity of design	7	5.38	9
Poor constructability	7	4.62	9
Construction			
Poor workmanship and construction errors leading to rework	50	38.46	1
Delays and interruptions causing a cost increase to the work package/project	36	27.69	2
Unreasonably tight project schedule causing a cost increase to the work package/project	15	11.54	3
Complexity of proposed construction methods/techniques	12	9.23	4
Contractors' incompetence in executing the work package/project	12	9.23	4
Changes in construction methods/techniques	11	8.46	6
Adoption of improper, poor, or unproven construction methods/techniques	11	8.46	6
Contractor's lack of experience in similar projects	8	6.15	8
Conflicting interfaces of work items	6	4.62	9
Pressure to deliver project on accelerated schedule (pressure to crash project duration)	6	4.62	9
Resource-related			
Unavailability of a sufficient amount of skilled labor in the project region	53	40.77	1
Unavailability or shortage of expected materials	48	36.92	2
Unavailability or shortage of expected equipment	31	23.85	3
Delay in materials delivery	27	20.77	4
Defective or non-conforming materials that do not meet the standard	22	16.92	5
Low labor productivity of local workforce	22	16.92	5
Subcontractors' failure; default of subcontractors	15	11.54	7
Unavailability of qualified subcontractors	15	11.54	7
Low productivity and efficiency of equipment	14	10.77	9
Equipment breakdown	13	10.00	10
Site conditions			
Unpredicted adverse subsurface conditions	54	41.54	1
Differing and unforeseen site conditions	35	26.92	2
Lack of readily available utilities on site (e.g., water, electricity, etc.) and unavailability of supporting infrastructure	20	15.38	3
Inadequate site investigations (soil tests and site survey)	17	13.08	4
Difficulties of access and work on site due to specific geographical constraints of the region	15	11.54	5
Late construction site possession	13	10.00	6
Unexpected underground utilities encounters	10	7.69	7
Delays in the right-of-way process	8	6.15	8
Ineffective control and management of traffic	8	6.15	8
Improper selection of project location	7	5.38	10
Contractual and legal			
Contradictions and vagueness in contract documents	41	31.54	1
Changes in project scope	22	16.92	2
Immaturity and/or unreliability of the legal system	21	16.15	3
Delays in resolving contractual disputes and litigations	20	15.38	4
Possibility of contractual disputes and claims	17	13.08	5
Frequent change orders	12	9.23	6
Change in codes and regulations	12	9.23	6
Excessive contract variation	10	7.69	8
Intense competition at the tender stage	8	6.15	9
Unclear roles and responsibilities of project stakeholders	8	6.15	9

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Table 6. (*Continued*.)

Description of risks	Number of articles	Percentage of articles	Rank
Economic and financial			
Unpredicted changes in the inflation rate	64	49.23	1
Project-funding problems	48	36.92	2
Fluctuations in currency exchange and/or difficulty of convertibility	43	33.08	3
Unpredicted changes in interest rates	33	25.38	4
Escalation of material prices	29	22.31	5
Delay in payments	29	22.31	5
Changes in tax regulation	25	19.23	7
Poor financial market or unavailability of financial instrument resulting in difficulty of financing	24	18.46	8
Unfavorable economic situations in the country (instability of economic conditions)	22	16.92	9
Market demand changes	16	12.31	10
Social			
Land acquisition and compensation problems (the cost and time for land acquisition exceeds the original plans)	28	21.54	1
Public opposition to the project (public objections, social grievances)	23	17.69	2
Differences in social, cultural, and religious backgrounds	21	16.15	3
Insecurity and crime (theft, vandalism, and fraudulent practices)	14	10.77	4
Strikes and labor disputes	14	10.77	4
Poor public relations with local contacts	10	7.69	6
Unfavorable social environment	8	6.15	7
Societal conflict and/or public unrest	8	6.15	7
Poor public decision-making process	7	5.38	9
Disturbances to public activities	5	3.85	10
Political			
Changes in government laws, regulations, and policies affecting the project	60	46.15	1
Political instability of the government (unfavorable political environment)	34	26.15	2
Delay or refusal of project approval and permit by government departments (excessive approval procedures)	32	24.62	3
Outbreak of hostilities (wars, revolution, riots, and terrorism)	26	20.00	4
Corrupt local government officials demand bribes or unjust rewards	24	18.46	5
High level of bureaucracy of the authority	16	12.31	6
Expropriation and nationalization of assets/facilities without reasonable compensation	16	12.31	6
Government's improper intervention during construction	15	11.54	8
Poor relations with related government departments	11	8.46	9
Government restrictions on foreign companies (e.g., import/export restrictions, mandatory technology transfer, differential taxation of foreign firms, etc.)	10	7.69	10
Environmental			
Adverse weather conditions (continuous rainfall, snow, temperature, wind)	60	46.15	1
Force majeure (natural and man-made disasters which are beyond the firm's control, e.g., floods, thunder and lightning, landslide, earthquake, hurricane, etc.)	52	40.00	2
Adverse environmental impacts of the project	30	23.08	3
Pollution associated with construction activities (dust, harmful gases, noise, solid and liquid wastes, etc.)	16	12.31	4
Strict environmental regulations and requirements	12	9.23	5
Poor environmental regulations and controls	7	5.38	6
Changes in environmental standards and permitting	6	4.62	7
Poor preliminary assessment and evaluation of environmental impacts of the project	5	3.85	8
Prosecution due to unlawful disposal of construction waste	5	3.85	8
Failure to obtain environmental approval	4	3.08	10
Health and safety			
Accidents occurring during construction	36	27.69	1
Inadequate safety measures or unsafe operations	28	21.54	2
Poor construction safety management	16	12.31	3
Damage to persons or property or materials due to poor safety and health management of the project	9	6.92	4
Failure to comply with HS&E standards or security plan	9	6.92	4
Ineffective protection of surrounding environment (e.g., adjacent buildings and facilities)	7	5.38	6
Epidemic illness	7	5.38	6
Strict health and safety regulations	6	4.62	8
Changed labor safety laws or regulations	6	4.62	8
Fatalities	5	3.85	10

Note: HS&E = health, safety, and environment.

The environmental risk category includes risks created by nature, impact on the environment caused by the project, and changes in environmental policies and regulations (El-Sayegh and Mansour 2015; Shrestha et al. 2017). The most frequently mentioned environmental risks in the selected articles were adverse weather conditions (46.15%), force majeure (40.00%), and adverse environmental impacts of the project (23.08%). Risks belonging to the health and safety category relate to accidents and injuries due to poor safety conditions and measures on the construction site, health-related issues on the construction site, and health and safety regulations (El-Sayegh and Mansour 2015). The top three health and safety risks identified from the selected articles were accidents

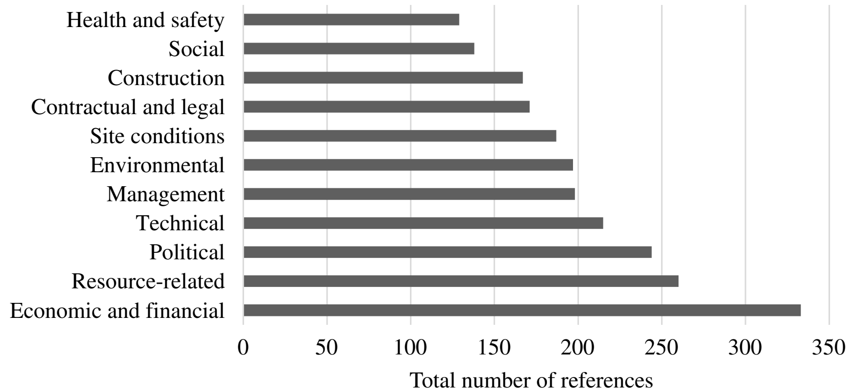

Fig. 4. Total number of references for the top ten risks in each category.

Table 7. Overall top 10 risks identified from the selected articles

Description of risks	Risk category	Number of articles	Percentage of articles	Overall rank
Unpredicted changes in the inflation rate	Economic and financial	64	49.23	1
Design errors and poor engineering	Technical	61	46.92	2
Changes in government laws, regulations, and policies affecting the project	Political	60	46.15	3
Adverse weather conditions (continuous rainfall, snow, temperature, wind)	Environmental	60	46.15	3
Unpredicted adverse subsurface conditions	Site conditions	54	41.54	5
Unavailability of a sufficient amount of skilled labor in the project region	Resource-related	53	40.77	6
Force majeure (natural disasters that are beyond the firm's control, e.g., floods, thunder and lightning, landslide, earthquake, hurricane, etc.)	Environmental	52	40.00	7
Poor workmanship and construction errors leading to rework	Construction	50	38.46	8
Unanticipated engineering and design changes	Technical	48	36.92	9
Unavailability or shortage of expected materials	Resource-related	48	36.92	9
Project funding problems	Economic and financial	48	36.92	9

occurring during construction (27.69%), inadequate safety measures or unsafe operations (21.54%), and poor construction safety management (12.31%).

The comparison made based on the total number of references for the top ten risks in each category (Fig. 4) shows that the economic and financial risk category was the most frequent in the selected articles. Potential reasons for this finding is that risks belonging to the economic and financial risk category can affect all project parties, span the entire project life cycle, have significant impact on both cost and schedule, influence risks in other categories, and pose significant threat to both international and local construction companies involved in a project. Health and safety and social risk categories were the least frequent in the selected articles. Empirical studies conducted by different researchers also reflect that health and safety and social risks were the lowest ranked risk categories (Edwards and Bowen 1998; El-Sayegh 2008). The overall top ten risks identified from the selected articles are presented in Table 7, along with their respective risk category, number of articles, percentage of articles, and overall rank. The results show that unpredicted changes in the inflation rate (49.23%); design errors and poor engineering (46.92%); changes in government laws, regulations, and policies affecting the project (46.15%); adverse weather conditions (46.15%); and unpredicted adverse subsurface conditions (41.54%) were the most common risks amongst all the risks identified from the selected articles.

The majority of the selected articles concentrated on the identification of negative risks and overlooked opportunities that could have a beneficial effect on achieving project objectives. In addition, the existing tools and techniques available for risk identification are more suitable for identification of negative risks than opportunities (Hillson 2002). Most of the selected articles focused on the identification of risks from the perspective of their impacts on an individual project objective, mainly cost or time, and rarely on quality, safety, and environmental objectives. Overlooking the multifaceted impacts of risks on project objectives in the identification process can lead to underestimation of project contingency allowance (Zou and Zhang 2007). In the majority of the selected articles, risk identification is focused on a specific project phase (predominantly the construction phase), rather than the entire project life cycle. Only a few of the selected articles identified both risks and their respective response strategies. Moreover, secondary risks that may arise due to the implementation of response strategies were given less attention. Additionally, the review conducted on the selected articles indicates that there is a lack of studies that examine critical risks from the perspectives of more than one project party. Identifying risks from the perspectives of different parties gives a better understanding of the attitude and perception of the project parties on various risks (Zou and Zhang 2007). Consequently, the development of a comprehensive risk identification framework that enables risk identification for multiple project objectives and project phases and from the perspectives of different project parties is an area that requires further investigation.

Conclusions and Recommendations for Future Work

This paper discusses a systematic review and detailed content analysis of previous studies related to risk identification in the construction industry and establishes research areas in need of further examination. The findings of the content analysis show that a combination of two or more risk identification tools and techniques were widely used in the selected articles. For identifying risks, literature review, questionnaire surveys, and expert interviews were the most frequently used tools and techniques in the selected articles, whereas diagramming and analysis-based risk identification tools and techniques were rarely used. The review of existing classification methods revealed that there is no standard or consensus on the categorization of risks in the construction industry. Risk classification based on the nature and source of risks was the most common method in the selected articles. A three-level RBS was used in a large proportion of the selected articles, and the top five common category names used for classifying risks based on their nature were economic, political, construction, financial, and management. In this paper, the risks identified from the selected articles were categorized into 11 categories: management, technical, construction, resource-related, site conditions, contractual and legal, economic and financial, social, political, environmental, and health and safety. The top five most frequently mentioned risks in the selected articles were unpredicted change of inflation rate; design errors and poor engineering; changes in government laws, regulations, and policies affecting the project; adverse weather conditions (continuous rainfall, snow, temperature, wind); and unpredicted adverse subsurface conditions. The comparison between risk categories reflects that the economic and financial risk category was the most frequently identified, whereas health and safety and social risk categories were the least frequently identified.

The findings of this paper are of value to both researchers and industry practitioners seeking a useful reference on common potential risks affecting construction projects for future risk identification, analysis, and modeling purposes. A comprehensive risk classification method applicable to different types of construction projects and project stakeholders has also been proposed. Using the research methodology adopted in this paper, future research should focus on the identification of common risks, risk identification tools and techniques, and risk classification methods for different contexts based on project type, project location, project stakeholders, and project delivery type; for example, the identification of common risks for public–private partnership infrastructure projects in a given country or region from the contractors' perspective. The findings of this paper show that there is a vast number of risk management tools and techniques and risk classification methods in the literature. Therefore, it has become increasingly challenging to select an appropriate tool and technique and classification method for risk identification on construction projects. Future research is required to develop a framework to assist with the selection of an appropriate risk identification tool and technique and risk classification method. In order to develop such a framework, important criteria that will be considered for the selection of risk identification tools and techniques and risk classification methods (e.g., complexity of the project, risk maturity of the organization, simplicity of use, completeness of the tools and techniques, etc.) will be identified, and a multicriteria decision-making model will be developed. In most construction risk assessment and analysis methods, risks are treated independently, and the dynamic nature of risks and causal interactions between risks are not considered. The causal interactions and dependencies between risks have considerable effect on risk assessment and analysis, and neglecting to account for this effect can lead to overestimation or underestimation of the risk (contingency) allowance. Therefore, future work is also required to develop a dynamic risk analysis model that is capable of accounting for the dynamic behavior, causal interactions, and dependencies between the most common risks identified in this paper in order to determine the concurrent and cumulative impact of risks on work package and project cost.

Data Availability Statement

All data generated or analyzed during the study are included in the published paper. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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Supplemental Data

Table S1 is available online in the ASCE Library (www.ascelibrary.org).

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