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An Extensive Literature Review on Risk Assessment Models (Techniques and Methodology) for Construction Industry

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ABSTRACT

This study looks into the many methods that are used in the risk assessment procedure that is used in the construction industry nowadays. As a result of the slow adoption of novel assessment methods, professionals frequently resort to strategies that have previously been validated as being successful. When it comes to risk assessment, having a precise analytical tool that uses the cost of risk as a measurement and draws on the knowledge of professionals could potentially assist bridge the gap between theory and practice. This step will examine relevant literature, sort articles according to their published year, and identify domains and qualities. Consequently, the most significant findings have been presented in a manner that is consistent with logic and is predicated on the temporal evolution between 1990 and 2015.

Keywords: Construction Project Risk, Risk Analysis, Risk Assessment Techniques, Risk Models.

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استعراض شامل للأدبيات حول نماذج تقييم المخاطر (التقنيات والمنهجية) لصناعة الانشاء

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الخلاصة

تبحث هذه الدراسة في الطرق العديدة المستخدمة في إجراء تقييم المخاطر المستخدم في صناعة البناء في الوقت الحاضر. نتيجة لبطء اعتماد أساليب التقييم الجديدة، يلجأ المهنيون في كثير من الأحيان إلى استراتيجيات تم التحقق من صحتها سابقًا على أنها ناجحة2015. عندما يتعلق الأمر بتقييم المخاطر، فإن امتلاك أداة تحليلية دقيقة تستخدم تكلفة المخاطر كقياس وتعتمد على معرفة المهنيين يمكن أن يساعد في سد الفجوة بين النظرية والممارسة. في هذه الخطوة، ستدرس الأدبيات ذات الصلة، وتفرز المقالات وفقًا للسنة التي نُشرت فيها، وتحدد المجالات والصفات. ونتيجة لذلك، عُرضت أهم النتائج بطريقة تتسق مع المنطق وتستند إلى التطور الزمني الذي حدث بين عامي 1990 و 2015.

الكلمات الرئيسية: مخاطر مشروع التشييد ،تحليل مخاطر،تقنيات تقييم المخاطر،نماذج المخاطر

1. INTRODUCTION

Risk can be controlled, reduced, pooled, transferred, or even accepted in some cases. One cannot turn a blind eye to it **(Latham, 1994; Rasheed, 2015a)**. Construction is a high-stakes industry because of the product's strategic importance and the whole sector's complexity **(Rasheed, 2015b).** Many people are involved, it takes a long time to make, and it uses an open production system, necessitating extensive communication and cooperation between the internal and external environments **(Bosh, 2006)**. This technological and organizational complexity level introduces tremendous dangers **(Zou et al., 2007**). Building jobs are often undertaken only once and present a challenge **(Flanagan and Norman, 1993).** According to **(Winch, 2003)**, this is the primary reason project managers must rely on subjective probabilities. Risk is often dealt with subjectively by adding an estimated contingent amount if something goes wrong **(Kangari and Riggs, 1989).** As a result, a risk assessment should be organized to use people's prior knowledge, experience, intuitive judgment, and rules of thumb **(Dikmen et al., 2007b).** Inevitably, risk assessment is linked to risk modeling. Risk is typically evaluated regarding its potential for occurrence and severity using the prevalent Probability-Impact (P-I) risk model or (L-I) model. However, scientists have critiqued the P-I risk model and proposed its improvements **(Al-Geelawee, 2016).** However, a dearth of studies summarizes the essential findings and gaps in the existing literature.
This work aims to learn about the current state of risk assessment, the state of risk analysis, the limitations of current risk assessment methodologies, and the future research directions on hazards in building projects. To the researcher's knowledge, the previous literature study reflects the primary development patterns in project risk modeling and assessment

throughout the last fifty years. The findings and implications of this review are analyzed in depth and discussed in the next portion of the report.

2. RESEARCH METHODOLOGY

Results from an extensive review of risk documentation modeling and assessment in building projects are presented in this study based on the analysis of basic studies starting with the 1990s, in which the most prominent studies are **(Mustafa and Al-Bahar, 1991; Williams, 1995; Ward, 1999)** and other studies extending to the twentieth century such as (**Tah and Carr, 2000; Xu and Tiong, 2001**; **Dikmen and Birgonul, 2006; Nieto-Morote and Ruz-Vila, 2011)** and many other important studies. The dangers of building projects, such as highways, roads, and building construction, are the primary subject of this research. The focus is on academic papers written in English that have been through a strict peer review process. Numerous documents on building risk assessment have been published over the past two decades. First, use keyword searches to find relevant research papers from different online sources and collect them. Some sources are the Emerald database, such as (**Science Direct, Taylor & Francis, Springer Link, Google Scholar, ProQuest, ABI/Inform; IEEE; Ingenta Connect; and Web of Science)**. Various phrases like "risks in construction projects," "risk quantification in construction projects," "risk analysis in construction projects," "risk quantification and analysis in construction," and "modeling project risks" are appropriate for this function. The thoroughness of the search was verified using several different permutations, however. The study examined articles published in databases over the past 20 years to determine how risk modeling and assessment have changed. More than 208 scholarly articles emerged from the investigation. In the end, though, only 68 papers were significantly more critical after a long refining process. Reading these publications allowed us to extract crucial data from them. The authors' names, the year the paper was published, the study's title, the journal's name, native country, research and analyzing data methods, manufacturing, the intention, and the aims are all included.

The presented publications in **Table 1** cover two decades of project risk modeling and evaluation. Later, paper analyses and literature review results will be discussed to elicit themes and patterns. Finally, the study concludes with a summary of the most important findings and a discussion of their significance.

3. A TIMELINE OF RISK ASSESSMENT'S DEVELOPMENT SINCE THE 1990S.

The practice of conducting risk assessments in the building sector is not new. It can trace its origins back to the 1950s when the Program Evaluation and Review Technique (PERT) was developed to address unpredictability in project duration. Traditionally, risks have been addressed by treating them as estimation variations, allowing Probability Theory [PT] to maintain its hegemony. However, beginning in the 1980s, trouble started to be viewed as an aspect of projects, and by the 1990s, risk management (RM) had become a well-established part of project management. During the 1990s, academics studied many theories to take account of the unique characteristics of construction risks and highlighted them **(Mustafa and Al-Bahar, 1991**; **Flanagan and Norman, 1993; Williams, 1995).**

3.1 Time from 1990 – 1999

As construction risk modeling and assessment gained traction in the 1990s, it became a popular study area. When assessing risk**, (Al Bahar and Crandall, 1990)** used influence diagrams and Monte-Carlo Simulation MCS. Analyzing the studies, it's clear that AHP has gotten much attention. Structured decision-making is made easier using this tool**. (Mustafa and Al-Bahar, 1991)** did a great job of evaluating the strengths and weaknesses of AHP and its applicability for assessing construction risk. **(Diekmann, 1992)** used influence diagrams to illustrate risky scenarios, and MCS and FST were used to calculate risk. It is also a technique employed by **(Huseby and Skogen, 1992)** to account for dependencies between risks before assessing them. **(Dey, 1994)**, P–I risk model was once again utilized when using AHP as part of a methodology that included objective and subjective evaluation elements. The proposed model could not assess risk; it could only consider the utility of various risky scenarios. A detailed evaluation of the literature on construction Risk Management RM tools and methods was carried out by **(Williams, 1995).** According to **(Williams, 1995)**, no research hasn't been done on analyzing risk impact on several project objectives simultaneously, and he blamed this on the absence of a standard evaluation scale. As a result, he recommended prioritizing risks by considering probability and impact. The P–I model inadequacies were also highlighted by **(Ward, 1999),** who advocated a more accurate risk assessment method. Alternatively, he suggested a weighted sum of alphabetical evaluations as an option. For risk assessment, alphabetical grading may not be the best option. Using such a rating while aggregating many risk assessments with differing results on distinct project objectives is quite tough**. (Wirba et al., 1996)** utilized FST to evaluate the risk likelihood of occurrence by utilizing linguistic characteristics. In this research, the risk response approach's cost is represented by the risk impact. Even though this paper is broadly cited quite frequently, there is cause for concern regarding applying the fuzzy weighted mean method to the aggregation of risk assessments. **(Dawood, 1998)** utilized MCS to predict the duration of a project or activity, modeling risk as an estimated variance. Again, the variance of project length showed the chance that the project schedule would be delayed; the more significant the variance, the greater the risk associated with project duration.

3.2 Time from 2000 – 2004

Efforts have ramped up to better analyze and assess construction risk since 2000, with tools becoming more complex thanks to the availability of high-capacity personal computers. Therefore, decision support systems frequently help with risk assessment (DSSs). As **(Chapman and Ward, 2000)** claimed, oversimplifying risk probability and impact estimations lead to unneeded uncertainty when using the Probability-Impact grid to evaluate risk. They advocated for a "minimalist" strategy that uses ranges rather than single scores to identify hazards and analyze their likelihood and implications. While the established technique did offer an estimate of the amount of risk associated with the project, the assessment methodology was significantly simplified. The project's risk level was established as the weighted aggregate of the individual evaluations, which were made using a specified scale from 0 to 100, where 0 indicates no danger, and 100 indicates the most significant risk. With the help of FST, (**Tah and Carr, 2000)** determined the likelihood of adverse events, their severity, and the relationships between the various risks. The authors attempted to address this shortcoming of the fuzzy averaging method by proposing a new

aggregation formula based on the maximum risk estimate, Emax, and a modification factor (ξ), as shown in the following example: $E = \xi * Emax$. Although this aggregation rule is an essential substitute for the averaging one, it may not always be the best option. For example, if there is more than one significant risk factor, it may be challenging to use. The researchers agreed that their approach required more accuracy.
(Baccarini and Archer, 2001) utilized the Department of Contract and Management Services in Western Australia's system for ranking projects according to their risk levels. Individual risk scores are calculated by averaging and multiplying the risk's likelihood of occurrence score with its influence on the project's cost, duration, and quality. Such a summing-up rule is overly simplistic and may not produce accurate evaluations. The model presented by **(Ben-David and Raz, 2001)** finds the optimal mix of risk-mitigation strategies while simultaneously minimizing overall costs. The approach helps estimate some hazards associated with a project but oversimplifies the scope of such risks. Using AHP and decision trees, **(Dey, 2001)** presented a DSS for early-stage construction risk management. As a result, the method does not attempt to measure the magnitude of any risk but instead suggests the least expensive possible course of action in response to each given risk. In addition, it did not provide any method for adding up the various risks' effects. Once again, PT-based techniques emerged in stochastic programming **(Xu and Tiong, 2001**). The FST was used by **(Tah and Carr, 2001)** to generate project risk ratings. They did not suggest a mechanism for merging the determined evaluations of risk impact on project duration, cost, quality, and safety. It might appear that the scholarly community has exhausted every theory and method for evaluating risk.
Additionally, researchers have always found that aggregating individual hazards is crucial. They have utilized various methods to arrive at a risk level that reflects the project overall. **(Baloi and Price, 2003)** provided a crucial overview of the many techniques and resources at our disposal when assessing risks. They concluded that FST was a practical option for the construction sector. Researchers were concerned about the meaning of "risk" and its connection to the concept of risk. Instead of "risk management," **(Ward and Chapman, 2003)** recommend "uncertainty management" for projects. They identified risk as anything that might endanger people or things. **(Choi et al., 2004)**, who used FST to analyze risk in underground building projects, also addressed the varying types of risk involved.

3.3 Time after 2005

Risk assessment and modeling publications have skyrocketed since 2005. Also, a clear upward trend toward better risk modeling may be seen. Most publications focus on risk as a source of project quality rather than estimating error. As a result of this dramatic change in attitude toward risk, many organizations now include risk analysis as part of their formal decision-making processes. The anticipated improvement in risk modeling and the widespread use of sophisticated DSSs are signs of the growing complexity of risk assessment. Everyone involved in the project can log in to the DSS online and give their opinions. The results of these evaluations are then aggregated and analyzed by weight. **(Cervone, 2006)** presented a new risk model to account for the interdependencies across hazards. They used influence networks to map the interrelationships among the variables that decide how long and how much something costs to build. **(Thomas et al., 2006)** made an alternative effort to analyze the interdependencies between project risks by using a fault tree to simulate various scenarios and employing linguistic variables to evaluate risk probability and impact. **(Dikmen and Birgonul, 2006)** evaluated dangers and opportunities in global construction projects using AHP inside an MCDM framework. Indeed, the relatively straightforward method of project risk generation is debatable. One of the significant drawbacks of employing AHP in risk assessment is the comparative character of the findings produced by AHP-based models. The model did not provide a project risk analysis; instead, it determined the benefit that could be anticipated from carrying it out. Therefore, the lower the level of risk in a project, the higher the predicted utility value. **(Aven et al., 2007)**, to better risk modeling, address the nature of risk, and suggest that specific hazards are more tractable than others. The concept of "risk manageability" was developed to express this idea**. (Aven et al., 2007)** state that a medium-risk choice with low manageability may be riskier than a high-risk option with excellent manageability. Risk controllability was another topic that **(Dikmen et al., 2007b)** covered, although in a somewhat different way.

Rather than treating manageability as a risk component, **(Dikmen et al., 2007a)** presented another suggestion to enhance risk modeling, in which they revisited the concept of risk "controllability" from a new angle. That is to say, the degree to which a risk can be controlled is discussed to provide economic justification for preventative measures. It was anticipated that the proposed model would be implemented at the enterprise level, while at the project level, the risk would be handled as a change in project parameters. By including the third variable, which they called the "Factor Index," **(Zeng et al., 2007)** managed further refinement of the P-I risk model (FI). This metric considers the external setting and the interplay between the various threats. To rephrase, it mimics the difficulty of doing a risk analysis in the setting of a real-world project. The formula for modeling risk is R = L* S *FI using the notation L for "likelihood of occurrence" and "S" for "severity of risk impact."

(Ackermann et al., 2007) handled risk assessment complexity. Interaction project hazards can be the most damaging, they say. They advised viewing project risks as a network of interconnected probable events or 'risk systematicity. One danger may increase the likelihood of others, they said. A holistic understanding of risk assessment complexity is necessary for realistic outcomes. **(Zhang and Zou, 2007)** incorporated FST and AHP for risk assessment in Chinese joint venture construction projects. **(Hang, 2007)** agreed with **(Zeng et al., 2007)** that risk assessment should not ignore the environment. He stated that utilizing statistical methods ignores the mitigating effect of the project environment on risk assessment. However, it did not offer a way to measure or incorporate vulnerability into a risk model. **(Vidal and Marle, 2012)** used it as a basis for an innovative method for managing project risks. **(Dikmen et al., 2007a)** considered risk a project attribute that can be handled by generating an accurate contingency total. **(Zou et al., 2007)** studied China's construction risks. Risk significance" is the degree to which a practical expert intuitively feels risk. It includes recognizing risk, the difficulty of obtaining information and adopting management skills, the degree of indirect or possible loss, and the relationship between project profitability and the analyst's risk attitude. **(Zayed et al., 2008)** suggested a risk model that ranks projects by risk level. The project risk level = R1 * R2. R1 results from two risk indices, R1 for macro-level risks and R2 for micro-level risks. R1 and R2 are weighted sums of risk effects assessed by experts, with AHP used to determine actual weights. The (P–I) model was not used in this paper. The method for calculating project risk levels ignores interdependencies. Stochastic processes kept popping up in the literature even though FST and AHP-based analytical approaches were the most common. At a given confidence level, **(Cioffi and Khamooshi, 2009)** proposed a statistical methodology for combining risk impacts and generating an overall effect, which led to an adequate contingency budget. In this research, researchers used the P-I risk model and defined risk impact as the money lost when a risk occurs. One flaw of this strategy was that it required averaging the probability of occurrence to carry out the aggregate with a certain degree of certainty. Furthermore, **(Molenaar, 2005)** offered a second stochastic method, the MCS-based methodology created by the Washington State Department of Transportation (WSDOT), for calculating project costs. The P-I risk model is used to quantify the magnitude of an event's potential influence on a project's budget. The risk was not addressed as a project attribute in **(Luu et al., 2009**)'s study; instead, it was modeled as the likelihood of construction project delay, as in the prior two articles. They also employed Bayesian Belief Networks (BBN) to model the interdependencies among potential building project delays and assign numerical values to the chances of each such delay. To evaluate the potential dangers of a project **(Fung et al., 2010)**.

The probability of an event occurring and its potential impact was used as inputs in the risk model **(Larsson and Field, 2002).** The strategy of aggregating distinct forms of risk impact. Scores between 0 and 1 were normalized for the three impact types. So, risk can be classified as 3 out of 5. The program could sort the hazards by score. However, it did not consider adding up those ratings to get an overall assessment of the project's vulnerability. In contrast, **(Mojtahedi et al., 2010)** sought to broaden the scope of traditional project risk assessment by considering health and safety concerns alongside environmental ones. To prioritize risks, they used the multiple-attribute group decision-making technique (GTOPSIS) to compile the varied perspectives of risk specialists.

The effects of risks on the project's timeline, budget, health, safety, and environment were also considered. AHP and FST were combined by **(Nieto-Morote and Ruz-Vila, 2011)** to deal with the subjectivity and complexity of construction risk assessment. **(Zeng, 2007)** and **(Zhang and Zou, 2007**), for example, proposed such a combination; nevertheless, the researchers here aimed to improve risk modeling and evaluation by adopting the risk model **(Cervone, 2006)** stated previously in the work. The language was employed to evaluate danger, severity, and categorization. The evaluations of several specialists were averaged using the fuzzy arithmetic average, and a risk assessment was calculated using the fuzzy multiplication algorithm. Using the Extended Fuzzy Cognitive Maps, **(Lazzerini and Mkrtchyan, 2011)** brought the FST back into the spotlight as a means of dealing with the subjectivity and complexity of risk assessment brought on by the interdependencies and causalities of risks (E-FCMs). In addition to aiding in group decision-making and risk assessment, the Fuzzy Cognitive Maps were utilized to synthesize the views of many specialists. **(Marle and Vidal, 2011)** added to the conversation about the difficulty of risk management by arguing that the way risks are currently assessed fails to consider their interdependencies. According to their findings, present methods treat interdependent hazards as if they were independent. Therefore, the researchers tackled project risks from a complexity-based approach and concentrated on recording the interactions between hazards that affect different parts of the project. In reality, the last two decades have seen an unprecedented focus on the issue of project complexity.

Several studies have looked into the nature of complexity and its correlation to risk in projects. It was common practice to view risk as contributing to or stemming from the complexity of a project. The inability to employ parametric statistical tools for predicting risk probability and impact was studied by **(Hashemi et al., 2011)**. They proposed using the Bootstrap nonparametric method to get interval values with fewer standard deviations. However, **(Fang and Marle, 2012**) took a unique approach to the complexity problem. They used the design structure matrix (DSM) to describe the incidental connections between hazards, which provided a graphical representation of the underlying complexity of the interdependencies between risks.

Also, using the AHP for the task of assessing interrelated risks. Through risk management, decision-makers may carry out identification, analysis, and control effectively and efficiently with the help of an integrated decision support system (DSS) used to manage the complexity of the assessment process. Ultimately, **(Vidal and Marle, 2012)** took a novel approach to risk assessment. **(Zhang, 2007)** used the idea of project vulnerability in conjunction with Systems Theory to argue that analyzing project risks could be more effectively carried out by concentrating on preexisting weaknesses in the project systems. Therefore, vulnerability management enables evaluating the frailties of the systems in charge of managing project risks instead of evaluating risks themselves. It was suggested that vulnerability management could be valuable for managing the projects' complexity and analyzing their risks. It is a novel approach to the problem, and it has the potential to inspire new methods of risk assessment and project evaluation.

4. ANALYSIS AND DISCUSSION

Two levels of analysis can be identified considering previous work on project risk assessment; an assessment and an estimation of the project's risk level.

4.1 Risk Assessment

Project risk assessment uses several methods. Initially, researchers employed PT-based statistical approaches for duration or cost risk **(Mustafa and Al-Bahar, 1991)**. The risk was viewed as an estimated variance. Accordingly, objective probability or frequency has long been sought. Many researchers conclude that intuition, experience, and personal judgment are vital for risk assessment **(Dey, 1994)**. FST was established to address subjectivity in construction risk assessment. Besides subjectivity, researchers encountered increased risk assessment complexity due to complicated building projects**.** Researchers have tried many ways to describe project risk interdependencies and environmental complexity **(Ackermann et al., 2007)**.
AHP was seen as a practical approach for assessing construction risk complexity. It provides a reasonable approach to evaluating risk implications and applying important ranking. Risk assessment's complexity has drawn much attention. AHP is popular. AHP's popularity during the last two decades reflects the shift in risk perception from an estimation variance to a project attribute. It describes a transition in risk assessment from "classicism" (using PT-based and simulation methods) to "conceptualism" (using analytical tools) **(Mojtahedi et al., 2010)**. Changing risk perception led to new risk assessment techniques. After a while found that the paradigm shift did not lead to more professionals using analytical tools, and the practitioners rarely use risk assessment tools. Risk assessment tools' low acceptance does not limit their usefulness. According to research, advanced risk assessment users realize their potential and benefits. The study will address how simplicity encourages professionals to utilize risk assessment tools. A user-friendly DSS must facilitate risk assessment by structuring its complexity and allowing experts to deploy their strategies and tactics quickly and transparently.
Regarding risk impact assessment, project quality risk analysis is strikingly overlooked, focusing instead on cost risk or duration cost **(Lazzerini and Mkrtchyan, 2011)**. Insufficient research exists on measuring the risk impact on project quality or other strategic goals. It lacks a risk assessment system that can understand all project success objectives. The lack of a standard scale causes scarcity, where risk cost is the most convenient scale.

Researchers have utilized risk cost to quantify risk impact **(Zeng, 2007; Zhang and Zou, 2007**). However, none employed risk cost to analyze the impact on project goals. When monetary equivalents are used to measure risk impact, the evaluation results in a contingency sum to cover the risk or a cost to mitigate it. It is worth studying an assessment method that uses risk cost as a standard scale to measure project risk. It could lead to a thorough risk assessment and accurate project risk assessment. The author feels that using risk cost to measure intangible elements like quality risk is feasible. Practitioners who price residual risks and give a contingency budget for covering them should be able to price the impact of known unknowns on project quality. Most existing risk assessment techniques provide a risk rating, numerical score, or language factor rather than a quantification. This may explain why these tools are not widely used. Risk cost as a measurement scale may help close the theory-practice gap.

4.2 The Level of Project Risk

Project risk was determined using different methods. Researchers traditionally employed PT-based PERT and MCS methodologies to combine activity duration and cost probability distributions to assess project cost overrun and delay risk. Project risk has evolved from an estimation variance to a project attribute. Initially, the risk was a project attribute that could be analyzed. This method is sufficient for modest projects but not complex ones **(Dey et al., 1994)**. Increasingly sophisticated approaches are used to manage hazards in complex projects. Influence diagrams, Bayesian networks, fault trees, and the hierarchical risk breakdown structure are used to identify, categorize, and structure project hazards. The complexity of the risk structures represented the project systems and interdependencies. Aggregating risk assessments across structures to estimate project risk levels proved difficult. In most circumstances, aggregation averages individual risk evaluations. The fuzzy averaging rule is commonly used to aggregate linguistic risk estimates. Averaging may not give an accurate risk estimate. In other circumstances, project risk was the weighted sum of individual assessments. This method assumes aggregated risks are independent.
Additionally, Utility Theory was used to calculate an approximate amount of project risk. The project's utility indicated its attractiveness or risk level; the lower the project utility, the higher the risk. A simple or weighted sum of individual utilities was used to calculate the total utility of the project. Again, the assumption of independence across risk factors limits the usefulness of this strategy **(Dikmen et al., 2004)**. It may be argued that starting with accurate risk assessments and using an efficient aggregation technique that preserves the structure of individual risk assessments is the key to achieving a reasonable level of project risk. Therefore, a good project risk assessment requires the investigation of a new method for rating hazards and the application of a reliable aggregation rule. Furthermore, unique options must be developed to appeal to the target audience. The gap between risk assessment theory and practice can only be closed by first recognizing the factors contributing to the current tools' low adoption rate.

4.3 Techniques for Risk Assessment

From the previous literature review, the most significant techniques, as shown in **Fig. 1**, demonstrate the risk assessment methods used by various researchers in various literature. An exhaustive investigation will reveal that more research has been published yearly since

2006, and this trend continued until 2015. The breakdown of these studies may be seen in **Fig. 2**.

Project Evaluation and Review Techniques (PERT), Probability and Impact (P&I), Monte-Carlo simulation (MCS), Analytical Hierarchy Process (AHP), Likelihood occurrence of risk (LR), and Fuzzy Logic are among the many approaches to risk assessment. PERT stands for Project Evaluation and Review Method. Only a handful of studies have attempted to use analytical neural networks (ANN), Bayesian belief networks (BBN), etc. **Fig. 1** reveals that most studies have used AHP, FUZZY, MCS, and LR risk assessment models. When applied to these four methodologies, the presented models produce accurate findings when measuring the risk level associated with construction projects.

The use of fuzzy logic allowed for the complexity and subjectivity of the construction risk assessment to be addressed. The AHP model is helpful because it takes a methodical approach to hierarchically organizing risk assessment, contributing to its effectiveness. When practitioners attempt to evaluate the project's risk during the beginning stages, they might not have sufficient evidence. As a result, creating a straightforward regression model for each project-specific activity is an absolute necessity. In addition, simplicity is among the most critical factors when encouraging professionals to use risk assessment tools in practice. **Table 1** shows the chronology of the techniques and tools used in risk assessment of construction projects or a comprehensive review from 1990 to the millennium and the details of the studies in terms of the age of publication, the tools used, and the author's name. It represents a comprehensive and holistic review of studies and research, the basis for analysis.

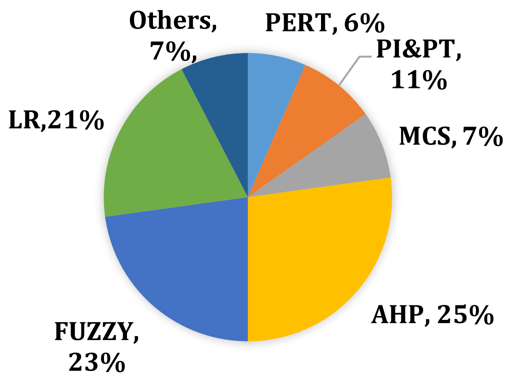

Figure 1. Methods of risk assessment utilized by several different studies

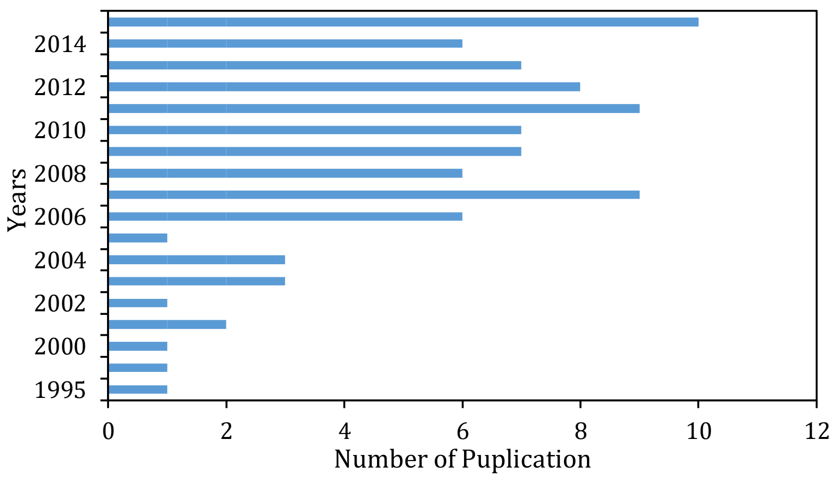

Figure 2. Annual publications quantity

Table 1. Review of key articles in project risk assessment models

Year	Another	Main tool
1990	**Hull**	MCS, PERT
1990	**Al-Bahar and Crandall**	Influence diagramming, MCS
1990	**Yeo**	PERT
1991	**Mustafa and Al-Bahar**	AHP
1992	**Diekmann**	MCS, FST, Influence diagramming
1992	**Huseby and Skogen**	Influence diagram, MCS
2000	**Chapman and Ward**	LR, Cognitive argument
2000	**Hastak and Shaked**	AHP
2000	**Tah and Carr**	FST
2001	**Baccarini and Archer**	LR
2001	**Ben-David and Raz**	Optimization through Microsoft Excel VBA
2001	**Dey**	AHP, Decision tree
2001	**Xu and Tiong**	Stochastic programming
2001	**Tah and Carr**	FST
2003	**Baloi and Price**	LR, Cognitive argument
2003	**Jannadi and Almishari**	LR, Cognitive argument
2003	**Ward and Chapman**	LR
2004	**Choi et al.**	FST
2005	**Molenaar**	MCS
2005	**Shang et al.**	FST
2006	**Cervone**	LR, Cognitive argument
2006	**Dikmen and Birgonul**	AHP
2006	**Poh and Tah**	Influence networks
2006	**Thomas et al.**	FST, Fault tree
2007	**Ackermann et al.**	The theoretical argument, Risk Register
2007	**Aven et al.**	LR, Cognitive argument
2007	**Cagno et al.**	LR, Cognitive argument
2007	**Dikmen et al. a**	Case-Based Reasoning, Utility Theory
2007	**Dikmen et al. b**	FST, Influence diagramming
2007	**Dikmen et al. c**	ANP
2007	**Hsueh et al.**	AHP, Utility Theory
2007	**Zeng et al.**	AHP, FST
2007	**Zhang and Zou**	AHP, FST
2007	**Zhang**	LR, Cognitive argument
2007	**Zou et al.**	LR, Cognitive argument
2008	**Han et al.**	LR, AHP
2008	**Zayed et al.**	AHP, Questionnaire
2009	**Cioffi and Khamooshi**	PT
2009	**Luu et al.**	Bayesian Belief Networks (BBN)
2010	**Mojtahedi et al.**	GTOPSIS
2011	**Hashemi et al.**	Bootstrap
2011	**Nieto-Morote and Ruz-Vila**	FST, AHP
2011	**Lazzerini and Mkrtchyan**	Fuzzy Cognitive Maps

2011	**Marle and Vidal**	The cognitive argument, Clustering heuristics
2012	**Fang and Marle**	AHP, Simulation
2012	**Vidal and Marle**	The cognitive argument, Systems Theory

5. CONCLUSIONS

The analysis that has been presented reveals noteworthy results, which can be summed up as follows:

1- After an extensive review of articles, as shown before, the(P–I) risk model still dominates, but improvements have been made. Recent advances reflect the increased complexity of construction projects and their dangers. Risk modeling and assessment are becoming more complicated to capture interdependencies between hazards and their interaction with the project environment. The improvement suggestions do not go far enough to account for risk characteristics, interdependencies across risks, the project environment's complexity, or the management team's knowledge. Understand project vulnerability to improve construction risk assessment. It is an innovative way to estimate risk using construction professionals' experience. Risk has shifted from being an estimation variance to being a project attribute. This transition led to a switch from PT-based to analytical risk assessment. FST and AHP have recently dominated the literature. Progressively more sophisticated DSSs are being created to address the expanding complexity of risk assessment. These DSSs provide risk identification, evaluation, aggregation, and project risk level calculation.

2-The review indicated that the literature lacks a comprehensive risk assessment approach that addresses risk impacts on multiple project objectives. Such a framework is needed to get realistic risk assessments, and the gap between theory and practice should spur attempts to develop more practitioner-friendly ideas and methodologies, the first step in establishing a realistic project risk level. Literature lacked a standard scale. Although several writers have proposed "risk cost' as a scale for assessing risk impact on project objectives, it has never been utilized systematically.

3- The analysis showed that no reliable aggregation rule creates a reasonable project risk level without altering the structure of the individual risk evaluations. Since they are predicated on supposition, traditional aggregation laws like average or weighted sum aren't always applicable for establishing a representative project risk level.

4- This study illustrates through past research that risk cost is commonly acknowledged, represented as a percentage of the project's initial cost, and is the most convenient and practical way to evaluate risk, given that it is a standard language that all parties involved in construction can comprehend. The suggested technique facilitates the practical experience and makes using risk cost for risk assessment easy. It may attract construction professionals and advance real-world risk assessment. This study is a component of a more significant research effort with the goals of rethinking construction risk modeling and evaluation and supporting the bridging of the existing gap between the theory and practice of construction risk assessment.

5- Researchers have made a tremendous contribution to advancing risk modeling and assessment, which this review has proved. It is disappointing that there is still a significant divide between theoretical understanding and actual application. However, the existing corpus of knowledge offers a solid base from which to study new options that have the potential to bridge the gap that now exists between theory and practice.

6- The comprehensive review indicated that further work has been published since 2006 and gradually increased until 2015. The amount of attention paid to project risk assessment varies from continent to continent.

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