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Construction Project Risk Analysis Based on Fuzzy Analytical Hierarchy Process (F-AHP): A Literature Review

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ABSTRACT

In a construction project, it generally takes a long time and is complex in nature, giving rise to uncertainty which in turn leads to risks. The impact of risk can affect the cost, quality and timing of project implementation. At each stage of the project, various risks and uncertainties are inseparable. To reduce the adverse impact on the achievement of the functional objectives of a construction project, it is necessary to carry out a risk assessment. Risk is a logical combination of probability and impact and it is necessary to use fuzzy logic to model the inaccuracy and uncertainty of human thinking. This study aims to compare the results of Risk Assessment with the Fuzzy Analytical Hierarchy Process (F-AHP) method against the risk variables identified in the Risk Management Project. From 30 journals reviewed, it shows that technical risk is the biggest risk in a construction project.

Keywords:

Risk Assessment, Risk Management, Risk Analysis, Fuzzy AHP.

1. Introduction

Construction industry is completely involved in realization of construction projects serving as an engine for a development of national and global economy. In many economies this industry is well developed and competitive branch of economy. In realization of each construction project, especially large infrastructural, industrial, and public projects, large number of participants is included: client (owner), contractor with subcontractors, engineer, domestic and international financial institution, producers and suppliers of materials and equipment and so on. These companies and institutions are organizationally in- dependent and project management team has key role in their integration and orientation to achieve the clients' objectives according to previously signed contracts and their own goals [1].

According to Mark et al. (2004), risk is simply the potential for complications and problems with respect to the completion of a project task and the achievement of a project goal. Risk is inherent in all project undertakings, as such it can never be fully eliminated, although can be effectively managed to mitigate the impacts to the achievement of project's goals. Burke argued that project risk management is defined by the project management body of knowledge: 'the processes concerned with identifying, analyzing, and responding to uncertainty throughout the project life cycle. It includes maximizing the result of positive events and minimizing the consequences of adverse events.' Perry broke down the process of risk management into identification of risk sources, assessment of their effects (risk analysis), development of management response to risk, and providing for residual risk in project estimates.

Although risk has been defined in various ways, some common characteristics can be found:

- A risk is a future event that may or may not occur.
- A risk must also be an uncertain event or condition that, if it occurs, influences, at least, one of the project objectives, such as scope, schedule, cost, or quality.
- The probability of the future event occurring must be greater than 0% but less than 100%.
- Future events that have a zero or 100% chance of occurrence are not risks. The impact or consequence of the future event must be unexpected or unplanned for.

Risk analysis phase of a project enables the estimation and evaluation of all potential risks that may arise during implementation. The risk analysis of the project is an effective way of ensuring that the strategies used to control potential risks of the project are profitable. Risk Analysis project involves a series of steps to quantify the impact of uncertainty on a project. These activities are risk identification, assessment of the likelihood and impact of the project estimate. The purpose of risk management analysis is to identify and estimate potential threats and then choosing the appropriate method to reduce or eliminate hazards. Management risk analysis consists of three coherent activities:

- Identifying threats.
- Assessment of their probability of occurrence.
- Estimate the impact on the project in terms of working time.

Identifying risks in a project is a basic step in the management of project risk management. Through special tools to identify risks, all data collected and analyzed with the aim to identify risks is an essential basis for risk analysis projects, risk assessment and, moreover, for an accurate survey of the future potential risks.

1.1. Fuzzy AHP method

The AHP is one of the extensively used multi-criteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand, and it can effectively handle both qualitative and quantitative data. AHP involves the principles of decomposition, pair wise comparisons, and priority vector generation and synthesis. Though the purpose of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems. [2]. The fuzzy AHP was developed by many authors and research for solving problems of multi criteria decision making. This process uses fuzzy numbers as elements of comparison matrices and main problem is to compute the fuzzy weights as eigenvectors of these matrices. As Buckley (2001) concluded, the direct approach of finding fuzzy eigenvalues and eigenvectors is computationally difficult. Foundations of the fuzzy AHP were presented by van Laarhoven and Pedrycz (1983). At present, there have been plenty of research that blend fuzzy logic, which is a popular method of incorporating uncertain parameters into the decision-making process, with analytic hierarchy process to form a model for risk assessment. Most of the fuzzy-AHP methods suggest each risk factor in a hierarchical framework is expressed as a fuzzy number, which is a combination of the likelihood of a failure event and the associated failure consequence, and AHP is used to estimate weights required for grouping hazards. Based on the risk estimates, risk assessment is to reveal the impact key risk factors for the success of the project by the corresponding indicator system and those evaluation criteria. It can also put forward early warning, forecasting and the corresponding preventive measures on the risk project. Most of the fuzzy-AHP methods suggest each risk factor in a hierarchical framework is expressed as a fuzzy number, which is a combination of the likelihood of a failure event and the associated failure consequence, and AHP is used to estimate weights required for grouping hazards. In this study, studied 30 journals that have studied risks in infrastructure projects based on the Fuzzy Analytical Hierarchy Process (F-AHP). From the journals studied, they are grouped according to their respective risks.

2. Methodology

This review is based on a summary of the literature obtained online from trusted sources that discuss Risk Management using Fuzzy Analytical Hierarchy Process (F-AHP), which is then reviewed and synthesized to provide the latest information. In this paper according to (Zavadskas, Turskis, and Tamošaitiene 2010) [3], risk was divided into 3 parts, namely: Internal Risk, External Risk, and Project Risk. Risk allocation structure is shown in Figure 1.

Internal risks can be devided according to the party who might be the originator of risk (intrinsic criteria): (1) Resource risk; (2) Project member risk; (3) Stakeholders Risks; (4) Designer Risk; (5) Contractor Risk; (6) SubContractor Risk; (7) Supplier Risk; (8) Team Risk; (9) Construction site risk; and (10) Documents and information risk. External risks are those risk that are beyond the control of the project (environmental criteria): (1) Political risk; (2) Economic risk; (3) Social risk; (4) Weather risk. Project risks (construction process criteria): (1) Time risk; (2) Cost risk; (3) Work quality; (4) Construction risk; and (5) Technological risk.

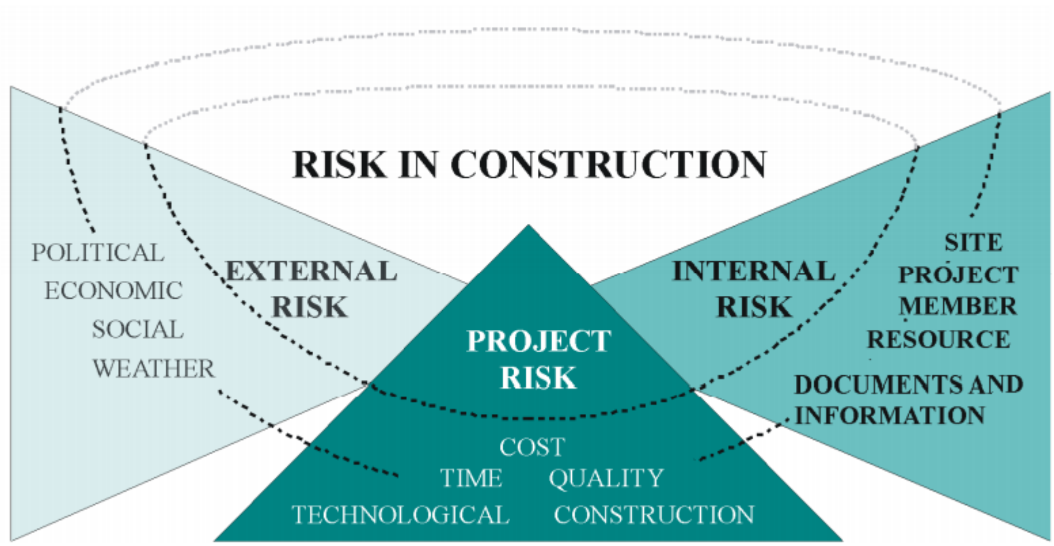

Figure 1. Risk allocation structure by level in construction object.

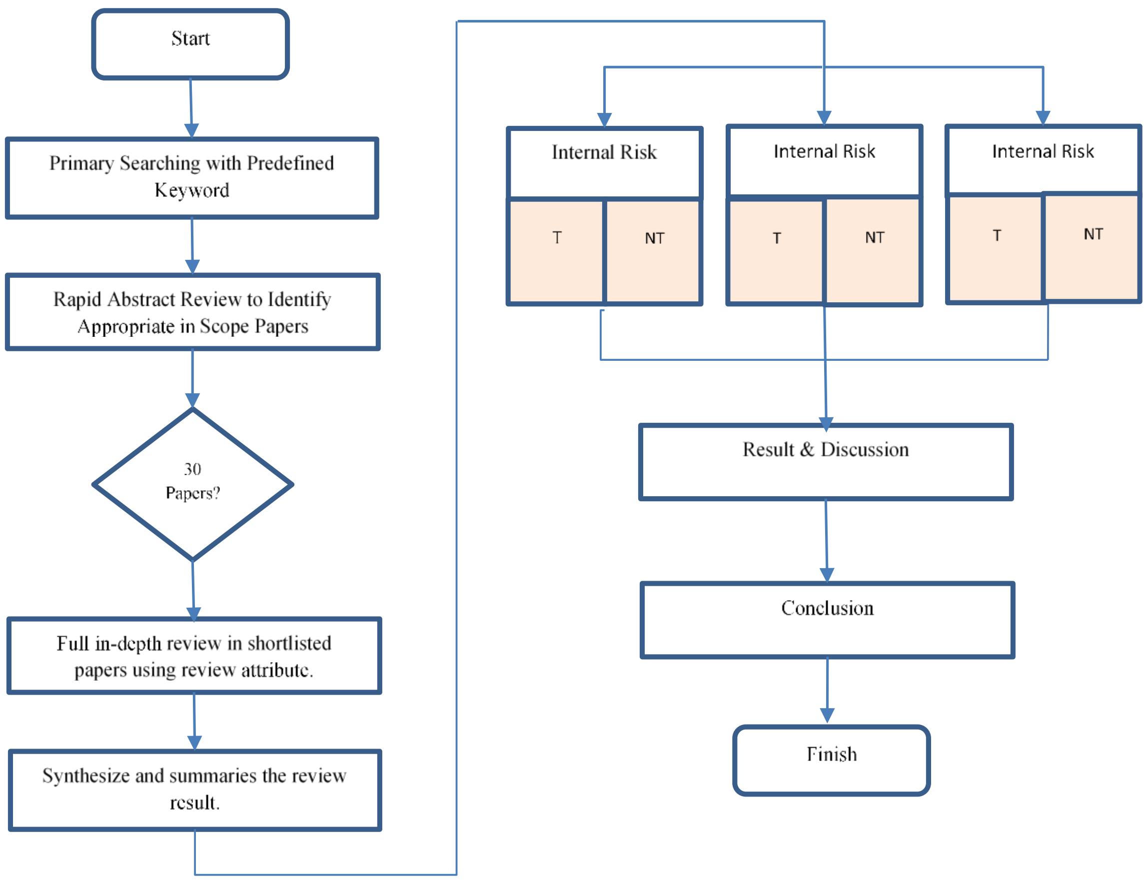

Figure 2. Study Framework: A Systematic Literature Review.

Of the three categories above, each is divided into two risk reviews, namely technical risk and non-technical risk. Technical risk (TR) assessment is concerned with assessing the probability that the system embodied in a design when constructed meet the performance requirements it is intended to meet, and, if a shortfall in performance is expected, how serious the shortfall is likely to be (Klein & Cork, 1998). In this article, technical risk related to: the amount of material lost, planning deficiency, design deficiency, project operational, conflicting interfaces between work items, inappropriate design and poor engineering, etc. Non-technical risk (NTR) is a risk that can affect a particular project directly, the cause is an unplanned and unexpected event that results in unwanted deviations from the original project delivery location administered by an external stakeholder (non-contractor). The existence of a transparent relationship between risk and external stakeholders differentiates NTR from technical risk within the project context. In other words, NTRs (also referred to as above-ground risks) usually originates from external stakeholders/environment (Ite, 2016). Non-technical risk (NTR) in this article includes disruption by landfill, low project residual value, approval time and procedure, management skill, warranty issues, financing, etc.

3. Results and Discussions

As mentioned, in this study, using a literature review with 30 journals (2007-2020) using Fuzzy-AHP in identifying various risks of construction projects and then creating a hierarchical structure of the risk factors.

3.1. Internal Technical Risk

Internal Technical Risk in project management can be caused by various things. In Keban located in East Region of Turkey, the power plant cannot generate electricity for a long time, and it causes a large amount of national material loss (Yucesan and Kahraman 2019) [4]. Next the risks involved in such PPP projects are unique because of the large amount of investment and long contractual concession period. From the ranking results the top risk factors is planning and design deficiency the top-ranked risk reminds the city/ urban planning decision-makers that every decision at the planning stage should be treated prudently (J. Li and Zou 2011) [5].

The successful accomplishment of green supply chain (GSC) production and business activities is comparatively difficult thanks to involvement of various risks. These risks and their respective sources have a bent to disturb the GSC functioning, and thereby, decline within the ecological-economic performance. Identification of risks and their subsequent analysis within the GSC are vital to understand and understand. The order of priority of categories of risks is given as, Operational > Financial > Supply Risk > Product recovery risks (PR) > Governmental and organizational related risks (GO) > Demand risks (D). (Mangla, Kumar, and Barua 2015) [6].

Furthermore, the execution of construction projects in metropolitan areas which are very appealing; but it is highly risky, competitive, and dynamic due to the complicated surrounding environments such as heavy traffic, transportation, multiple stakeholders' competency, removal of existing pipelines utilities and other facilities (Kou and Lu, 2013). The following six risk factors viz. ground water seepage, conflicting interfaces between work items, design drawing errors, inappropriate design and poor engineering, super cyclonic storm, and heavy rainfall have been found very significant in the context of the case construct project (Samantra, Datta, and Mahapatra 2017) [7].

An empirical study of metropolitan rapid transit project in Pakistan has been presented on the important issue of cost overrun, and its potential control measures have been acquired through. In order to develop a cost-risk contingency framework, risk and cost-related results are re-evaluated by generating a large number of iterations in Monte Carlo Simulation (MCS) for each cost-risk scenario. While exploring the significance of critical risk factors for cost overrun, important risk factors such as “inappropriate design and poor engineering,” “increase in the price of construction material” and “delay in transferring existing facilities” are found that need additional budgeted cost for mitigating and controlling those risks to successfully achieve the project progress and maintaining stability in budgeting. (Afzal et al. 2020) [8].

3.2. Internal Non-Technical Risk

Low project residual value (after 30 years of operation in Public Private Partnerships (PPPs) case project) shows that the experts are majorly concerned with the quality and serviceability of the expressway when it is returned to the government after 30 years of operation. Lack of qualified bidders shows that the experts are concerned with obtaining a competitive bid because of insufficient numbers of qualified bidders for PPP projects, thus creating difficulties. Long project approval time reflects the government’s bureaucratic policies. This is the cause of NTR in the procure infrastructure projects method, such as expressways, bridges, water plants, and power plants (J. Li and Zou 2011) [5]. Construction projects risk assessment is often conducted to determine the priority or the optimal scheme of projects. The 10 top construction project risks’ relative importance index of King Abdulaziz University (KAU) are: the risks of delays due to excessive approval procedures for each of the project parameter, the risks for cost, time related delay, quality related issues, environmental risks, and safety problems of construction projects (Taylan et al. 2014) [9].

The value of the project, the type of contract, and the total construction area can also be the NTR in a project. The findings indicate that “contract-related characteristics” have the highest weights among major project characteristics. The main reason for this finding is that deficiencies in a contract subsequently lead to uncertainties in all remaining stages of the project. For instance, ambiguities in the contract are likely to cause either design changes or reworks, which may lead to the occurrence of new risks. The experts rated “contract type” as the second most important project characteristic that can contribute to the occurrence of the risks of the construction projects. (Okudan and Budayan n.d., 2020) [10].

A new method for risk assessment of a tunnel project where there are three main parameters called taskmaster, adviser, and contractor. The proposed model is built based on interactive framework of a game theory where, in making decision, each player considers other possible risks choices. The results reveal that collaboration strategies give the highest outcome for the three players. It also recommends owner managers, design managers, and contractor managers to make collaboration in undertaking innovation while the operator managers need to let an independent organization clearly identify the appropriate risk mitigation measures to be implemented in a timely manner (Aliahmadi, Sadjadi, and Jafari-Eskandari 2011) [11].

Determination of an appropriate mark-up while bidding for international construction projects is a critical decision. Level of mark-up is a function of risks associated with a project. It is assumed that after bidding phase, if the company is awarded the project, a more detailed risk analysis will be carried out so that potential risk events are identified, impacts of risks on time and cost can be quantified, specific responses can be generated, and a risk management plan can be prepared. There are only two factors, namely experience and contract conditions, are identified as influencing factors. In a more detailed risk model, which is critical to prepare a good risk management plan, specific response strategies such as ‘‘insurance’’, ‘‘transfer of risk to another party’’, ‘‘taking necessary precautions’’ etc. should be considered. Moreover, individual contract clauses such as ‘‘escalation’’ and ‘‘liquidated damages’’ should be taken into account as they significantly affect the impact of risk factors (Dikmen, Birgonul, and Han 2007) [12].

High Impact of contractor on cost, time, and quality of project, refers to the role of contractor in the project. The method of choosing the contractor based on the important criteria which indicator company better equipped in terms of the availability of expertise, staff, maintaining the records and the financial ability define the strength and ability of the contractor to do a particular work rather than only on the least bid offered will help us having better contractor for efficient execution of the project (Ali, Khodadadi, and Dean Kumar, 2013) [13].

A manifold of research has been developed in order to select the project delivery system that best meets all project requirements and owner needs. For this purpose, the Turnkey system is compared with EPC system in different risk attitudes. In fact, selecting an appropriate delivery system is a decision-making problem. Selecting an appropriate project delivery system that meets all the owners’ needs and satisfies project requirements is of great importance for project success. (Mostafavi, Karamouz, 2010) [14].

3.3. External Technical Risk

The condition of the landfill is one of the technical external risks in the project. There are 4 journals that discuss the risks regarding the state of landfills, disturbance by weather, and natural conditions. Although industry, makes a considerable contribution to the Chinese economic development, its safety record is that the worst within the world. Methane has been regarded as one of the most deadly dangers in underground coal mining because of its explosion risk. The research results show that two risk factors, B2, namely, ventilation resistance, P(B2=S1)=19.9%, and B18, namely, friction between rock, P(B18=S1)=20.20, are the most likely to be direct causes of gas explosion (M. Li et al. 2020) [15].

Base on an investigation of the construction environment, the risk assessment group constructs a factor index (FI) hierarchy which consists of four sections, i.e. human factors, site factors, material factors, and equipment factors sections. Each section has several major risk factors. (Zeng, An, and Smith 2007). In construction projects in metropolitan, the following factors viz. groundwater seepage, super cyclonic storm, and heavy rainfall have been found very significant in the context of the case construct project (Samantra, Datta, and Mahapatra 2017) [7].

Exploration of deep earth requires ultra-deep drilling attempts on the ocean or continent, which is that the main goal of scientific drilling projects currently established. Uncertain geological complexity, high requirement for R&D of critical equipment as well as high demand of practical performance has to be encountered during a scientific drilling project, making it full of challenge and risks. Risk management, therefore, is critically proposed for scientific drilling projects to scale back the risks. Therefore, the risk level for the project can be construed as “high”. Moreover, among various risks, “junk in the hole” is the most critical risk, with “crooked hole” being the second, and with “blowout” being the third. (J. Liu, Li, and Wang 2013) [16].

3.4. External Non-Technical Risk

The underground pipeline corridor project in China may be a capital-intensive project with an outsized investment and an extended construction cycle. Through the danger assessment, the essential risks faced by the project are financial, management risks, market risks, political risks, construction risks, and natural risks. The results show that the financial risk of L-city's underground pipe corridor PPP project is far bigger, followed by market risk and management risk; within the secondary indicators, the financing risk, market demand change, rate of interest risk, rate of exchange risk, and legal and regulatory risk are bigger, and inflation risk, operation and maintenance cost risk, enterprise change risk, special purpose vehicle's capacity shortage risk, and public opposition risk are next. (X. Liu and Fang n.d.) [17]. the construction of huge renewable energy projects is characterized by the good uncertainties related to their administrative complexity and their constructive characteristics. For correct management, it's necessary to undertake a radical project risk assessment before construction. the best risks for project Time are ‘Bank financing’, ‘Delays in obtaining the development license’, ‘Delays in obtaining approval of the environmental impact’, ‘The change in energy policy, ‘Construction delays of the facility connection infrastructure’. Logically, from the purpose of view of the project term, the foremost important risks are those associated with delays. (Serrano-Gomez and Munoz-Hernandez 2019) [18].

The international markets are attractive to China’s construction enterprises because some overseas projects are profitable. The total risk of a world construction project is often divided into five sections: political, economic, cultural/legal, technical/ constructional, and another risk. If getting to proceed with the venture (JV) project, the foreign contractor must take appropriate risk management strategies to affect the risks appropriately. The key risks are often preliminarily identified as per the expert’s judgment. The methods to manage these risks are proposed by Li et al. (1999) and Shen et al. (2001), including to “carefully select its local partner, make sure that an honest JV agreement is drafted, choose the proper staff and subcontractors, establish good project relationships, and secure a good construction contract with its client” Li et al. 1999 and “improving cooperation with government agencies, employing contracts to manage risks properly and controlling technical risks” (Shen et al. 2001) Among the project-specific risks, the client’s income and project delay are considered the main risks influencing the success of the JV (G. Zhang and Zou, 2010) [19]. While exploring the importance of critical risk factors for cost, important risk factors like “inappropriate design and poor engineering,” “increase within the price of construction material” and “delay in transferring existing facilities” are found that need the additional budgeted cost for mitigating and controlling those risks to successfully achieve the project progress and maintaining stability in budgeting. (Afzal et al. 2020) [8].

3.5. Project Technical Risk

Kuo and Lu in 2013 [20] identified risk factors within the five risk dimensions, spring water seepage, typhoons, conflicting interfaces between work items, design drawing errors, and heavy rainfall are the five risk factors with the very best relative impacts on construction project performance. Underestimation of spring water seepage can cause substantial damage at underground construction sites because it affects the soil structure within the excavation areas. On the idea of an investigation of the development environment, the danger assessment group constructs an element index (FI) hierarchy which consists of 4 sections, i.e. human factors, site factors, material factors, and equipment factors sections. Each section features some major risk factors. (Zeng, An, and Smith 2007) [21]. Since modular construction is naturally distinct from conventional construction, existing risk management research for onsite construction can't be directly applied to modular construction. (Xian Li et al. n.d.) has proposed a generic risk management framework for modular construction; the innovative contribution of this paper comprises two aspects: (1) the precise risk factors are identified supported the unique activities involved in modular construction, accommodating both offsite and onsite construction environments; and (2) the tactic of quantifying the danger factors' variation and impacts is generic; the quantification results assist in subsequently controlling and mitigating risk. Although the likelihood for a few marginal regional variations in risk factors exists, it's reliable to use the identified risk factors and assess risk impact for modular construction on the idea of the experience of those practitioners. In Iranian housing industry show that construction project managers consider the financial risk because the most vital major factor for the success and failure of the development projects. After the financial risk, the factor "project management" is of the very best rank and most vital role in the success and failure of projects. The factor "project type" is of the third rank. Three factors external risk, "contract risk", and "operational risk" have subsequent ranks with much far away from the opposite factors. Regarding the high importance of the three factors "financial risk", "project type", and "project management", the sub-factors associated with these factors like "project funding", "number of activities", and "executive manager's support" have the five highest priority. The less importance of factor "operational risk" has led to rock bottom rank for the sub-factor "losses to the development equipment." (Gohar et al., 2009) [22]

According to the R&D project's life cycle, the danger is especially limited on R&D implementation and launch phase, that the danger of research and development personnel qualification, risk in research and development environments, risk in managers' decision in the implementation phase, while the danger in the cooperative enterprise, risk in competitive enterprise in the launch phase, which accounted for the highest five among the danger of R&D project. Risk management should be particularly strengthened in the implementation and launch phase. (IEEE, 2015) [23]. In all the development safety accidents, the high falling accident is that the most serious construction accident of 5 big hurts which are threatening building workers. Risk assessment is that an important means the way to prevent and control falling from height accidents. supported "human-machine - environment - Management" complex system, the danger assessment index system about 4 major categories and 23 subcategories include the standard of things of production personnel and the production equipment factors and the environmental conditions factors and the safety management factors was established. (Shi et al. 2012) [24].

Desalination projects play an important role within the water system of coastal regions with scarce water resources. The risks related to desalination projects are worth investigating, especially for large-scale projects. The danger identification and evaluation processes of large-scale desalination projects. The primary level of risk indicators are identified include water intake and outfall risk, processing risk, financial risk, and circumstance risk. (Y. Zhang et al. 2020) [25].

Select response actions regarding response strategy: Risk response actions should be selected proportional to the acceptable response strategy. Generally, a risk response strategy is often divided into four categories (Wang, Chou 2003; Ashley et al. 2006): (1) risk avoidance (i.e. changing plan/design to get rid of the risk); (2) risk transference (i.e. transferring the responsibility of risk management to other parties); (3) risk mitigation (i.e. alleviating risk magnitude by reducing any of risk components like occurrence (P), consequence (C) or employed control number (CN); (4) risk acceptance (i.e. doing nothing and accept any resulting consequences). Having selected several response actions regarding a correct risk response strategy, the foremost appropriate response action/actions group must be selected. This selection is administered supported by three criteria including cost, time, and quality. (Ahmadi et al. 2017) [26].

Health and safety risks are among the foremost significant risks in construction projects since the development industry is characterized by a comparatively high injury and death rate compared to other industries. Adequate prioritization of safety risks during risk assessment is crucial for planning, budgeting, and management of safety-related risks. The results indicate that the item 'Trips & falls' requires the foremost significant investment among the nine risk items. the danger item 'Machinery & Equipment has the second-highest risk, followed by the item 'Electricity & lighting'. the things 'Fire & explosions', 'Vibration', and 'Neurological' have to risk magnitudes between 3 and 4 and are classified because of the risk items with a medium magnitude. Finally, the things 'Burns', 'Temperature', and 'Ventilation' are classified because of the risk items with a coffee magnitude. The danger magnitudes provide crucial information for the project decision-makers during the planning and budgeting of accident/injury prevention investments (Aminbakhsh, Gunduz, and Sonmez 2013) [27].

3.6. Project Non-Technical Risk

Included within the Project Non-Technical Risk factor are those associated with the value, time, and quality of the project. Thompson and Perry (1992) attributed the failure of projects to the shortage of effective management of risk events, which frequently results in overlooking milestones and targets. Project risk management has become the foundation for successful project management. The fuzzy AHP approach has been adopted to unravel the multicriteria deciding problem during which the value impact (CI), time impact (TI), and scope/quality impact (SI) are required to be aggregated into one term. The danger criticality analyzer (RCA) was developed to implement the proposed framework. The results obtained confirmed the potential and therefore the usefulness of the tactic to supply valid Failure mode and effect analysis (FMEA) results. (Abdelgawad, Fayek, 2010) [28]. If getting to proceed with the venture (JV) project, the foreign contractor must take appropriate risk management strategies to affect the risks appropriately. The key risks are often preliminarily identified as per the expert's judgment. The methods to manage these risks are proposed by Li et al. (1999) and Shen et al. (2001), including to "carefully select its local partner, confirm that an honest JV agreement is drafted, choose the right staff and subcontractors, establish good project relationships, and secure a good construction contract with its client" Li et al. 1999 and "improving cooperation with government agencies, employing contracts to manage risks properly and controlling technical risks" (Shen et al. 2001) Among the project-specific risks, the client's income and project delay are considered the main risks influencing the success of the JV .After the financial risk, the factor "project management" is of the very best rank and most vital role in the success and failure of projects. The factor "project type" is of the third rank. Regarding the high importance of the three factors "financial risk", "project type", and "project management", the sub-factors associated with these factors like "project funding", "number of activities", and "executive manager's support" have the five highest priority." [29].

3.7. Summary and Results

The summary of the paper review related to risk management with Fuzzy Analytical Hierarchy Process (F-AHP) shown in Table 1.

Table 1. Summary Literature Review Infrastructure Risk Analysis of Based on Fuzzy Analytical Hierarchy Process (F-AHP).

No	Reference Number	Risk Category						Result
		Internal		External		Project		
		T	NT	T	NT	T	NT	
1	[15]			√		√		The results show that the method of fuzzy AHP and Bayesian Network is feasible and applicable. It can be used as a decision-making tool to prevent coal mine gas explosions and provide decision makers with a technical guide for managing the coal mine gas explosion risk.
2	[4]	√						The risk assessment has an important influence on the control and decision making for a healthy operation of the hydroelectric power plant. New project partners or renovated substations can easily benefit from modern power plant control and automation systems in order to get optimized mechanical and electrical support especially in the areas of planning, operations and maintenance.
3	[5]	√	√				√	From the research showed that planning deficiency, low project residual value (after 30 years of operation), lack of qualified bidders, design deficiency, and long project approval time were assessed as the top five risks for the project, and the feedback from the experts showed that these results reflected the actual project risk situation.
4	[17]				√		√	the results research show that the financial risk of L-city's underground pipe corridor PPP project is much bigger, followed by market risk and management risk; in the secondary indicators, the financing risk, market demand change, interest rate risk, exchange rate risk and legal and

								regulatory risk are bigger, and inflation risk, operation and maintenance cost overrun risk, enterprise change risk.
5	[9]					√	√	The aim of a hybrid fuzzy AHP and fuzzy TOPSIS model is to assess the overall risks of construction projects in which the descriptions of criteria and their observations are imprecise, vague, and uncertain. This study comprises the selection of construction projects and assessment of their risks under vague and uncertain environments.
6	[28]						√	Fuzzy logic and fuzzy analytical hierarchy process AHP are used to address the limitations of traditional FMEA. In essence, this method explores the concept of fuzzy expert systems to map the relationship between impact, probability of occurrence, and detection/control and the level of criticality of risk events.
7	[20]				√	√		This study employs a fuzzy multiple criteria decision making (FMCDM) approach to systematically assess risk for a metropolitan construction project. Consistent fuzzy preference relations (CFPR) are used to measure and investigate the relative impact on project performance of twenty identified risk factors included in four risk dimensions. The fuzzy multiple attributes direct rating (FMADR) approach is employed to analyze the occurrence probability of multiple risk factors.
8	[6]	√					√	The used fuzzy AHP approach so useful in dealing with the human subjectivity and ambiguity involved in the process of risk analysis. In this research, an effort has been made to know the most important risk in GSC context, and the findings would be useful for industries in managing and reducing the consequences of the risks in GSC. The analysis of the results indicates that operational category risks are the most important risks in GSC. Sensitivity analysis is also conducted to examine the priority ranking stability.
9	[10]		√					The results showed that each characteristic has a different effect level on the risk occurrence; therefore, finding similar cases without considering these differences does not enhance the accuracy and comprehensiveness of the risk identification process. The findings indicate that "contract-related characteristics" have the highest weights among major project characteristics
10	[30]		√			√		All the risks related to an international construction project are analyzed through a hierarchical risk breakdown structure in this

								paper. Based on the three-level hierarchical structure, a risk index (R) model is proposed, which performs two functions: evaluate sources of risk and accordingly prioritize the projects.
11	[7]	√		√		√		From amongst twenty identified risk factors (under five risk dimensions), the following six risk factors viz. ground water seepage, conflicting interfaces between work items, design drawing errors, inappropriate design and poor engineering, super cyclonic storm, and heavy rainfall have been found very significant in the context of the case construct project.
12	[18]				√			This new approach introduces a new parameter in risk analysis, known as 'Confidence Level'. This new parameter analyses the linguistic aspects of expert opinion, varying the answers according to their coherence and weighting their judgements regarding impact and probability.
13	[31]	√	√					This paper presents a new methodology for construction project risk analysis to deal with risks associated with the construction projects in the complicated situations in which the information to assess risks is unquantifiable, incomplete or non-obtainable. The approach allows members in the risk assessment group to make their judgements by means of linguistic terms instead of real numbers.
14	[11]		√					The risk assessment plays an important role for tunnel projects especially when they are built inside the city where many civilians are involved with the consequences of the project. The proposed method of this paper has presented a combined fuzzy AHP and game theory to assess and evaluate different risk factors in tunnel project.
15	[19]		√		√		√	Based on expert judgment, the weight coefficients of risk groups and risk factors are acquired with the aid of the AHP techniques and the fuzzy evaluation matrixes of risk factors are founded through fuzzy set theory. Then the aggregation of weight coefficients and fuzzy evaluation matrices produces the appraisal vector of risky conditions of the JV.
16	[21]		√	√		√		Factor index is therefore introduced to structure and evaluate these factors and integrate them into the decision-making process of risk assessment. This article presents a risk assessment methodology to cope with risks in complicated construction situations. The application of fuzzy reasoning techniques provides an effective tool to handle the uncertainties and subjectivities arising in the construction process.

17	[8]	√			√			The findings and implication for project managers could possibly be achieved by assuming the proposed cost-risk contingency framework under high uncertainty of cost found in this research. Furthermore, this procedure may be used by experts from other engineering domains by replacing and considering the complex relationship between complexity-risk factors.
18	[32]					√		This research has proposed a generic risk management framework for modular construction; the innovative contribution of this paper comprises two aspects: (1) the specific risk factors are identified based on the unique activities involved in modular construction, accommodating both offsite and onsite construction environments; and (2) the method of quantifying the risk factors' variation and impacts is generic; the quantification results assist in subsequently controlling and mitigating risk
19	[12]		√					The aim of this paper is to propose a fuzzy risk assessment methodology for international construction projects and develop a tool to implement the proposed methodology. The proposed methodology uses the influence diagramming method for construction of a risk model and a fuzzy risk assessment approach for estimating a cost overrun risk rating.
20	[22]		√			√		The risk factors that derived from available papers in literature must be localized for Iran environment and conditions. Therefore 38 risk factors have been identified and classified in 9 main classes. Evidence show that the quality factor is more important than other main factors and business and work environment.
21	[13]		√					In this study, for contractor selection unlike the conventional methods that are based on lowest value suggested for the project implementation, the selection of a contractor is based on the contractor's ability to do the project. The potential contractors using the contractor eligibility bylaw. In this paper, combination of the risk management process and fuzzy logic, have been used to identify and assess the risks of the contractors.
22	[14]		√					Project delivery system alternatives are ranked using fuzzy technique for order preference by similarity to ideal solution (TOPSIS) method based on their utility membership functions and by evaluating the distance of each project delivery alternative from fuzzy ideal solutions. In addition, the risk attitude of the decision maker is considered in the model by using derived utility

								membership functions corresponding to the risk attitude of the decision maker.
23	[23]	√				√		According to the R&D project's life cycle, the risk is mainly limited on R&D implementation and launch phase, (i) that the risk of research and development personnel qualification, (ii) risk in research and development environmental, (iii) risk in managers' decision in implementation phase, (iv) the risk in cooperative enterprise, (v) risk in competitive enterprise in launch phase, which accounted for the top five among the risk of R&D project. Risk management should be particularly strengthened in implementation and launch phase.
24	[24]		√			√		Based on "human - machine - environment - Management" complex system, the risk assessment index system about 4 majors categories and 23 subcategories include: (i)the quality of factors of production personnel and the (ii) production equipment factors and (iii) the environmental conditions factors and (iv) the safety management factors were established.
25	[1]		√					This paper proposes a new procedure for determination of the weights of criteria and alternatives in the Fuzzy analytic hierarchy process (FAHP) with trapezoidal fuzzy number using a new method for finding eigenvalues and eigenvectors of the criteria and alternatives, which is based on expected values of the fuzzy numbers and their products
26	[25]	√				√		This paper presents the risk identification and evaluation processes of large-scale desalination projects. Two levels of risk indicators are identified**,** and the first-level risks include water intake and outfall risk, processing risk, financial risk and circumstance risk. With the identified risk indicators, an integrated fuzzy comprehensive evaluation (FCE) and analytic hierarchy process (AHP) method is introduced to conduct quantitative risk evaluations for large-scale desalination projects.
27	[16]			√		√		This paper, therefore, proposes a fuzzy synthetic evaluation approach for scientific drilling project risk assessment. Four criteria — probability, severity, non-detectability and worsening factor are utilized to evaluate individual and overall risks comprehensively. Linguistic terms instead of numerical values are employed to evaluate each risk normally done by experts. AHP/ANP is used to determine sensible weights of each criterion.
28	[26]	√				√		The main criteria analyzed for prioritizing potential risk events are cost, time and quality which are quantified and combined using fuzzy AHP. A new expert system is suggested for identifying an appropriate risk response strategy

								for a risk event based on risk factor, control number and risk allocation. The results show that the response action of "changing paving construction technology from asphalt pavement to RCC pavement" can successfully cope with the risk event of "increase in tar price" and have the minimum deviation.
29	[29]						√	Results of the proposed fuzzy approach showed that the ranking of the factors influencing on failure and success of the construction projects in Iran is as follows: financial risks, project management, project type, external, contract, and operational risks. The results indicate that construction project managers usually consider risk factors before start of the project (such as project funding, organization familiarity level, definition of the objectives, and selection of the project team) more important than other risk factors. This indicates importance of planning and definition of objectives and responsibilities before start of the projects.
30	[27]					√		The proposed framework presents a robust method for prioritization of safety risks to create a rational budget for accident/injury prevention during planning and budgeting of construction projects. However, the framework might require too many pairwise comparisons for large and complex projects, which may require longer implementation times.

3.8. Risk Group

From reviewed journals, project risk research with Fuzzy AHP is carried out all the time as one of the most influential risk rating methods in a construction project as shown in Figure 3. Knowing this risk rating is expected to avoid the greatest risks and anticipate it in advance.

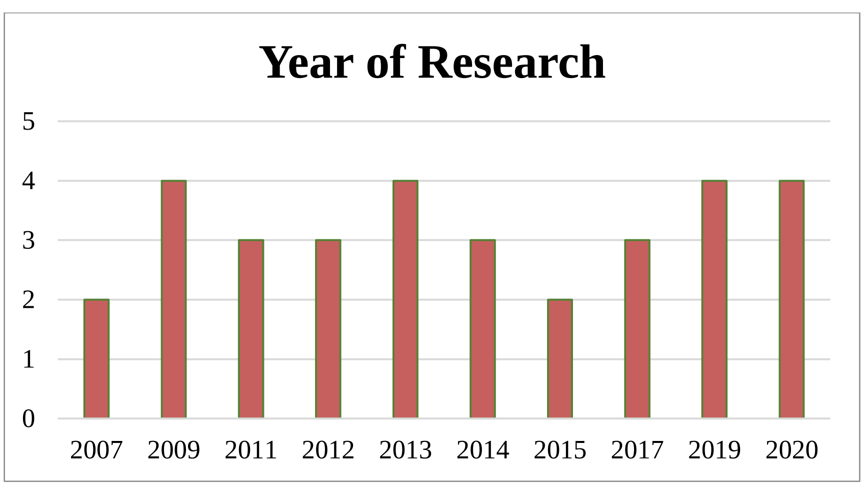

Figure 3. Articles based on years of research.

Table 1. The Recapitulation of Selected Journals Analyzed.

Risk Category		Research Journal
Internal	Technical Non-Technical	2, 3, 8, 11, 13, 17, 26, 28 3, 9, 10, 13, 14, 16, 19, 20, 21, 22, 24, 25
External	Technical Non-Technical	1, 10, 11, 16, 26, 27 4, 7, 12, 15, 17
Project	Technical Non-Technical	2, 5, 10, 11, 16, 18, 20, 23, 24, 26, 27, 28, 30 3, 4, 5, 6, 8, 15, 29

Based on the review of the articles above, it is found that the most likely risk in project management is a technical risk either in the project or internal risk.

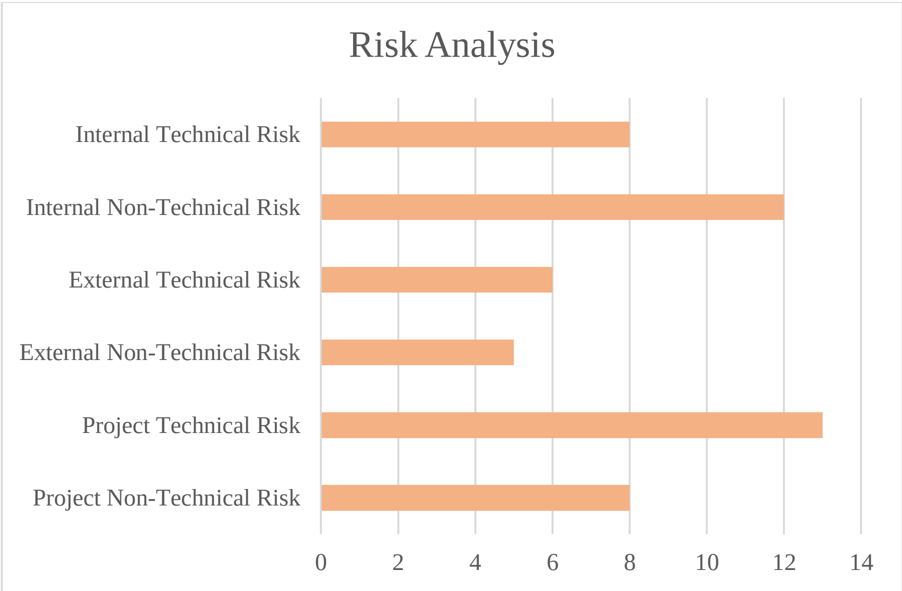

Figure 4. Bar Chart Analysis of Research Articles Based on Risk Assessment with Fuzzy-AHP method.

While the summary of risk in construction projects based on Fuzzy AHP method on articles review is showed in the below Table 3.

Table 3. Risk Summary

Internal Technical Risk	Internal Non-Technical Risk
- Material loss - Planning & design deficiency - Operational - Conflicting between work items - Project processing - Poor engineering	- Lack of qualified bidders - Approval procedure - Contract conditions - Management skill
External Technical Risk	**External Non-Technical Risk**
- Disruption by landfill - Site factors - Circumstance risk - Supply risk - Weather conditions	- Market demand - Political factors - Economic Factors - Cultural / legal factors - Environment issue - Bank financing - Contractor cash flow

Project Technical Risk	**Project Non-Technical Risk**
- Technological risk - Safety factors - Response action - Equipment factors	- Cost risk - Time risk - Quality risk

From the risk factors from the fuzzy AHP rating analysis, it can be seen that external non-technical risks have the most risk factors and often these factors carry a large enough risk in the sustainability of a construction project. The biggest risk in a construction project is technical risk, both internal and project, and this can be a consideration in planning and controlling a project.

4. Conclusions

From the review of the articles, can be concluded that (i) The Technical Risk risks have the greatest impact on construction risk project for either internal or project category, (ii) Technical risk on construction project base on Fuzzy-AHP rating includes material loss, planning & design deficiency, operational, conflicting between work items, project processing, poor engineering, disruption by landfill, site factors, circumstance risk, supply risk, weather conditions, technological risk, safety factors, response action and equipment factors.

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