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Master's Thesis

電廠專案於設計階段之關鍵風險因素與管理

Risk management in design phase of Design-Build power plant projects

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摘要

設計階段的風險為影響工程項目成功與否的關鍵要素。針對越南之電廠統包興建工程，本研究揭示並識別設計階段之關鍵風險因素，根據影響程度和可能性對其進行排名，進而提出相對應之風險管理對策。首先，透過回顧過去文獻以及深入訪談資深專家，共計識別並檢視了 37 項設計風險。接著採用李克特五點量表進行問卷調查，包括各設計風險之影響程度及發生可能性。針對 106 份有效問卷進行數據分析。本研究以探索性因素分析歸納出六種類型：設計團隊缺乏能力和經驗的風險；設計方案不當的風險；設計團隊缺乏責任感的風險；低效率的文件覆核以及各方利益相關者不良合作的風險；投資者的要求變更的風險；以及遭到投資者的反對和誤解的風險。最後，透過回顧相關研究、專家訪談以及越南發電廠的案例研究，討論歸納出對應之風險管理手段，以降低設計風險並取得更好的工程成果。具體建議包括：採用國際設計標準；於設計階段使用建築資訊模型；制定明確的設計流程和有效的人才管理策略等。本研究之發現有助於越南電廠興建專案於設計階段之風險分析，也為利害關係人提供了設計過程中的風險清單和管理手段。

關鍵詞：風險管理；探索性因素分析；設計風險；設計建造；發電廠項目

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Abstract

Design risks can have a significant impact on construction project success. Focusing on the Design-Build power plant projects in Vietnam, this study lists the design risk factors and ranks them according to the level of impact and possibility, and then suggests appropriate risk management countermeasures. A comprehensive analysis of related research and in-depth interviews with construction specialists in Vietnam resulted in the identification and evaluation of 37 design risk factors. A survey consisting of a five-point Likert scale was distributed to 150 people working in the construction industry regarding the level of impact and possibility for design risks. This produced 106 valid answers for the analysis of the data. According to exploratory factor analysis, six groups could be formed from these factors: risk of design team lack of capacity and experience, risk of improper design scheme, risk of design team lack of responsibility, risk of inefficient document review and poor cooperation between stakeholders, risk of change and requested by owner, and risk of disagreement and misunderstanding by owner. Last, through reviewing related studies, interviewing experts, and a case study of a power plant project in Vietnam, specific design risk management activities have been suggested to mitigate design risks and achieve better project results, including using international design standards, using Building Information Modeling (BIM) in designing phase, having a clear design process, and having an effective human resource management strategy. The findings contribute to the knowledge of Design-Build participants about design risk analysis and risk management activities of power plant projects in Vietnam. More fundamentally, the findings enhance Design-Build participants' understanding and awareness of the level of impact and possibility of risk factors during the design phase. This

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research also provides stakeholders with a checklist and analysis of risks during the design process, enriching research on risk analysis and management.

Key words: risk management, exploratory factor analysis, design risk, design-build, power plant projects.

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Chapter 1. Introduction

1.1. Research background

One of Southeast Asia's rising stars, Vietnam is a nation that is developing quickly nowadays. The nation has accomplished important economic milestones in the last ten years, maintaining strong annual GDP growth rates of 6% to 7% on average (Anh, 2023). With an economy with such a high and continuous growth rate, energy security should be considered a top concern in economic development policy in Vietnam today. Facing the requirements of industrialization and modernization of the country, Vietnam's energy demand is constantly increasing, while energy supply is increasingly depleted. Therefore, the country needs to have a specific roadmap in building a sustainable energy model for the future. The investing and expansion in renewable power plants, for instance: wind, solar energy and especially Liquefied natural gas LNG plants is an important component of Vietnam's energy plan.

With the current growth rate, the competition in the construction industry will also be increasingly intense. Construction industry has now increased in both quantity and quality, there was no big difference in construction technology among contractors. Competition among construction-based businesses bid price and project completion schedule of the contractor. These two factors are determined mainly by financial ability, construction technology and project management ability of contractors. Therefore, innovative procurement systems emerge and Design-Build (DB) methods become increasingly common for construction projects (Songer and Molenaar, 1996), in lieu of traditional Design-Bid-Build delivery systems.

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Design-Build was formerly thought to be just one of several different ways to deliver projects. Benefits of the design-build approach include reduced project implementation time, lower costs, fewer design-construction conflicts, and unquestionably faster construction. The DB delivery method will be a widely used form due to the previously mentioned reasons. DB delivery systems are becoming more and more commonplace worldwide, particularly in developed nations like the United States, the United Kingdom, Japan, Taiwan, and so forth. According to some estimates, the DB method was being used in the United States to produce nearly 40% of all buildings in 2002 (Rowlinson and Walker, 1995). Vietnam has been using the Design-Build delivery system project model since 1996. The first project, the Pha Lai 1 Thermal Power Plant, was started in 2001 and finished by the Japanese general contractor Sumitomo. The development of DB power plant projects then has been increased gradually. From the first project up to now, several power plant projects in Vietnam have applied the DB method. Even though these projects have been completed, still many problems such as project owners need to bear more risks, DB facilities are not high quality, and maintenance issues are not adequately considered (Ling F.Y.Y. et al, 2000). Therefore, managing risks from the design stage will minimize problems that can arise later. Reducing obstacles to entry for DB contractors in the DB market can be greatly aided by a thorough understanding of design risk in DB projects and the efficient management of this risk. It also increases the project's likelihood of success, at least according to the DB contractor (Wang et al., 2015). Stated differently, it is likely that exceptional design risk management will be a major source of competitive advantage in the pursuit of a positive feedback loop that involves gaining new business and building a solid reputation for meeting owners' demands and completing projects on schedule.

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1.2. Research objectives

This research aims to (1) determine design risks in D-B power plant projects in Vietnam by reviewing related literature and interviewing experts, (2) rank the risks among founded risk factors, (3) group risk variables using exploratory factor analysis (EFA) into distinct themes, and (4) find specific design risk management activities to mitigate design risks.

1.3. Research scope

The study focuses on identifying and managing risks affecting the efficiency of DB power plant projects in the design phase, especially in LNG power plants. In addition, the research also studies about the aspect of different stakeholders implementing power plant projects carried out in the Design-Build delivery method.

The research's survey subjects include people with experience in the field of design and construction, and individuals who have been participating in DB power plant projects, and the data were collected in Hanoi, Vietnam.

1.4. Research contributions

This research will provide risk factors that contractors may encounter when designing DB power plant projects and its ranking in Vietnam. Besides that, surveyed data would be analyzed in different points of views so that stakeholders could know more about the current situation in Vietnamese markets. So, the study's findings would enhance Design-Build participants' understanding and awareness of the level of impact and possibility of risk factors during design phase. Thereby, several management activities should be applied to reduce the impact of risks and avoid these risks when implementing the next project.

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1.5. Organization of the Thesis

This thesis is divided into six chapters. Apart from the overall overview provided in Chapter 1, Chapter 2 provides an overview of the definition of design phase of Design-Build power plant projects, also related studies conducted in the past. Chapter 3 presents the methodology of this research. Next, Chapter 4 shows the analyzed results from the surveyed questionnaires and its discussion. Chapter 5 provides the management activities to control the design risk through literature review, expert interview and a case study. Finally, Chapter 6 concludes the research's outcomes, provides the research limitation and suggestions for the future research.

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Chapter 2. Literature review

This chapter provides an introduction to the design phase of Design-Build power plant projects. It will help better understand the design process, as well as the risks when implementing the design. In addition, there are risk management measures during the design phase of the Design-Build project. Finally, the limitations of previous studies when studying risk management in the design phase are discussed.

2.1. Definitions

2.1.1. Design-Build delivery system

Design-build is a form of project delivery in which the investor signs a contract with a single company as the general contractor to plan, design, and construct the project. The general contractor can be a design company associated with a construction contractor, a construction contractor hires design experts to prepare designs, or a contractor performs both design and construction themselves.

In contrast, in the traditional design-bid-build (DBB) delivery system, investors contract with the design unit to provide the design and then contract with the construction contractor to build the project according to that design (Alann M. Ramirez, 2005). The fundamental difference between DB and DBB in contracts is, in particular, how risk and responsibility for design details is transferred from the owner to the contractor. In a DBB contract, the investor hires a designer to develop the final construction drawings (James E. Koch et al., 2010). But the design-build form helps the investor work with a single responsible party instead of with both the design unit and the contractor when a dispute occurs. It also minimizes the investor's

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risks and obligations regarding work progress and coordination. It also allows the investor to know the cost of the project early, before the design is fully completed, reducing risks to the investor such as complaints and increased costs for the project (especially if it is legal). maximum price guarantee or fixed price). On the contrary, because it is responsible for both design and construction, the D&B contractor bears most of the project risks and this can increase costs for the contractor (Alann M. Ramirez, 2005).

The investor's role in this method is small and only emphasized on detailed issues before the project begins. Typically, the investor provides technical specifications related to the project so that the contractor's design unit can prepare the final designs. The contractor prepares a final design that meets the requirements for purpose and function, meets the needs of the investor and completes the detailed design.

The design-build general contractor undertakes a significant risk but if the project is managed well, it can also yield significant profits. Since the design and construction departments are the same team, specialist construction will allow for final designs that are more cost-effective in terms of construction costs. In the design-build form, suppliers and subcontractors are hired directly by the general contractor. The design-build general contractor can choose the form of contract: unit price, fixed price, etc. and often organizes competitive bidding for subcontracts to get the lowest overall price for the project, etc to generate profits.

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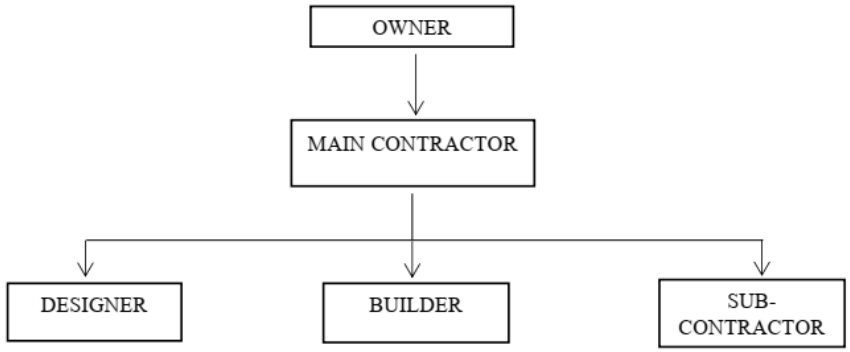

Figure 2.1. Relationship of parties in Design-Build contract

2.1.2. Design phase

The process of designing construction projects involves producing sets of plans, drawings, and specifications that are clear, thorough, integrated, and meet client needs while taking into account resource limitations related to technology, finance, and the environment. The design and construction process is divided into phases, common to all projects, based on key sign-off points required from the client.

During this phase, decisions are made regarding size and structural type requirements of the project and a conceptual design is prepared. This phase involves the preparation of sketch drawings and related service details (Tarez Hegazy, 2002).

Design phase includes two main stages: basic design and detailed design. Basic design phase: architectural plans, evaluates alternative technologies, decides on size, function and compares economic options. This phase results in a series of preliminary plans and initial specifications that can be reviewed and refined. Evaluation focuses on investor approval, external financial resources, compliance with planning with regulatory agencies, licenses, safety standards, environmental impact, etc. Detailed design stage: The process of analyzing

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and designing structures to comply with standards. Includes many detailed technical drawings: architecture, structure, landscape, MEP, firefighting, etc.

Investors clearly understand their needs for the use of the project and they produce very detailed summary documents, setting out criteria such as working environment, usable space and quality standards, etc. These are called scopes of work which are used to establish the basic policy for design work.

From the customer's needs in the request for proposal, the design unit can develop ideas and sketch designs for the project. The design and budgeting processes create a set of project information for owner approval. Once approved, the next step for the design is schematic design, where all the underlying systems for the project are developed and tested for feasibility. The objective is to correct briefs and design solutions, including plan arrangements, site plans, construction methods, final specifications, and detailed budget and schedule costs. The client must be satisfied that the schematic design meets the agreed requirements and should approve this, along with the time and cost budget.

The design unit develops complete design information. Once the various systems are designed and detailed, they can be created into packages to allow the project manager to begin production and construction work (Colin Gray and Will Hughes, 2001).

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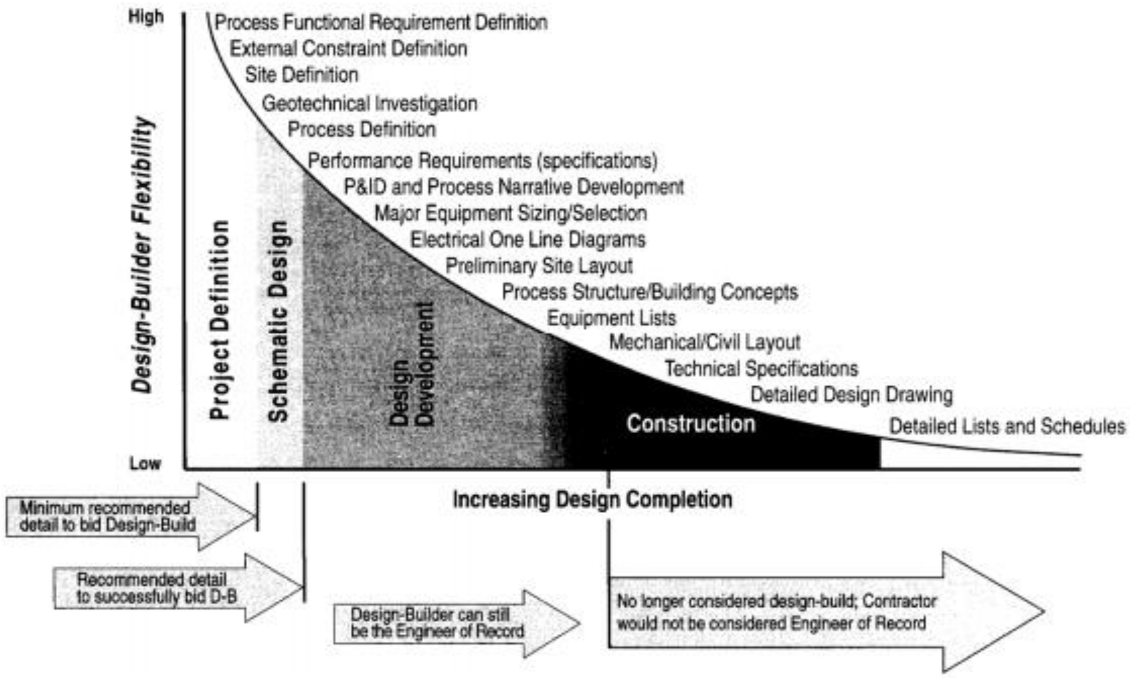

Figure 2.2. Impact of design completion on the DB contractor (Ken Fredrickson, 2001)

2.1.3. Risk

Risk is uncertainty or adverse hazards for the project, this uncertainty arises from the project's speculation about the future, based on estimates, assumptions or a few facts about the resources, time, requirements. Risk often causes forecast results to deviate from reality. Risks are of two types: beneficial risks and adverse risks. Several guidelines published by the Project Management Institute (PMI) and the UK Association for Project Management (APM) define risk as follows:

- Risk of an uncertain event or condition that, if it occurs, has a positive or negative effect on the project objectives - PMI.

- Risk that there is an uncertain event or set of circumstances that, if it occurs, will have an impact on the achievement of project objectives – APM.

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Risk management is a system for identifying and quantifying risks affecting a project in order to make informed decisions about managing those risks. According to PMBOK, risk management is the processes involved in identifying, analyzing and responding to uncertainty throughout the project life cycle (Harold Kerzner, 2017). There are five stages of risk management (Roger Flanagan and George Norman, 1994). First of all is identifying risks, which means identifying sources and types of risks. Second is risk classification. This step is identifying the type of risk and its impact on people or organizations. Third is risk analysis. At this phase, evaluate the consequences associated with a type of risk or combination of risks using analytical techniques, evaluate the impact of risks using different risk measurement techniques. Fourth is the risk attitude. The attitude of the person or organization making the decision affects every decision about risk. Fifth is risk response. At this stage, decision makers consider how to manage risk by moving it or retaining it.

2.1.4. Risk in design phase

Construction project design risks are technical changes in the design field that directly impact construction project performance, potentially resulting in a design that does not meet the requirements for a project. This includes designs that are fundamentally flawed, infeasible, ineffective, unstable or below the investor's standards. A poor design can hinder the progress of the project (Karim El-Dash et al., 2006).

More broadly, design risk can refer to the following two types of events: (1) Design errors result in a product being built, but not meeting regulatory standards, legal requirements and any conditions imposed by environmental or other regulations. Such circumstances mean

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that the project has to be changed, causing delays and above all increased costs. (2) Design errors lead to the project not meeting the standards required in the contract.

In comparison to traditional construction projects, design-build contractors carry significantly greater financial, technical, and social risks as the unit in charge of design, procurement, and construction. As such, they must properly manage related activities, of which design management is crucial. Because design-build contracts are fraught with uncertainty, it can be difficult to agree on how designs meet client requirements, which is also a source of dispute during project implementation. Disputes between contractors, customers, designers, consultants, suppliers, subcontractors, local communities, and the government also arise from poor design planning, inaccurate design documents, expensive construction costs of design decisions, and unreasonable delays in providing drawings and design fees. These factors could result in losses for all parties involved in the project.

2.1.5. Power plant projects

A power plant is an industrial facility that generates electricity from primary energy, such as fossil fuels, nuclear, renewable, or hybrid systems. Most power plants use one or more generators that convert mechanical energy into electrical energy in order to supply power to the electrical grid for society's electrical needs.

Power plants in this study were categorized into thermal power plants, hydropower plants, nuclear power plants, and any other combined-cycle power plant. However, under this category, combined-cycle power plants are the most common type in Vietnam in recent years. Therefore, the scope of this study's results for power plants will cover this key area, but other sources in this category can be included in this research to enhance future studies.

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Southeast Asia's renewable technology has attracted increasing interest over the past ten years. However, the government of Vietnam is more concerned with promoting economic growth through all means possible than it is with preserving the environment through the green energy transition. Vietnam is concerned about reducing its carbon footprint, and renewable energy sources have the potential to emerge as the most affordable energy source. However, there are still numerous financial, legal, and political obstacles in the way of achieving this objective. Vietnam must be cautious to avoid becoming overly ambitious in its green transition, incurring debt, or accepting funding for projects that are premature, reckless, or ill-considered. In the end, Vietnam's energy policy will be determined by its own interests. Any developing nation that does not have the same level of risk tolerance as wealthier countries may find a "energy transition" to be dangerous, and Vietnam is prone to falling into this trap (Kathryn Neville, 2022).

It is unlikely that Vietnam will succeed by merely adopting the energy road maps of developed nations. The nation's over reliance on solar energy and its investments in cutting-edge technologies like hydrogen are impediments to the advancement of its energy sector. Vietnam should put more effort into developing an energy adaptation plan that addresses its current vulnerabilities before hastily ending its reliance on fossil fuels in favor of riskier green investments that could ultimately stall and prolong its energy transition.

Through a series of government-backed feed-in tariffs, Vietnam established a significant footprint in wind and solar energy in an effort to wean itself off fossil fuels in the past (Kathryn Neville, 2022). One significant aspect of Vietnam's energy strategy, which is going through growing pains, is the expansion of LNG. Over the following ten years, Vietnam's

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National Power Development Plan VIII (PDP8) anticipates an increase in LNG capacity (Decision 500/QD-TTg, 2023). However, PDP8-backed LNG projects have had trouble securing funding from lenders wary of the real return on investment. Opportunities for foreign direct investment are frequently focused on renewable energy since decarbonization plans are the top priority for investors concerned about the climate. The environmental community believes that LNG and other carbon-intensive resources will become less profitable in comparison to renewable energy sources by 2037, making these resources less appealing as investments (Kathryn Neville, 2022). However, in order to support Vietnam's industrial expansion and close the gap with more environmentally harmful fuels like coal, LNG still needs to be developed as a significant base load fuel.

However as of right now, Vietnam has no LNG-to-power facilities running. LNG-fueled power generation of new projects until 2030 is estimated by the most recent draft plan (PDP8) to be 23,900 MW, or 16.4% of the nation's total power generation. A further 14,930 MW would come from plants that were switched to LNG fuel because there was not enough natural gas available domestically (An Hoa and Bao Long, 2022). Vietnam's energy transition will be a convoluted and protracted process. Low-carbon emitting fossil fuels like LNG will have to be part of the cost of change, but developing nations like Vietnam shouldn't view this negatively.

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2.2. Related studies

2.2.1. Related studied to identify design risks

Risk management is not anything new in the construction industry. PMBOK lists risk management as one of nine focuses in project management and explains it as a systematic process of identifying, analyzing and responding to project risks (S. Iqbal et al., 2014). The DB delivery method allows employers to transfer responsibility and design risk to the DB contractor, so design risk factors have a big impact on project progress (Akinci and Fischer, 1998). A study investigates other sources of risk in DB projects to be classified into three risk groups in terms of cost, time and quality (Olabode E. Ogunsanmi, 2004). The author recommends strategies that include plan, monitor, coordinate, control, transmit communication and decision making to achieve success of the project. Any mistakes or omissions in the design could result in redesigns or modifications of DB contractors, which could lead to budget overruns, delays in project completion, poor quality, or even project failure (Williams and Johnson, 2013).

In 2001, a study identified success factors of a design-build project and examined the importance of these factors to project outcomes (Albert P.C. Chan et al., 2001). The six success factors of the project are: commitment of the project team, capacity of the contractor, assessment of risks and responsibilities, needs of the owner and constraints required by the investor. From the results of multivariate regression, the commitment of the project team, the capacity of the investor is considered very important to bring the project to success, the capacity of the contractor also contributes to the project time efficiency and effectiveness.

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The article also identifies time and cost efficiency as well as design quality and workmanship as the main factors contributing to the overall success of a D&B project.

A research conducted in Hong Kong pointed out the need to separate design and design management (Edwin H. W. Chan et al., 2005). Architects and engineers who design the project are not suited to carry out design management on D&B projects, and appoint an experienced person as manager responsible for overall design management. The selected D&B contractor must be able to manage the design and be responsible for design information and any differences in the overall design. The roles of design and design management should be clearly defined in the contract to avoid misunderstandings and disputes.

S. Thomas et al. (2002) listed four main design-related risks in the design-new-construction (DN&C) system that contractors need to pay attention to: the design ability of design team, lack of fees for establishing a design team in the early stages, relationships between team members, design time. Another study conducted in Hong Kong on the variables influencing D&B project success produced a design-build project success index using 12 major factor groups (Edmond W. Lam et al., 2008), offering project stakeholders useful suggestions for improving the implementation of D&B projects.

To compare the risks of the investor and the contractor and to understand and properly distribute risks in a D&B project, a research was conducted in the US (Tran DQ and Molenaar, 2014). The authors identify and analyze 39 common risks, divided into 7 main groups associated with D&B projects by using exploratory factor analysis. Afterwards, in an expanded study, DQ Tran and Sai P.K. Bypanemi (2018) showed that project delivery decision is significantly impacted by eight risk factors, according to the authors: (1) delays

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in the completion of railroad agreements; (2) the complexity of the project; (3) the uncertainty surrounding the geotechnical investigation; (4) the right-of-way (ROW) process; (5) unforeseen utility encounters; (6) work-zone traffic control; (7) challenges in obtaining environmental documentation; and (8) delivery schedule delays.

A different Chinese study found 23 design risk factors in total and divided them into 6 categories through exploratory factor analysis EFA: risk of an inappropriate design team, risk of the designer's negligence, risk of the designer's inexperience, risk of inaccurate or delayed information from third parties, risk of an inappropriate design scheme, and risk of a design modification and employer review (Junying Liu et al., 2017). The study advances the database delivery technique and strengthens risk analysis research. Additionally, the research provides DB contractors a list to assess project design risks in order to achieve success.

Research concerning risk response strategies that focus on these areas is urgently required. A research of Xianbo Zhao and Lin Yang (2020) developed a list of complex project risks as well as a risk association complex-network model that is applicable to engineering practice, thus providing theoretical support for risk management in complex projects and an understanding of risk response strategies for decision makers, because the complexities could directly or indirectly trigger risks, while the risks in turn affect the project objectives (Hans Bakker et al., 2022).

2.2.2. Related studies of risk's management methods

Risk management is essential, and its importance increases as the difficulty and complexity of a project increase (Ashuri and Durmus-Pedini, 2010). Varying with perspective and context, the risk generally refers to an uncertain event, condition, or

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information that adversely affects achieving an objective (ISO 2009; PMI 2013). Among the risk management steps of exploring, assessing, and responding to risks, exploration is the most critical because undiscovered risks cannot be responded to. A construction project is especially challenging; it involves many people, a long duration, and heavy capital and resource investment (El-Sayegh and Mansour, 2015). In certain ways, a power plant project is frequently more complex than other kinds of projects. Thus, it is crucial to consider and manage both specific and general risks in power plant projects.

Managerial actions should be taken towards the identified risks and threats (Krantikumar Mhetre et al., 2016). The response strategy and approach chosen depend on the kind of risks concerned. In total, eight types of risk response were introduced: risk avoidance, risk transfer, risk mitigation/ reduction, risk exploit, risk share, risk enhance, risk acceptance, contingency plan. However, for effective management of risks, the importance is how stakeholders in the construction industry perceive each risk. The preventive technique "production of accurate schedule by getting updated projected information and referring to similar projects" gained respondents attention while the most effective remedial technique was "close supervision and coordination with the contracting parties" (S. Iqbal et al., 2014).

2.3. Chapter summary

This chapter provides an introduction to the design phase of Design-Build power plant projects. By reviewing literature, it can be seen that most studies indicated risks in the entire cycle life of the project, not only focusing on the design phase. Besides, questionnaire surveys and expert interviews are two common methods applied, so that the survey data is different

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and subjective according to the respondents. Meanwhile, there is no survey data in Vietnam so the available data may not be suitable for implementation.

Based on the studies mentioned above and other related studies, the research has formed a list of potential design risk factors that can affect a Design-Build power plant project. The list of 45 design risk factors after reviewing literature is described in Table 2.1. In addition, management actions have also been studied. Eight types of risk response were mentioned: risk avoidance, risk transfer, risk mitigation / reduction, risk exploit, risk share, risk enhancement, risk acceptance, and contingency plan.

Table 2.1: Summary table of design risks from literature review

No.	Design risks	References
R1	Inadequate design standard/specification adopted	S. Thomas and Martin Skitmore (2002); Junying Liu et al. (2017)
R2	Project complexity	Edmon W. Lam et al. (2008); Tran DQ and Molenaar (2014); Sai PK Bypanemi and DQ Tran (2018)
R3	Unproven design solutions adopted	Junying Liu et al. (2017)
R4	Budget overrun in design	S. Iqbal et al. (2014)
R5	Design materials do not match with provided	Junying Liu et al. (2017)
R6	Concept of design is not clear	S. Thomas and Martin Skitmore (2002); Hans Bakker et al. (2022)
R7	Incomplete input/ design drawings, documents	Olabode E. Ogunsanmi (2004); Edwin H.W. Chan et al. (2005); Junying Liu et al. (2017)

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R8	Constructability of design	Olabode E. Ogunsanmi (2004)
R9	Defective or omission in design	Olabode E. Ogunsanmi (2004); S. Iqbal et al. (2014); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R10	Designers' unfamiliarity with requirements of codes/standards	Junying Liu et al. (2017); Hans Bakker et al. (2022)
R11	Conflicting of lack of norms and standards, specifications	Hans Bakker et al. (2022)
R12	Design behind schedule	Olabode E. Ogunsanmi (2004); Edwin H.W. Chan et al. (2005); Tran DQ and Molenaar (2014); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R13	Dispute about design responsibility	Edwin H.W. Chan et al. (2005)
R14	Original design was flawed, and later designers continued to rely on original results	Edwin H.W. Chan et al. (2005); S. Thomas and Martin Skitmore (2002)
R15	Insufficient geological investigation or unknown geological conditions	Tran DQ and Molenaar (2014); Junying Liu et al. (2017); Sai PK Bypanemi and DQ Tran (2018)
R16	Incomplete check on input/ design drawings, documents	Olabode E. Ogunsanmi (2004); Edwin H.W. Chan et al. (2005); Junying Liu et al. (2017)
R17	Information between calculations and drawings not match	Olabode E. Ogunsanmi (2004)
R18	Delay of resolving matter of involved in parties	Albert P.C. Chan et al. (2001); Sai PK Bypanemi and DQ Tran (2018)

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R19	Contractor has not been thoroughly prepared for the design process	Albert P.C. Chan et al. (2001); Edmon W. Lam et al. (2008)
R20	The contractor's design team worked under multiple constraints on the D&B project	Albert P.C. Chan et al. (2001)
R21	Inaccurate information from related parties	S. Iqbal et al. (2014)
R22	Client misunderstands contractor's proposal	Edwin H.W. Chan et al. (2005); Hans Bakker et al. (2022)
R23	Separation of design and site supervision	Edwin H.W. Chan et al. (2005)
R24	Inaccurate, missing, vague, or illegal information in client's requirements	Edwin H.W. Chan et al. (2005); Edmon W. Lam et al. (2008); Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R25	Unduly long period of design review required by client	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R26	Communication gap or misinterpretation on exchange information between client and designers	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R27	Delayed information from suppliers	Albert P.C. Chan et al. (2001); Sai PK Bypanemi and DQ Tran (2018)
R28	Involvement of different technical disciplines	Hans Bakker et al. (2022)
R29	Difficulty in coordination between different designers	Edmon W. Lam et al. (2008); Hans Bakker et al. (2022)
R30	Teamwork ability is not effective	Edmon W. Lam et al. (2008)
R31	Design team has not reached high performance	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R32	Design consultants lack of technical software handling skills	Junying Liu et al. (2017)

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R33	Design consultants lack of documents management skills	Sai PK Bypanemi and DQ Tran (2018)
R34	Churn among core designers	Edwin H.W. Chan et al. (2005); Junying Liu et al. (2017)
R35	Difference between designers' work habits and local practice	S. Thomas and Martin Skitmore (2002)
R36	Commiment of design team	S. Thomas and Martin Skitmore (2002)
R37	Lack of professional designers	Junying Liu et al. (2017); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R38	Team leader lacks experience and management skills	Edwin H.W. Chan et al. (2005); Edmon W. Lam et al. (2008)
R39	Inexperienced design consultant	S. Thomas and Martin Skitmore (2002); Edmon W. Lam et al. (2008); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R40	Designers' incompetency	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R41	Client's requirement for design changes	Tran DQ and Molenaar (2014); Junying Liu et al. (2017); S. Iqbal et al. (2014)
R42	Client's disagreement on source of main equipment or materials	Olabode E. Ogunsanmi (2004); Junying Liu et al. (2017)
R43	Changes or improper scope/ work definition in contract	S. Iqbal et al. (2014)
R44	Construction permit has not been approved	S. Iqbal et al. (2014)
R45	Payment delays	S. Iqbal et al. (2014)

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Chapter 3. Methodology

This chapter describes the methodology used for the study. This chapter's main objective is to make it clear how to conduct research in an appropriate manner. This chapter is divided into sections on research strategy, research design, questionnaire design, sample scope, and tools and techniques for data analysis.

3.1. Research strategy

The research strategy is the way in which the research objectives can be questioned (Naoum S. G., 1994). There are two fundamental types of research strategies: qualitative and quantitative methods. Qualitative methods include the collection of objective data and the examination of the relationship between objective data and the accordance of the data with theories and the finding of the previous research. On the other hand, the quantitative approach seeks to gain insights and to understand people’s perception. This research adopted the opinion of quantitative research to identify the risk factors of the design phase of Design-Build power plant projects and management activities to control the risks.

3.2. Research design

This study's research methodology consisted of seven consecutive phases, which are outlined and depicted in Figure 3.1.

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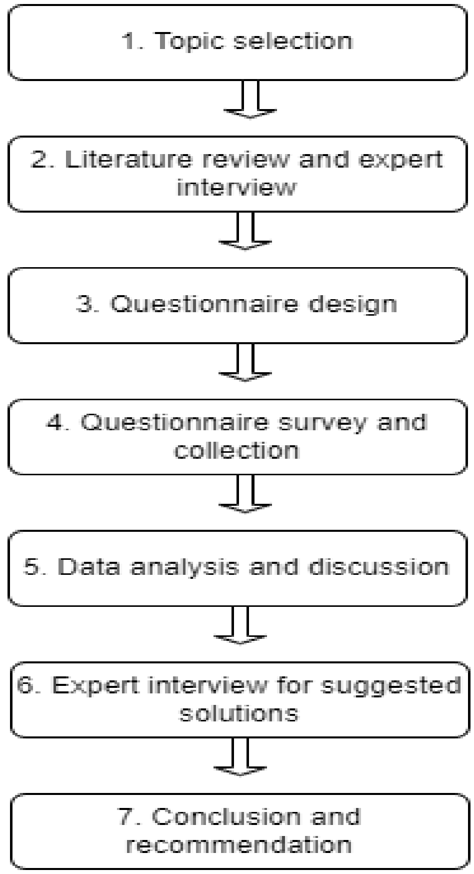

Figure 3.1. Research flowchart

The first phase was topic selection that consisted of making proposals of identifying and defining problems, setting up the research's objectives. The second phase was literature review on potential risk factors when design Design-Build power plants and also several risk management activities to control the risks, which generated 45 design risk factors (Table 2.1).

The third phase was the questionnaire design of the study. In which, the draft questionnaire survey was sent to two specialists in combination with exploratory interviews to ask for their verifying, adjusting and adding the uncover risk factors in Vietnam, and also deleting the unsuitable factors and overlapping factors. The chosen specialists should have at least 15 years of experience in the design phase of DB power plants. The risk factor

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descriptions were then updated based on the interviews to make them more accurate and readable. After adjusting, the final list of risk in the design phase of Design-Build power plant projects was set down to 37 design risk factors, which shows in Table 3.1. The background of interviewees and the meeting report are shown in Appendix A and B. Before sending out the questionnaire survey, a pilot version was created to serve as the final list of design factors and reviewed by 5 people in consulting firms who also participated in DB power plant projects. The purpose of the pilot survey was to ensure that respondents had a consistent understanding of the factors before the questionnaires were distributed. This step led to changes being made to the questionnaire in response to feedback from the practitioners regarding the questions and their descriptions' readability, rationality, accuracy, and comprehensibility. Then, the questionnaire was ready to survey.

Next, questionnaire survey and collection were executed from February 2024 to March 2024 among construction engineers who had experience of management in the design phase of DB power plant projects in order to evaluate the impact of risk factors and its level of possibility. In this phase, the questionnaire was sent out to get the assessment from the respondents in Vietnam. In the questionnaire survey, respondents were asked to provide key parameters concerning their reference project, including project type, scale, etc and rate the impact and possibility of the 37 design risk factors according to their experiences. A five-point Likert scale (1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high) applied respectively to the level of impact and level of possibility was used for measurement.

Then, the collected data will be processed by the SPSS V25 program and a discussion process would be carried out to obtain the objective of the research. Four types of statistical

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analysis should be carried out to obtain the objectives of the research, those are validity and reliability testing, descriptive analysis, ANOVA analysis and exploratory factor analysis (EFA).

After that, the study would move to analyze a case study of a Design-Build power plant project in Vietnam to find out risk's management activities to control the critical risks. At this step, an interview with experts would be conducted to verify the solutions and recommendations of controlling risks when designing a DB power plant.

The final phase included conclusions and recommendations of the study.

Table 3.1: Summary table of design risks in Design-Build power plant projects

No.	Design risks	References
R1	Inadequate design standard/specification adopted	S. Thomas and Martin Skitmore (2002); Junying Liu et al. (2017)
R2	Unproven design solutions adopted	Junying Liu et al. (2017)
R3	Poor constructability of design	Olabode E. Ogunsanmi (2004)
R4	Budget overrun in design	S. Iqbal et al. (2014)
R5	Concept of design is not clear	S. Thomas and Martin Skitmore (2002); Hans Bakker et al. (2022)
R6	Defective or omission in design	Olabode E. Ogunsanmi (2004); S. Iqbal et al. (2014); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R7	Designers' unfamiliarity with requirements of codes/standards	Junying Liu et al. (2017); Hans Bakker et al. (2022)

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R8	Conflicting because of lack of norms and standards, specifications	Hans Bakker et al. (2022)
R9	Separation of design and site supervision	Edwin H.W. Chan et al. (2005)
R10	Design behind schedule	Olabode E. Ogunsanmi (2004); Edwin H.W. Chan et al. (2005); Tran DQ and Molenaar (2014); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R11	Dispute about design responsibility	Edwin H.W. Chan et al. (2005)
R12	Original design was flawed, and later designers continued to rely on original results	Edwin H.W. Chan et al. (2005); S. Thomas and Martin Skitmore (2002)
R13	Insufficient geological investigation or unknown geological conditions	Tran DQ and Molenaar (2014); Junying Liu et al. (2017); Sai PK Bypanemi and DQ Tran (2018)
R14	Incomplete check on input documents	Olabode E. Ogunsanmi (2004); Edwin H.W. Chan et al. (2005); Junying Liu et al. (2017)
R15	Inconsistency among core designers	Edwin H.W. Chan et al. (2005); Junying Liu et al. (2017)
R16	Differences between designers' work habits and local practice	S. Thomas and Martin Skitmore (2002)
R17	Frequent substitutions of design team members	S. Thomas and Martin Skitmore (2002)
R18	Difficulty in coordination between different design consultants	Edmon W. Lam et al. (2008); Hans Bakker et al. (2022)
R19	Teamwork ability is not effective	Edmon W. Lam et al. (2008)
R20	Designers's distraction/ not reached high performance	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)

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R21	Designers lack of technical software handling skills	Junying Liu et al. (2017)
R22	Designers lack of documents management skills	Sai PK Bypanemi and DQ Tran (2018)
R23	Lack of professional designers	Junying Liu et al. (2017); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R24	Team leader lacks experiences and management skills	Edwin H.W. Chan et al. (2005); Edmon W. Lam et al. (2008)
R25	Inexperienced design team	S. Thomas and Martin Skitmore (2002); Edmon W. Lam et al. (2008); Hans Bakker et al. (2022); Xianbo Zhao and Lin Yang (2020)
R26	Design changes from different technical disciplines of design team	Hans Bakker et al. (2022)
R27	Delay of resolving matters between all of involved stakeholders	Albert P.C. Chan et al. (2001); Sai PK Bypanemi and DQ Tran (2018)
R28	Inaccurate information from involved stakeholders	S. Iqbal et al. (2014)
R29	Owner/ main contractor misunderstands designer's proposal	Edwin H.W. Chan et al. (2005); Hans Bakker et al. (2022)
R30	Inaccurate, missing, vague, or illegal information in owner's requirements	Edwin H.W. Chan et al. (2005); Edmon W. Lam et al. (2008); Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R31	Unduly long period of design review by onwer/ main contractor	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers	Tran DQ and Molenaar (2014); Junying Liu et al. (2017)

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R33	Payment delays	S. Iqbal et al. (2014)
R34	Owner/ main contractor requests to proceed design without signing contract	Interview
R35	Owner requests for design changes	Tran DQ and Molenaar (2014); Junying Liu et al. (2017); S. Iqbal et al. (2014)
R36	Ower/ main contractor's disagreement on source of main equipment or materials	Olabode E. Ogunsanmi (2004); Junying Liu et al. (2017)
R37	Changes or improper scope/ work definition in contract	S. Iqbal et al. (2014)

3.3. Data collection

3.3.1. Questionnaire design

The survey questionnaire is designed to evaluate the level of impact and level of possibility of factors. One of the most commonly used forms of measuring abstract concepts in socio-economic research is Likert scale. In this study, a Likert scale was used with five levels to get respondents' opinions.

There were 4 steps to complete the questionnaire:

- Step 1: Summarize risk factors from the literature review.

- Step 2: Issue a draft questionnaire survey form.

- Step 3: Interview experts to supplement and refine the risks appropriate to the environment in Vietnam. The two chosen specialists have at least 15 years of experience in the design phase of DB power plants. Based on the interviews, revisions such as eliminating the same

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meaning factors, combining factors, describing factors more clearly, adding factors that occurred in Vietnam were made to improve their readability and accuracy. Details of adjusted factors are in Appendix B of this thesis. After adjusting, the final list was 37 risk factors.

- Step 4: Issue a pilot questionnaire survey and complete the mass survey questionnaire.

The content of the survey includes 2 sections:

- Section A: General information: Includes work experience, position, organization, scale of projects involved, ... of individuals who participated in the survey.

- Section B: Evaluate the level of impact and level of probability of risk factors when implementing a design-build power plant project by the scale level:

Level of impact: 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

Level of probability: 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

3.3.2. Sample size and data collection method

Gorsuch (1974) characterized that sample sizes (N) above 200 as large and below 50 as small. Therefore, this study aims that sample size should be at least 50, and as much as possible.

Purposive sampling is the sample strategy taken into account for this investigation. This also applies to judgment sampling. Selecting only the information that is absolutely necessary, the researcher searches for people who are willing to share their knowledge or experience (Bernard, 2002). By using a purposeful sampling technique, data collection time can be

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shortened and professionals with pertinent characteristics can be gathered to participate in pertinent surveys.

This survey was carried out mainly in Hanoi, Vietnam. Therefore, several Vietnamese organizations in the construction field were selected to assess design risk factors, especially those organizations involved in power plant projects. Selected responsive organizations come from groups such as investor, design consultant, contractor, project management unit, and government agency of construction. The questionnaire survey would be sent directly to survey respondents via the internet (Google Forms).

3.4. Statistical analysis

After being gathered from the questionnaire survey, the data was input into an Excel spreadsheet. Data was then converted to SPSS software after that. One of the most well-known analytical programs is SPSS, particularly for quantitative research. To achieve the goals of the study, four types of statistical analysis are performed: validity and reliability testing, descriptive analysis, ANOVA analysis and exploratory factor analysis (EFA).

3.4.1. Reliability and validity analysis (Cronbach's alpha α coefficient)

Cronbach's alpha is a coefficient of reliability. It is commonly used as a measure of internal consistency or reliability of the items which are mentioned in questionnaire surveys. The measurement reliability is essential to the validity of the results of the questionnaire survey. This research also adopted Cronbach's alpha approach to test the reliability of surveyed data in Likert-type scale. The larger the value of Cronbach's alpha, the better

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reliability in each component. A good scale is when Cronbach's Alpha coefficient $\alpha \geq 0.8$, the smallest acceptable value is 0.7.

3.4.2. Ranking factors

Ranking the design risk factors helps to prioritize risk management efforts, allocate resources effectively, develop mitigation strategies, support decision-making, improve communication, and facilitate continuous improvement. It ensures that project teams focus their attention on the most critical risks, leading to more efficient and successful project outcomes.

This research ranks the risk factors that would occur when designing a DB power plant project by employing the index analysis method. The data are processed through three types of indices:

• Possibility index: This index expresses occurrence possibility of risk factors during design phase of DB power plant project. It is computed as per following formula:

$$P.I. = \frac{\sum_{1}^{5} a_i.n_i}{5.N} \qquad \text{(Equation 3.1)}$$

Where: a = constant expressing the weight assigned to each response (ranges from 1 for Very low to 5 for Very high); n = frequency of each response; N = total number of responses.

• Impact index: This index expresses the impact of risk factors during the design phase of a DB power plant project. It is computed as per following formula:

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$$I.I. = \frac{\sum_{1}^{5} a_i.n_i}{5.N} \qquad \text{(Equation 3.2)}$$

Where: a = constant expressing the weight assigned to each response (ranges from 1 for Very low to 5 for Very high); n = frequency of each response; N = total number of responses.

• Importance index: This index expresses the overview of factors based on both their possibility and impact. It is computed as per following formula:

$$IMP.I. = P.I \times I.I \qquad \text{(Equation 3.3)}$$

3.4.3. ANOVA analysis

Determining whether or not the results of a statistical analysis are statistically significant is crucial. This is a measure of the likelihood that under the null hypothesis, there will be a result that is equally extreme or more extreme than the observed result. The significance level in an ANOVA analysis is used to assess whether research findings from a sample of respondents differ significantly from one another. The significance level, also known as the alpha level, is the probability of rejecting the null hypothesis in the event that it is true. In an ANOVA analysis, the null hypothesis states that there is no appreciable difference between the group means that are being compared. The null hypothesis is rejected if the probability of getting the observed result or a more extreme result is less than 5% or 1%. Usually, the significance level is set at 0.05 or 0.01. The significance level for this study would be set at 0.01. To test the differences between groups of survey participants, students used ANOVA test with a significance level of 0.01 (1%) for 37 factors, divided into 2 cases:

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Case 1: Variables with Sig coefficients greater than the confidence level of 0.01 conclude there is no difference between groups.

Case 2: Variables with Sig values less than 0.01 conclude that there are differences between groups. Conduct analysis of differences between groups.

3.4.4. Exploratory factor analysis EFA

The 37 design risk factors' latent variables were investigated using exploratory factor analysis, which also helped to narrow down the number of manageable latent factors that could be used to express the correlations between a wide range of related variables.

One multivariate statistical technique for determining relationships between variables and organizing comparable variables into factor groups is called exploratory factor analysis (EFA). This approach looks for the underlying structure in a group of related variables. Using EFA, one can condense a set of k observed variables into a set F that has more statistically significant factors ($F < k$). Because the results of the EFA analysis condense pertinent variables into factors, they aid in reducing the volume of data and facilitate easier data analysis and interpretation.

A set of observed variables is to be reduced using exploratory factor analysis (EFA) into a set of more significant factors that retain the majority of the original variable's content and information. A data set of measured variables' number of influencing factors and their degree of influence on the relationship between each factor and each measurement variable are two key objectives of exploratory factor analysis (EFA).

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An EFA factor is a variable with observable properties derived from some shared traits that are not directly observable. Greater correlations between the factor and the observed variables, and vice versa, are indicated by higher loading coefficients for factors. An observational variable set with a high correlation amongst them and a low correlation with other variables in the data set, determines each factor. In order of the factor's explanatory power, they are typically measured by the total variance among the observed variables. A measurement of the difference between variable values in a data set is variance, aside from that.

Below are some criteria used in EFA to evaluate the relationship between variables:

- KMO (Kaiser-Meyer-Olkin) coefficient: consider whether the data is suitable for factor analysis. Coefficient KMO is greater than 0.5, then factor analysis of data is appropriate.

- Bartlett test: statistical quantities used to examine variables are correlated in the population. Sig coefficient < 0.05 means analysis appropriate EFA factor.

- Factor loading coefficient: simple correlation coefficient between variables and factors. This coefficient should be greater than or equal to 0.5.

- Communality coefficient (> 0.5): amount of variation in an explanatory variable common with other variables considered in the analysis.

- Initial Eigenvalue (> 1): portion of variation explained by each factor.

Nevertheless, in order to apply EFA analysis, a test regarding the required sample size is required. However, determining the appropriateness of the sample size is a very

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challenging problem. Hair et al. (2009) recommended that a minimum sample size of 50, preferably 100, be used for EFA analysis. Aiming for a 5:1 ratio of observations to measured variables, which indicates that at least 5 observations are required for each measured variable. Habing (2003) cites Stevens (2002) as saying that a factor is considered reliable if it includes three or more measurement variables. As a result, the sample size is suitable, with 106 valid survey responses for the 37 study design risk factors (or a ratio of roughly 3:1).

3.5. Chapter summary

This chapter described the methodology used for the study, including research strategy, research design, questionnaire design, sample scope and data analysis tools and techniques. Summary of surveyed data analysis methods are shown as Table 3.2.

Table 3.2: Table of lists of methods and analysis tools

No.	Analysis method	Analysis tool	Standard values
1	Data description	Descriptive statistics	
2	Reliability test	Cronbach Alpha Coefficient	$\alpha \geq 0.8$, acceptable value is 0.7
3	Ranking of risk factors	Average value	$P.I. = \frac{\sum_{1}^{5} a_i.n_i}{5.N}$; $I.I. = \frac{\sum_{1}^{5} a_i.n_i}{5.N}$ $IMP.I. = P.I \times S.I$
4	Test of differences between research respondents groups	ANOVA test	Sig. ≥ 0.01
5	Analyze of correlation between independent variable and dependent variable	Exploratory factor analysis EFA	KMO > 0.5 Sig < 0.05 Factor loading coefficient ≥ 0.4

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Chapter 4. Questionnaire results and discussion

4.1. Introduction

This chapter mainly discusses the results of questionnaires by Vietnamese construction professionals. The aims and purposes of this chapter were to rank the risk factors in the D&B system in design phases of power plant projects, analyze the different points of view about design risk factors, and proceed by grouping those factors. The outline of the data analysis procedure is presented as Figure 4.1 as follows.

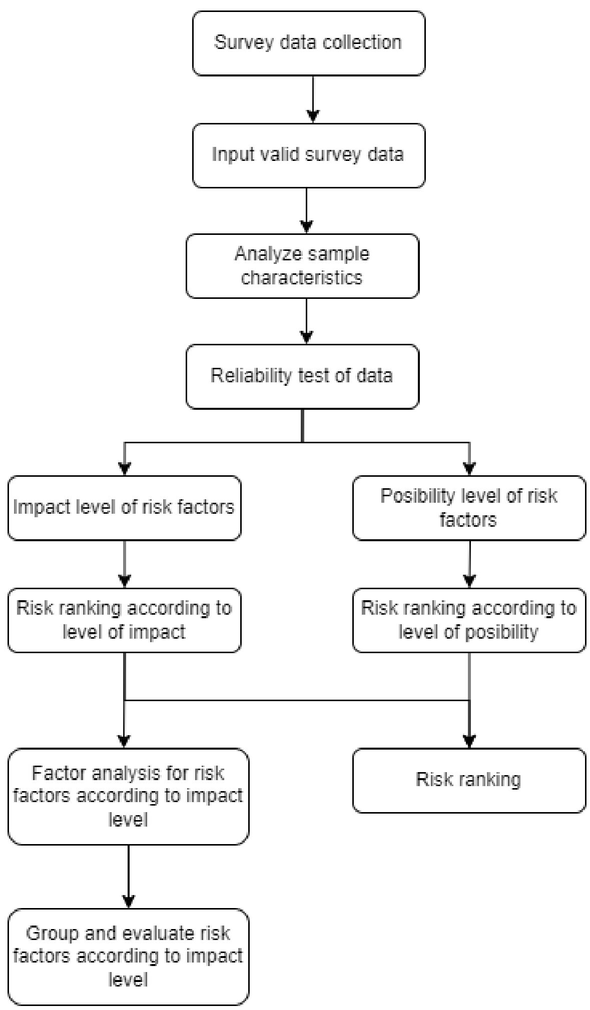

Figure 4.1 Procedure of data analysis

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4.2. Profile analysis of respondents

The questionnaire's first section is meant to collect demographic data. Inquiries concerning the construction industry, participation in D&B power plant projects, and knowledge of risk management during D&B power plant project design were made by respondents. To ensure that the participants in a given study are a representative sample of the intended population for generalization purposes, demographic data collection is used.

There is a total of 113 recorded answers among 150 sets of sent questionnaires, comprising 106 valid responses for final analysis, with a response rate of 70.67%. In contrast to the typical response rate of 20–30% found in the majority of postal questionnaire surveys used in construction industry research, this rate was deemed reasonable (Liu et al., 2016).

4.2.1. Years of experience in construction industry

Respondents provided information about their years of experience in the construction industry from groups of below 5 years, from 5 to 9 years, from 10 to 14 years, from 15 to 19 years, and above 20 years. The allocation rate is shown in Table 4.1 and Figure 4.2.

Table 4.1. Number of years of experience in the construction industry

Properties	Number	Percent (%)	Cumulative percent (%)
Below 5 years	43	40.6	40.6
5 - 9 years	35	33.0	73.6
10 - 14 years	12	11.3	84.9
15 - 19 years	9	8.5	93.4
Above 20 years	7	6.6	100.0
Total	106	100.0	

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The majority of people surveyed have experience in the industry within 10 years (73.6%). This data reflects the current age of personnel working in the construction industry in Vietnam. Thus, in terms of years of working experience, this sample set is still representative of the majority of people participating in the construction field in Vietnam today. Therefore, it would increase the reliability of the research results.

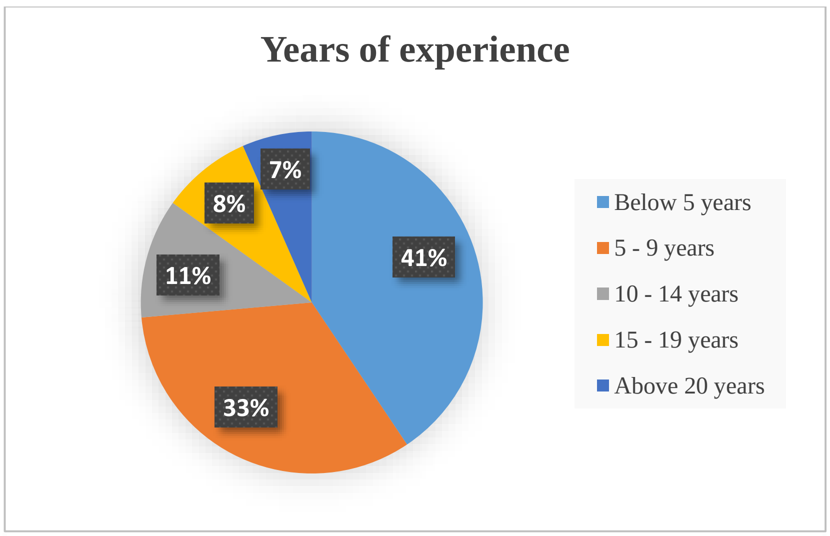

Figure 4.2. Percentage of years of experience in the construction industry

4.2.2. Current expertise of respondents

The surveyed respondents come from groups of architect, structural engineer, quantity surveyor, project manager, and site engineer. The allocation rate is shown in Table 4.2 and Figure 4.3.

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Table 4.2. Current expertise of surveyed respondents

Properties	Number	Percent (%)	Cumulative percent (%)
Architect	11	10.4	10.4
Structural engineer	28	26.4	36.8
Quantity surveyor	10	9.4	46.2
Project manager	33	31.1	77.4
Site engineer	24	22.6	100.0
Total	106	100.0	

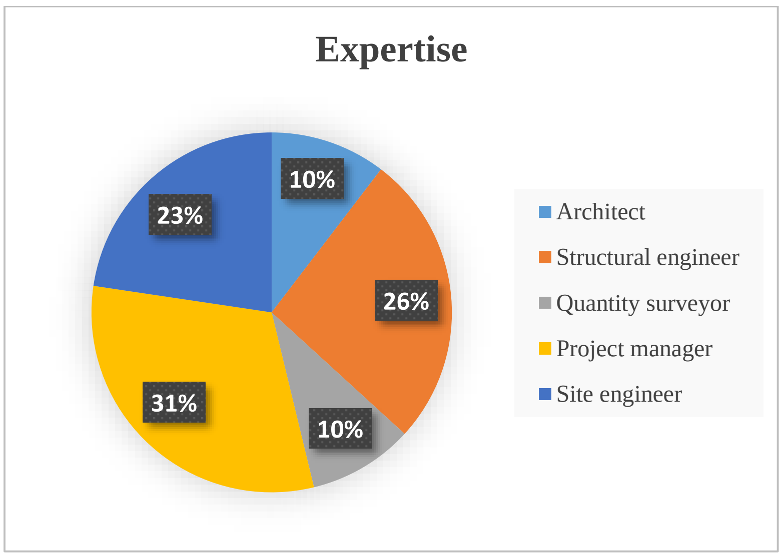

Figure 4.3. Current expertise of surveyed respondents

The research study that was carried out involved workers from a variety of professions. Among them, the survey results mostly focused on people with expertise in the field of design, for instance: architect, structural engineer, and quantity surveyor (46.2%) and people working in project management (31.1%). Those involved respondents are the subjects who understand the project and design process, increasing the accuracy of the research.

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4.2.3. Current organization of respondents

Surveyed respondents when participating in power plant projects in the form of Design-Build under the units of owner (private owner, public authority), design consultant, contractor (construction contractor, Design-Build contractor), and project construction management units PCM. The allocation rate is shown in Table 4.3 and Figure 4.4.

Table 4.3. Current organization of surveyed respondents

Properties	Number	Percent (%)	Cumulative percent (%)
Private owner	13	12.3	12.3
Design consultant	37	34.9	47.2
Contractor	34	32.1	79.2
Public authority	2	1.9	81.1
PCM	20	18.9	100.0
Total	106	100.0	

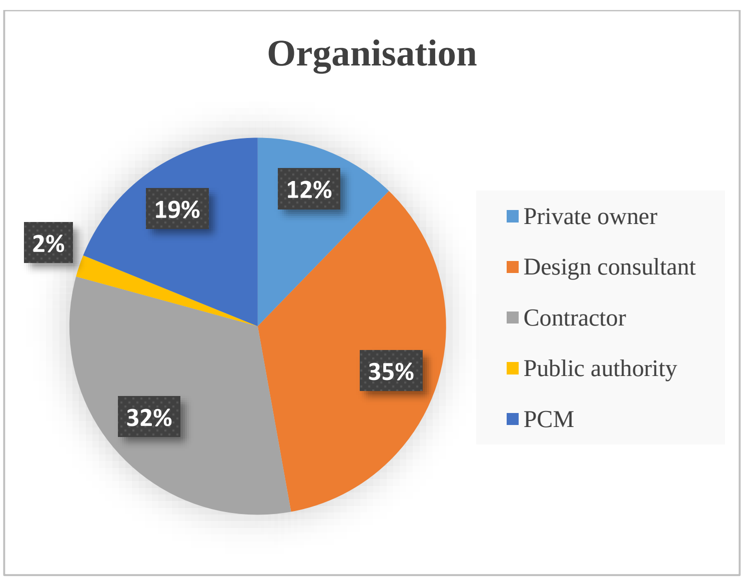

Figure 4.4. Current organization of surveyed respondents

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According to the survey results, the majority of survey subjects participating in projects carried out in the form of Design-Build belong to design consultants (34.9%) and construction contractors (32.1%). These results are consistent with the research object and proposed research scope of the study.

4.2.4. Capacity of power plant project

Among the 106 valid responses, survey participants were asked about the size and capacity of the largest power plant they had ever participated in. Details of the capacity of power plant projects in the survey are shown in Table 4.4. The results show that most power plant projects are large-scale projects, which is suitable for research.

Table 4.4. Largest capacity power plant project

Characteristics		Response	
		N	Percent (%)
Largest capacity power plant project that you have participated in	1500 MW	23	21.7
	2600 MW	22	20.8
	1200 MW	3	2.8
	1320 MW	51	48.1
	144 MW	1	0.9
	4000 +- 400 MW	1	0.9
	2x120 MW	1	0.9
	622 MW	3	2.8
	3900 MW	1	0.9
Total		106	100.0

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4.3. Reliability test

The measurement reliability of the questionnaire was evaluated by Cronbach's Alpha coefficients to investigate the internal consistency among the attributes of the respective constructs on the Likert scale. The results of reliability of impact level and possibility level are summarized respectively in Table 4.5 as follows.

Table 4.5. Reliability test

Reliability Statistics		
	Cronbach's Alpha	N of Items
Impact level	0.962	37
Possibility level	0.973	37

Cronbach's Alpha coefficient for the impact level and possibility level respectively are 0.962 and 0.973, which exceed the common threshold 0.7 as suggested by Nunnaly (1978). Hence, this result is suitable for research.

4.4. Risk ranking

4.4.1. Risk ranking according to level of impact

After performing calculation, the scores of the impact level are presented as Table 4.6.

Table 4.6. Impact index (I.I.) of factors in design phase of Design-Build power plant projects (N= 106)

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No.	Design risks	Mean	Std. Deviation	Impact index	Rank
R6	Defective or omission in design	3.64	1.388	0.728	1
R4	Budget overrun in design	3.58	1.154	0.717	2
R35	Owner requests for design changes	3.47	1.173	0.694	3
R34	Owner/ main contractor requests to proceed design without signing contract	3.44	1.204	0.689	4
R10	Design behind schedule	3.39	1.418	0.677	5
R33	Payment delays	3.38	1.150	0.675	6
R3	Poor constructability of design	3.34	1.120	0.668	7
R25	Inexperienced design team	3.32	1.370	0.664	8
R9	Separation of design and site supervision	3.28	1.193	0.657	9
R26	Design changes from different technical disciplines of design team	3.25	1.094	0.649	10
R21	Designers lack of technical software handling skills	3.23	1.181	0.645	11
R28	Inaccurate information from involved stakeholders	3.18	1.094	0.636	12
R30	Inaccurate, missing, vague, or illegal information in owner's requirements	3.15	1.161	0.630	13
R24	Team leader lacks experiences and management skills	3.14	1.142	0.628	14
R5	Concept of design is not clear	3.13	1.164	0.626	15
R22	Designers lack of documents management skills	3.13	1.180	0.626	16
R23	Lack of professional designers	3.12	1.119	0.625	17

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R36	Owner/ main contractor's disagreement on source of main equipment or materials	3.12	1.039	0.625	18
R37	Changes or improper scope/ work definition in contract	3.08	1.015	0.617	19
R29	Owner/ main contractor misunderstands designer's proposal	3.07	1.252	0.613	20
R12	Original design was flawed, and later designers continued to rely on original results	3.04	1.272	0.608	21
R27	Delay of resolving matters between all of involved stakeholders	3.02	1.060	0.604	22
R1	Inadequate design standard/specification adopted	2.96	1.272	0.592	23
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers	2.95	1.150	0.591	24
R2	Unproven design solutions adopted	2.92	1.266	0.583	25
R19	Teamwork ability is not effective	2.88	1.127	0.575	26
R31	Unduly long period of design review by owner/ main contractor	2.86	0.970	0.572	27
R18	Difficulty in coordination between different design consultants	2.85	1.058	0.570	28
R13	Insufficient geological investigation or unknown geological conditions	2.78	1.155	0.557	29
R14	Incomplete check on input documents	2.76	1.134	0.553	30
R20	Designers' distraction/ not reached high performance	2.75	0.996	0.549	31

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R7	Designer's unfamiliarity with requirements of codes/standards	2.74	1.275	0.547	32
R8	Conflicting because of lack of norms and standards, specifications	2.51	1.098	0.502	33
R17	Frequent substitutions of design team members	2.45	1.156	0.491	34
R15	Inconsistency among core designers	2.43	1.042	0.487	35
R11	Dispute about design responsibility	2.41	1.058	0.481	36
R16	Differences between designers' work habits and local practice	2.25	1.273	0.451	37

From the above ranking table, it can be seen that the top ten design risk factors are rated highest in terms of impact level that need to be taken into account when designing a power plant in the form of design-build contract are respectively:

1. Defective or omission in design

2. Budget overrun in design

3. Owner requests for design changes

4. Owner/ main contractor requests to proceed design without signing contract

5. Design behind schedule

6. Payment delays

7. Poor constructability of design

8. Inexperienced design team

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9. Separation of design and site supervision

10. Design changes from different technical disciplines of design team

When surveying expert opinions, the above risks were assessed by experts as one of the important risks affecting the design process and project effectiveness. The above risk factors mostly come from designer's errors, or design changes. These risk factors all affect the quality, schedule and cost of the project.

4.4.2. Risk ranking according to level of possibility

After performing the calculation, the scores of the possibility level are presented as Table 4.7.

Table 4.7. Possibility index (P.I.) of factors in design phase of Design-Build power plant projects (*N*= 106)

No.	Design risks	Mean	Std. Deviation	Possibility index	Rank
R35	Owner requests for design changes	3.57	1.352	0.713	1
R26	Design changes from different technical disciplines of design team	3.42	1.460	0.685	2
R6	Defective or omission in design	3.32	1.370	0.664	3
R10	Design behind schedule	3.18	1.278	0.636	4
R4	Budget overrun in design	3.04	1.249	0.608	5
R9	Separation of design and site supervision	3.04	1.218	0.608	6

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R18	Difficulty in coordination between different design consultants	2.92	1.147	0.583	7
R27	Delay of resolving matters between all of involved stakeholders	2.91	1.246	0.581	8
R34	Owner/ main contractor requests to proceed design without signing contract	2.88	1.152	0.575	9
R28	Inaccurate information from involved stakeholders	2.87	1.164	0.574	10
R22	Designers lack of documents management skills	2.86	1.283	0.572	11
R3	Poor constructability of design	2.85	1.111	0.570	12
R17	Frequent substitutions of design team members	2.84	1.139	0.568	13
R33	Payment delays	2.78	1.295	0.557	14
R31	Unduly long period of design review by onwer/ main contractor	2.76	1.134	0.553	15
R37	Changes or improper scope/ work definition in contract	2.71	1.086	0.542	16
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers	2.68	1.176	0.536	17
R20	Designer's distraction/ not reached high performance	2.63	1.124	0.526	18

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R36	Owner/ main contractor's disagreement on source of main equipment or materials	2.62	1.183	0.525	19
R12	Original design was flawed, and later designers continued to rely on original results	2.56	1.155	0.511	20
R29	Owner/ main contractor misunderstands designer's proposal	2.56	1.266	0.511	21
R5	Concept of design is not clear	2.55	1.251	0.509	22
R19	Teamwork ability is not effective	2.52	1.035	0.504	23
R7	Designer's unfamiliarity with requirements of codes/standards	2.49	1.289	0.498	24
R21	Designers lack of technical software handling skills	2.74	1.157	0.491	25
R30	Inaccurate, missing, vague, or illegal information in owner's requirements	2.43	1.302	0.487	26
R8	Conflicting because of lack of norms and standards, specifications	2.40	1.224	0.479	27
R25	Inexperienced design team	2.40	1.240	0.479	28
R2	Unproven design solutions adopted	2.38	1.390	0.475	29
R24	Team leader lacks experiences and management skills	2.34	1.257	0.468	30
R23	Lack of professional designers	2.32	1.215	0.464	31

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R1	Inadequate design standard/specification adopted	2.30	1.289	0.460	32
R14	Incomplete check on input documents	2.29	1.195	0.458	33
R15	Inconsistency among core designers	2.28	1.271	0.457	34
R13	Insufficient geological investigation or unknown geological conditions	2.18	1.329	0.436	35
R11	Dispute about design responsibility	2.13	1.204	0.426	36
R16	Differences between designers' work habits and local practice	2.11	1.245	0.423	37

From the ranking results based on the average value of possibility level of design risks, most of the risks have an average value greater than 2, therefore the design risks proposed in the study are likely to appear during the project life cycle. Among them, top ten design risks ranked highest according to survey participants are:

1. Owner requests for design changes

2. Design changes from different technical disciplines of design team

3. Defective or omission in design

4. Design behind schedule

5. Budget overrun in design

6. Separation of design and site supervision

7. Difficulty in coordination between different design consultants

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8. Delay of resolving matters between all of involved stakeholders

9. Owner/ main contractor requests to proceed design without signing contract

10. Inaccurate information from involved stakeholders

The above risk factors are all important risks that are highly likely to occur and should be kept in mind when performing design.

4.4.3. Risk ranking

According to Garry Creedy (2006): Risk rating is a combination of level of probability and level of impact of that risk factor: Risk = (Possibility index) × (Impact index). After performing the calculation, the ranking and scores of the risk factor are presented as Table 4.8.

Table 4.8. Ranking of factors in design phase of Design-Build power plant projects

No.	Design risks	I.I.	P.I.	IMP.I	Rank
R35	Owner requests for design changes	0.694	0.713	0.4948	1
R6	Defective or omission in design	0.728	0.664	0.4834	2
R26	Design changes from different technical disciplines of design team	0.649	0.685	0.4446	3
R4	Budget overrun in design	0.717	0.608	0.4359	4
R10	Design behind schedule	0.677	0.636	0.4306	5
R9	Separation of design and site supervision	0.657	0.608	0.3995	6
R34	Owner/ main contractor requests to proceed design without signing contract	0.689	0.575	0.3962	7

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R3	Poor constructability of design	0.668	0.57	0.3808	8
R33	Payment delays	0.675	0.557	0.3760	9
R28	Inaccurate information from involved stakeholders	0.636	0.574	0.3651	10
R22	Designers lack of documents management skills	0.626	0.572	0.3581	11
R27	Delay of resolving matters between all of involved stakeholders	0.604	0.581	0.3509	12
R37	Changes or improper scope/ work definition in contract	0.617	0.542	0.3344	13
R18	Difficulty in coordination between different design consultants	0.57	0.583	0.3323	14
R36	Owner/ main contractor's disagreement on source of main equipment or materials	0.625	0.525	0.3281	15
R5	Concept of design is not clear	0.626	0.509	0.3186	16
R25	Inexperienced design team	0.664	0.479	0.3181	17
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers	0.591	0.536	0.3168	18
R21	Designers lack of technical software handling skills	0.645	0.491	0.3167	19
R31	Unduly long period of design review by owner/ main contractor	0.572	0.553	0.3163	20
R29	Owner/ main contractor misunderstands designer's proposal	0.613	0.511	0.3132	21

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R12	Original design was flawed, and later designers continued to rely on original results	0.608	0.511	0.3107	22
R30	Inaccurate, missing, vague, or illegal information in owner's requirements	0.63	0.487	0.3068	23
R24	Team leader lacks experiences and management skills	0.628	0.468	0.2939	24
R23	Lack of professional designers	0.625	0.464	0.2900	25
R19	Teamwork ability is not effective	0.575	0.504	0.2898	26
R20	Designers's distraction/ not reached high performance	0.549	0.526	0.2888	27
R17	Frequent substitutions of design team members	0.491	0.568	0.2789	28
R2	Unproven design solutions adopted	0.583	0.475	0.2769	29
R7	Designers' unfamiliarity with requirements of codes/standards	0.547	0.498	0.2724	30
R1	Inadequate design standard/specification adopted	0.592	0.46	0.2723	31
R14	Incomplete check on input documents	0.553	0.458	0.2533	32
R13	Insufficient geological investigation or unknown geological conditions	0.557	0.436	0.2429	33
R8	Conflicting because of lack of norms and standards, specifications	0.502	0.479	0.2405	34
R15	Inconsistency among core designers	0.487	0.457	0.2226	35
R11	Dispute about design responsibility	0.481	0.426	0.2049	36

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R16	Differences between designers' work habits and local practice	0.451	0.423	0.1908	37

From the results of ranking design risks, the ten highest ranked design risks respectively are:

1. Owner requests for design changes: During design stage, project owner often changes the idea of product shape, function or technology to suit investment purposes. Many investors request changes when detailed design drawings are completed, or add details while the contractor is constructing. Changing this many times would affect designer's initiatives, quality and aesthetics of the project, and slows down the construction progress.

2. Defective or omission in design: Defects or omissions can result in design flaws, inconsistencies, functionality issues, or failure to meet the intended purpose or user needs. These disadvantages can lead to dissatisfaction among clients, negative user experiences, costly revisions or rework, and potential damage to the reputation of the designer or organization.

3. Design changes from different technical disciplines of the design team: As a design-build general contractor, the contractor must coordinate and synchronize many disciplines during the design process to produce a single construction design document. The design documents of the contractor's design departments often clash with each other. Disciplines often rely on the basic design to follow, so clashes occur when combined with each other. When making changes, this would affect the construction progress.

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4. Budget overrun in design: Budget overruns in design may include inaccurate initial cost estimates, unforeseen complexities or scope changes, inadequate project planning, poor resource management, or unrealistic client expectations. Moreover, designers frequently overdesign in an attempt to minimize subpar risk and produce an ostensibly prudent design that the employer will readily accept, which dramatically raises project costs (Junying Liu et al., 2017). Budget overruns can lead to financial strain, compromised project quality, strained client relationships, and potential delays in project completion.

5. Design behind schedule: When a design is behind schedule, it can lead to delays in the overall project timeline and various challenges. There can be several factors contributing to the design falling behind schedule, such as inadequate resource allocation, unexpected complexities, scope changes, or inefficiencies in the design process.

6. Separation of design and site supervision: The separation of design and site supervision can introduce challenges and potential issues in construction projects. When design and site supervision are handled by separate entities or teams, it can lead to miscommunication, discrepancies, and a lack of coordination between the two aspects of the project. The absence of direct collaboration and alignment between designers and site supervisors can also lead to a disconnect between the intended design and its execution on-site.

7. Owner/ main contractor requests to proceed design without signing contract: Proceeding without a signed contract means that there is no legally binding agreement in place to protect the rights and interests of both parties. This situation can lead to potential disputes regarding payment terms, project scope, intellectual property rights, or project

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deliverables. It also leaves the design team vulnerable to potential non-payment or changes in project requirements without proper compensation.

8. Poor constructability of design: Design is not optimized for efficient and practical construction. Some common causes of poor constructability include overly complex or ambiguous design details, inadequate consideration of construction methods and techniques, lack of coordination between design disciplines, or failure to incorporate input from construction professionals. When a design is not constructible, it can lead to construction delays, cost overruns, rework, and compromised quality. Construction teams may encounter difficulties in interpreting or implementing the design, resulting in errors, conflicts, or the need for design modifications on-site. This can impact productivity, increase construction time, and strain the project budget.

9. Payment delays: Payment delays can have significant impacts on design projects, causing financial strain and various challenges for design teams. When payments are delayed, it can disrupt cash flow, hinder project progress, and affect the ability to meet financial obligations such as paying employees or subcontractors, purchasing materials, or covering operating costs. Payment delays can lead to frustration, strained relationships, and potential legal disputes.

10. Inaccurate information from involved stakeholders: Inaccurate information can stem from miscommunication, lack of understanding, intentional misrepresentation, or changes in project requirements that were not effectively communicated. The impact of inaccurate information can result in design errors, delays, rework, and increased costs.

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4.5. ANOVA test

ANOVA, or Analysis of Variance, is a test used to determine differences between research results from a group of respondents. To test the differences between groups of survey participants, students used ANOVA test with a significance level of 0.01 (1%) for 37 factors, divided into 2 cases.

Case 1: Variables with Sig coefficients greater than the confidence level of 0.01 conclude there is no difference between groups.

Case 2: Variables with Sig values less than 0.01 conclude that there are differences between groups. Conduct analysis of differences between groups.

4.5.1. Testing differences between groups in experience

After performing the calculation, equality of means in experience is shown as Table 4.9 below. As a result, from the above table, all variables have Sig. coefficients > 0.01, so these variables have no difference between different survey groups in terms of work experience.

Table 4.9. Equality of Means in experience

Design risk factors	Statistic[a]	df1	df2	Sig.
R1	3.771	2	62.172	0.028
R2	4.875	2	63.660	0.011
R3	2.385	2	62.115	0.100
R4	2.367	2	61.382	0.102

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R5	1.992	2	62.641	0.145
R6	3.034	2	60.200	0.056
R7	3.394	2	64.010	0.040
R8	1.418	2	65.542	0.250
R9	5.544	2	58.127	0.060
R10	3.275	2	61.119	0.045
R11	2.331	2	60.115	0.106
R12	3.209	2	61.851	0.047
R13	1.437	2	65.452	0.245
R14	0.882	2	62.521	0.419
R15	1.241	2	63.993	0.296
R16	1.272	2	65.420	0.287
R17	0.872	2	63.877	0.423
R18	1.804	2	63.533	0.173
R19	1.704	2	61.539	0.191
R20	0.573	2	62.419	0.567
R21	9.940	2	56.861	0.011
R22	3.814	2	62.738	0.027
R23	3.976	2	58.611	0.024
R24	6.301	2	61.589	0.032
R25	4.368	2	62.789	0.017
R26	2.832	2	60.340	0.067
R27	1.558	2	62.362	0.219
R28	6.551	2	59.155	0.026
R29	2.432	2	59.744	0.097

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R30	2.764	2	60.731	0.071
R31	2.710	2	60.589	0.075
R32	1.264	2	59.324	0.290
R33	4.467	2	59.595	0.016
R34	1.804	2	60.348	0.173
R35	2.045	2	62.250	0.138
R36	1.125	2	63.122	0.331
R37	1.588	2	61.152	0.213

a: Asymptotically F distributed.

4.5.2. Testing differences between groups in expertise

After performing the calculation, equality of means in expertise is shown as Table 4.10.

Table 4.10. Table of Equality of Means in expertise

Design risk factors	Statistic[a]	df1	df2	Sig.
R1	2.118	4	34.951	0.099
R2	1.567	4	36.391	0.204
R3	0.980	4	38.438	0.430
R4	0.930	4	36.504	0.457
R5	0.602	4	35.100	0.664
R6	1.944	4	36.188	0.124
R7	1.808	4	35.953	0.149
R8	2.475	4	34.650	0.062
R9	1.570	4	39.769	0.201
R10	13.185	4	37.028	0.000

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R11	3.688	4	34.183	0.013
R12	8.170	4	36.180	0.000
R13	3.846	4	37.310	0.010
R14	6.063	4	36.553	0.076
R15	3.220	4	37.922	0.023
R16	1.990	4	35.116	0.118
R17	2.610	4	37.597	0.051
R18	5.205	4	38.311	0.019
R19	4.005	4	39.699	0.080
R20	1.788	4	35.714	0.153
R21	6.202	4	37.092	0.063
R22	3.674	4	36.311	0.013
R23	3.098	4	36.499	0.027
R24	7.131	4	34.695	0.000
R25	10.070	4	35.482	0.000
R26	3.759	4	37.919	0.011
R27	5.676	4	37.099	0.011
R28	0.607	4	36.426	0.660
R29	4.028	4	37.145	0.082
R30	1.759	4	38.115	0.157
R31	5.450	4	36.508	0.015
R32	0.600	4	36.632	0.665
R33	8.003	4	34.999	0.000
R34	8.052	4	34.700	0.000
R35	3.133	4	34.145	0.027
R36	3.918	4	37.753	0.093
R37	2.275	4	36.438	0.080
a. Asymptotically F distributed.				

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After ANOVA analysis to test the average difference for the variables, variables R10 "Design behind schedule", R12 "Original design was flawed, and later designers continued to rely on original results", R24 "Team leader lacks experiences and management skills", R25 "Inexperienced design team", R33 "Payment delays" and R34 "Owner/ main contractor requests to proceed design without signing contract" have sig coefficients < 0.01, so the hypothesis of variance between survey groups of the variables is homogenous, which means there is a difference in the opinions of survey participants regarding these variables.

Figure 4.5 shows the mean of different opinions among survey participating groups of people who are working in different expertise in the construction industry in Vietnam.

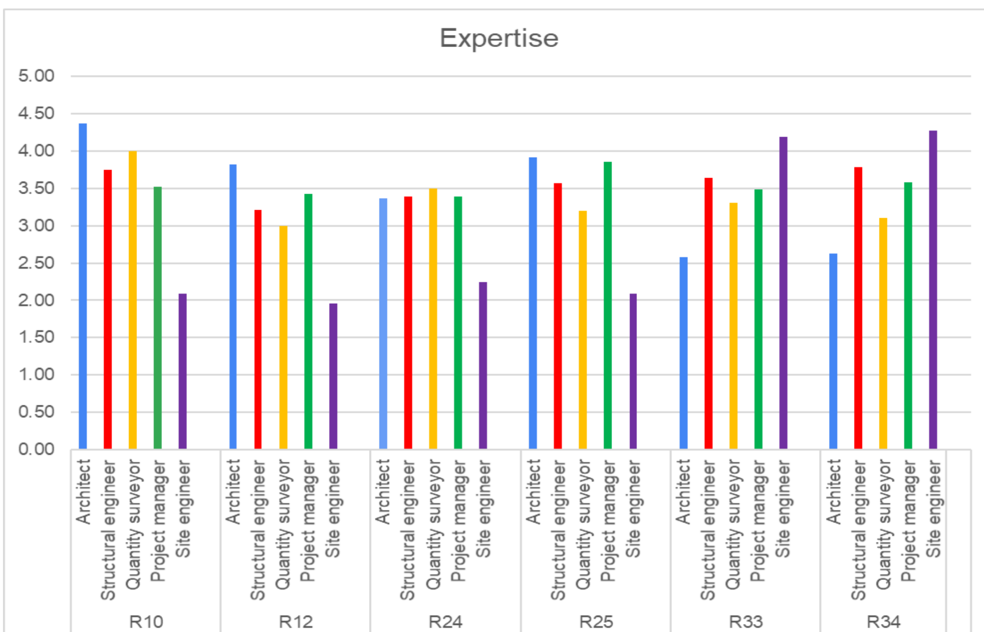

Figure 4.5. Differences between groups in expertise

Site engineers on average have a different aspect from other expertises because they usually work with the final version of drawings and documents, so for them some risks they might not think that these factors really impact the all over design phase. This explained why

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for R12 “Original design was flawed, and later designers continued to rely on original results", R24 “Team leader lacks experiences and management skills”, and R25 “Inexperienced design team”, site engineer group has an average mean score lower than other groups. In addition, when designing power plant projects, the design phase is often quite far ahead of the construction phase, therefore in general the design schedule might not affect too much on the overall progress of the whole project. Site engineer group has the mean number about factor R10 “Design behind schedule” was 2.08, meanwhile others have the total number from 3.52 to 4.36. On the other hand, when there is a change or the amount of work arises, the investor often requires the work to be performed before signing an additional contract, as R34 “Owner/ main contractor requests to proceed the design without signing contract”. This causes huge risks for construction contractors because it directly affects the contractor's resources, cash flow, and progress. That explained why the site engineer group had the mean number of 4.18, higher than the average total mean number of this factor was 3.38. Site engineers feel that this factor affects their interests more. Besides, R33 “Payment delays” directly affect all parties involved in the project, especially activities at the construction site, so site engineers believe that this factor has a lot of impact on the project.

To get a more detailed look at the differences between expertise groups, a ranking of expertise's groups for various design risk factors in the design phase of a power plant project was performed. The table includes different categories or roles such as Architect, Structural Engineer, Quantity Surveyor, Project Manager, and Site Engineer. The ranking results are described in Table 4.11 as below.

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Table 4.11. Ranking of expertise's group

Ranking of expertise's group										
Rank	Architect		Structural Engineer		Quantity Surveyor		Project Manager		Site Engineer	
	Risk factor	Mean	Risk factor	Mean	Risk factor	Mean	Risk factor	Mean	Risk factor	Mean
1	R10	4.36	R6	3.93	R10	4.00	R25	3.85	R4	3.33
2	R6	4.27	R34	3.79	R6	3.70	R35	3.79	R1	3.17
3	R34	4.27	R4	3.75	R9	3.70	R29	3.64	R6	3.08
4	R33	4.18	R10	3.75	R4	3.60	R21	3.61	R3	3.04
5	R4	4.00	R33	3.64	R26	3.50	R34	3.58	R5	3.00

Analyzing the table can provide valuable insights into the relative importance and impact of different risk factors as seen by each expertise group. For example, if a risk factor has a high mean value for the Architect category but a low mean value for the Structural Engineer category, it suggests that the Architect group considers that risk factor to be more significant or impactful compared to the Structural Engineer group. In which, in site engineer group, the risk R3 “Poor constructability of design” and R5 “Concept of design is not clear” were of interest to the site engineer team because these two factors directly affect construction work at the construction site. This information can assist project teams in several ways. Firstly, it helps in identifying the areas where different expertise groups have varying perceptions of risk factors. This understanding can be used to facilitate communication, collaboration, and consensus-building among the different groups, ensuring that all perspectives are considered in the risk management process. Secondly, the rankings can guide the allocation of resources and efforts towards addressing the most critical risk factors. If a risk factor consistently ranks high across multiple expertise groups, it indicates its overall significance and the need for focused attention and mitigation strategies. Additionally, the

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table can aid in decision-making during the design phase. By considering the rankings and the specific concerns of each expertise group, project teams can make informed choices regarding design alternatives, trade-offs, and risk mitigation strategies. It is important to note that the analysis of this table should be done in conjunction with other relevant data and considerations. The rankings provided by expertise groups are subjective and based on their specific perspectives and experiences. Project teams should use the table as a tool for discussion, collaboration, and informed decision-making rather than solely relying on it as the sole determinant of risk prioritization and mitigation.

4.5.3. Testing differences between groups in surveyed participation organization

After performing the calculation, equality of means in participation organization is shown as Table 4.12.

Table 4.12. Equality of Means in organization

Design risk factors	Statistic[a]	df1	df2	Sig.
R1	4.110	3	45.346	0.012
R2	1.305	3	42.312	0.285
R3	3.597	3	41.357	0.021
R4	1.976	3	46.275	0.131
R5	2.415	3	46.232	0.079
R6	4.099	3	44.149	0.012
R7	1.173	3	46.794	0.330
R8	2.066	3	45.720	0.118
R9	1.364	3	44.662	0.266
R10	17.236	3	45.456	0.000

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R11	3.168	3	46.264	0.033
R12	7.693	3	43.200	0.000
R13	5.078	3	44.628	0.041
R14	6.068	3	47.881	0.014
R15	3.504	3	50.243	0.022
R16	1.130	3	42.395	0.348
R17	0.773	3	45.804	0.515
R18	5.361	3	44.223	0.031
R19	3.915	3	41.816	0.015
R20	2.848	3	45.102	0.048
R21	6.868	3	43.797	0.068
R22	4.107	3	43.621	0.012
R23	4.796	3	43.869	0.056
R24	10.682	3	44.698	0.000
R25	16.233	3	46.163	0.000
R26	4.752	3	45.087	0.058
R27	6.599	3	44.122	0.088
R28	1.630	3	44.976	0.196
R29	5.524	3	45.206	0.026
R30	5.686	3	44.417	0.022
R31	6.777	3	47.906	0.067
R32	0.903	3	47.900	0.446
R33	9.047	3	45.244	0.000
R34	8.982	3	46.628	0.000
R35	5.287	3	44.640	0.033
R36	6.122	3	42.683	0.015
R37	4.995	3	46.394	0.044

a: Asymptotically F distributed.

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After ANOVA analysis to test the average difference for the variables, variables R10 "Design behind schedule", R12 "Original design was flawed, and later designers continued to rely on original results", R24 "Team leader lacks experiences and management skills", R25 "Inexperienced design team", R33 "Payment delays" and R34 "Owner/ main contractor requests to proceed design without signing contract" have sig coefficients < 0.01, so the hypothesis of variance between survey groups of the variables is homogenous, which means there is a difference in the opinions of survey participants regarding these variables.

Figure 4.6 shows the mean of different opinions among survey participating groups of people who are working in different organizations in the construction industry in Vietnam.

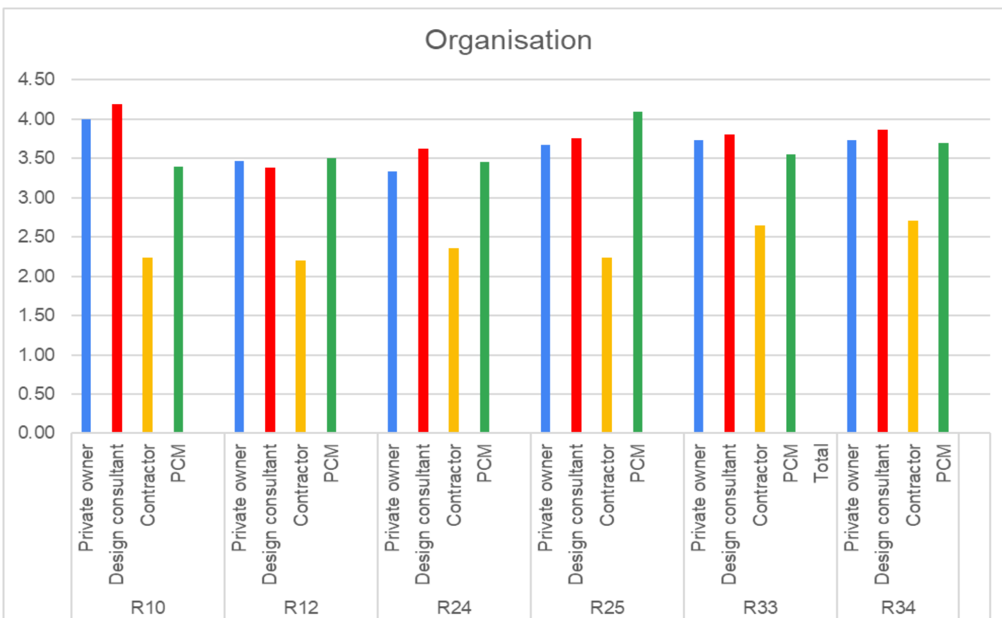

Figure 4.6. Differences between groups in organization

As can be seen in Figure 4.6, the trend of organization group's answers is similar to that of expertise, because almost all of the questionnaire respondents with a background as site engineers work for contractors.

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To get a big picture of the differences between each organization groups, a ranking of expertise's groups for various design risk factors in the design phase of a power plant project was performed. The ranking includes different groups of respondant's worikng organization such as Owner, Design consultant, Construction contractor and Project construction management unit PCM. The ranking results are described in Table 4.13 as below.

Table 4.13. Ranking of organization's group

Ranking of organization's group								
Rank	Owner		Design Consultant		Contractor		PCM	
	Risk factor	Mean	Risk factor	Mean	Risk factor	Mean	Risk factor	Mean
1	R6	4.00	R10	4.19	R4	3.24	R25	4.10
2	R10	4.00	R6	4.11	R1	3.18	R35	3.90
3	R21	3.85	R4	3.92	R6	3.00	R29	3.90
4	R35	3.77	R34	3.86	R9	2.97	R21	3.90
5	R33	3.69	R33	3.81	R3	2.94	R34	3.70

It can be said that the difference between groups is not too large. If compared with the overall ranking of factors, it can be seen that most of the risk factors designed by organizational group have similar design factors. This is explained by the fact that most of the survey participants are working for construction design organizations or investors. However, for the PCM group, there are some risks they are also more concerned about than R25 "Inexperienced design team", R29 "Owner/ main contractor misunderstands designer's proposal", and R30 "Inaccurate, missing, vague, or illegal information in owner's requirements". From the perspective of the project management team, these factors greatly affect the decision-making ability of the person responsible for the design, affecting the

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design quality of the project. Thefore, project participated parties should execute more discussion, collaboration, and informed decision-making rather than solely relying on it as the sole determinant of risk prioritization and mitigation.

4.6. Exploratory factor analysis EFA

Based on survey data, conduct to analyze 37 design risks in terms of impact level using Principal Component Analysis (PCA) analysis method with varimax rotation, stopping to extract risks with eigenvalue < 1, using KMO and Bartlett's test methods to measure the compatibility of data samples for EFA. The results of the KMO test and Bartlett's test are presented in Table 4.14 as follows.

Table 4.14. Results of KMO test and Bartlett's test

<table>
<tr><th colspan="3">KMO and Bartlett's Test</th></tr>
<tr><td colspan="2">Kaiser-Meyer-Olkin Measure of Sampling Adequacy.</td><td>0.850</td></tr>
<tr><td rowspan="3">Bartlett's Test of Sphericity</td><td>Approx. Chi-Square</td><td>4247.540</td></tr>
<tr><td>df</td><td>528</td></tr>
<tr><td>Sig.</td><td>0.000</td></tr>
</table>

From the above results of KMO and Bartlett's test, it is shown that the coefficient KMO is 0.850 > 0.5. Therefore, design risk surveyed data is suitable for factor analysis. In addition, Bartlett's Test has a Sig. coefficient < 0.05, so using factor analysis for 37 design risks is appropriate. Statistics of initial variance explained are shown in Table 4.15.

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Table 4.15. Total variance explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	16.562	44.763	44.763	6.649	17.970	17.970
2	5.113	13.818	58.582	5.843	15.792	33.762
3	3.667	9.911	68.493	5.462	14.762	48.524
4	1.914	5.172	73.664	4.760	12.865	61.389
5	1.280	3.460	77.124	4.647	12.559	73.948
6	1.063	2.872	79.996	2.238	6.048	79.996
7	0.930	2.514	82.510			
8	0.777	2.101	84.611			
9	0.667	1.802	86.413			
10	0.541	1.461	87.874			
11	0.467	1.262	89.137			
12	0.449	1.213	90.350			
13	0.358	0.968	91.318			
14	0.354	0.956	92.274			
15	0.314	0.849	93.123			
16	0.293	0.793	93.916			
17	0.273	0.739	94.655			
18	0.257	0.695	95.350			
19	0.221	0.596	95.947			
20	0.197	0.532	96.479			
21	0.172	0.466	96.945			
22	0.143	0.387	97.332			

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23	0.137	0.370	97.702			
24	0.123	0.332	98.034			
25	0.112	0.302	98.336			
26	0.106	0.287	98.623			
27	0.077	0.208	98.831			
28	0.071	0.192	99.023			
29	0.065	0.174	99.198			
30	0.058	0.158	99.355			
31	0.051	0.139	99.494			
32	0.042	0.114	99.608			
33	0.040	0.108	99.716			
34	0.037	0.101	99.817			
35	0.027	0.072	99.889			
36	0.024	0.064	99.953			
37	0.017	0.047	100.000			

Extraction Method: Principal Component Analysis.

Initial Eigenvalue coefficient = 2.238 > 1: the portion of variation explained by each factor meets the factor extraction condition. The results of the first rotation created 6 groups that explained 79.996% of the entire variable, greater than 50%. Table 4.16 shows the six factor loadings extracted from factor analysis technique except for loading values less than 0.4. The varimax orthogonal rotation of principal component analysis is used in this study to group factors.

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Table 4.16. Rotated component matrix

Rotated Component Matrix[a]							
No.	Design risk	Component					
		1	2	3	4	5	6
R21	Designers lack of technical software handling skills	0.788					
R24	Team leader lacks experiences and management skills	0.764					
R23	Lack of professional designers	0.757					
R22	Designers lack of documents management skills	0.729					
R6	Defective or omission in design	0.719					
R10	Design behind schedule	0.698					
R25	Inexperienced design team	0.563					
R3	Poor constructability of design	0.541					
R9	Separation of design and site supervision	0.521					
R4	Budget overrun in design	0.502					
R2	Unproven design solutions adopted		0.861				
R7	Designers' unfamiliarity with requirements of codes/standards		0.844				
R1	Inadequate design standard/specification adopted		0.823				
R5	Concept of design is not clear		0.776				
R8	Conflicting because of lack of norms and standards, specifications		0.767				
R28	Inaccurate information from involved stakeholders		0.492				
R16	Differences between designers' work habits and local practice			0.899			
R17	Frequent substitutions of design team members			0.841			
R15	Inconsistency among core designers			0.729			
R20	Designers's distraction/ not reached high performance			0.716			

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R13	Insufficient geological investigation or unknown geological conditions			0.713			
R14	Incomplete check on input documents			0.641			
R11	Dispute about design responsibility			0.527			
R12	Original design was flawed, and later designers continued to rely on original results			0.519			
R19	Teamwork ability is not effective				0.810		
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers				0.751		
R27	Delay of resolving matters between all of involved stakeholders				0.719		
R18	Difficulty in coordination between different design consultants				0.672		
R31	Unduly long period of design review by onwer/ main contractor				0.518		
R26	Design changes from different technical disciplines of design team				0.460		
R35	Owner requests for design changes					0.840	
R34	Owner/ main contractor requests to proceed design without signing contract					0.762	
R33	Payment delays					0.734	
R37	Changes or improper scope/ work definition in contract					0.628	
R30	Inaccurate, missing, vague, or illegal information in owner's requirements					0.610	
R29	Owner/ main contractor misunderstands designer's proposal						0.610

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R36	Owner/ main contractor's disagreement on source of main equipment or materials							0.533

Extraction Method: Principal Component Analysis.

a: Rotation converged in 12 iterations.

As a result of factor rotation, six group factors were obtained. After consulting the previous researches in advance, each risk group is named respectively as follows:

DR1: Risk of design team lack of capacity and experience

DR2: Risk of improper design scheme

DR3: Risk of design team lack of responsibility

DR4: Risk of inefficient document review and poor cooperation between stakeholders

DR5: Risk of change and requested by owner

DR6: Risk of disagreement and misunderstand by owner

4.6.1. DR1: Risk of design team lack of capacity and experience

The risk of design team lack of capacity explained approximately 17.97% of the variance in design risk factors. It encompassed ten components: (1) R21. Designers lack of technical software handling skills, (2) R24. Team leader lacks experiences and management skills, (3) R23. Lack of professional designers, (4) R22. Designers lack of documents management skills, (5) R6. Defective or omission in design, (6) R10. Design behind schedule, (7) R25. Inexperienced design team, (8) R3. Poor constructability of design, (9) R4. Separation of design and site supervision, and (10) R4. Budget overrun in design.

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Lack of experience can cause designers on a design team to be less skilled in technical software handling because of things like poor training, limited exposure to software tools, time constraints, fear of technology, and a lack of resources and support for skill development. In addition, designers might not have received formal training or education in document management techniques, they might not have had enough exposure to effective document management tools or systems, or they might have placed more of an emphasis on design-related work than organizational details. Challenges like difficulty in effectively leading and motivating the team, managing conflicts, setting goals, giving feedback, and facilitating communication can arise from the team leader's lack of experience and skills. Additionally, economic factors such as budget constraints or cost-cutting measures, may lead organizations to overlook the importance of hiring professional designers. An inexperienced design team can face several challenges due to their limited knowledge and skills. These challenges include a lack of understanding of design principles and best practices, limited exposure to different design projects and industries, and a lack of proficiency with design tools and software. Lack of high quality professional design, experience and knowledge in handling problems may cause many problems in the design process, affecting the quality and cost of the project.

The inexperience of the design team may result in defective or omission in design, poor constructability of design, separation of design and site supervision, which lead to design behind schedule and budget overrun. Designers need to be equipped with basic knowledge, rules and regulations for designing a project. For designers with many years of experience, they will be able to control the calculation results, limit errors and omissions in the design,

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and at the same time come up with appropriate solutions to both meet the quality of the project and investor's budget.

4.6.2. DR2: Risk of improper design scheme

The risk of improper design scheme accounted for 15.792% of variance and comprised six design risks: (1) R2. Unproven design solutions adopted, (2) R7. Designer's unfamiliarity with requirements of codes/standards, (3) R1. Inadequate design standard/specification adopted, (4) R5. Concept of design is not clear, (5) R8. Conflicting because of lack of norms and standards, specifications, and (6) R28. Inaccurate information from involved stakeholders.

A project is a brief endeavor started with the intention of producing a special product, service, or outcome (Guide, 2004). Unproven design solutions have the potential to cause project operation failure or to fall short of the production capacity requirements set forth by the employer. The characteristics and pertinent requirements of the foreign host country may not be known to database contractors working on international projects, which can have a substantial impact on project goals. (Zhi, 1995; Eybpoosh et al., 2011). For instance, some Vietnamese designers might not comprehend the level of design precision and drawing styles required by foreign clients, which could result in design documentation that is not in compliance with the employer's specifications. Furthermore, it is frequently the case that insufficient design standards or specifications are adopted, particularly in international projects. Designers need to take extra care when it comes to conflicts between design standards. To choose the proper design standards to use, designers need to be aware of the regulations, laws, and application review forms of the host nation.

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The design concept will be unclear when the design scheme is ambiguous and vague, and the designer may misinterpret the investor's intentions. Furthermore, inaccurate or lacking information from stakeholders can result in misinterpretations, misplaced expectations, and mistakes in the final design. A lack of knowledge or comprehension, a misunderstanding, or improperly communicated changes in requirements can all lead to inaccurate information. This may lead to delays, rework, a waste of time and resources, and stakeholder unhappiness.

4.6.3. DR3: Risk of design team lack of responsibility

The risk of design team lack of responsibility represented a proportion of 14.762% of variance and incorporated eight components: (1) R16. Differences between designers' work habits and local practice, (2) R17. Frequent substitutions of design team members, (3) R15. Inconsistency among core designers, (4) R20. Designers's distraction/ not reached high performance, (5) R13. Insufficient geological investigation or unknown geological conditions, (6) R14. Incomplete check on input documents, (7) R11. Dispute about design responsibility, and (8) R12. Original design was flawed, and later designers continued to rely on original results.

Differences between designers' work habits and local practices can lead to challenges and conflicts in the design process. These differences may include variations in work schedules, communication styles, decision-making processes, or approaches to problem-solving. Frequent substitutions of design team members can create challenges and disruptions in the design process. This can result in delays, inconsistencies, and difficulties in maintaining a cohesive design vision. Frequent substitutions can also impact team morale, as

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it may create a sense of instability and hinder effective collaboration. The design team's stability promotes cohesion and provides significant benefits for decision making (Slotegraaf and Atuahene-Gima, 2011).

For the construction industry, ethics and professional responsibility are extremely important. If the job designer does not have a sense of responsibility for the products he or she creates, the design documents will easily result in errors. The designer's mood is an issue that needs attention. When the designer is in a good mood and a relaxed spirit, the creation of quality ideas will result.

Unknown geological conditions or inadequate geological investigation can result in untrustworthy design data for database contractors. Unreliable design data leads to poorly informed designs that are incompatible with the construction of the excavation, foundation, and footing (Zou et al., 2007). When documents are not thoroughly reviewed or verified, it can result in errors, inconsistencies, or missing information being incorporated into the design. This can lead to design flaws, delays, rework, or even critical mistakes that impact the overall project. Careful inspection and early detection of design errors should be carried out according to a specific process and also avoid dispute for responsibility during the design stage.

4.6.4. DR4: Risk of inefficient document review and poor cooperation between stakeholders

The risk of inefficient document review and poor cooperation between stakeholders was responsible for 12.865% of variance and consisted of six factors: (1) R19. Teamwork ability is not effective, (2) R32. Communication gap or misinterpretation on exchange information

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between owner/ main contractor and designers, (3) R27. Delay of resolving matters between all of involved stakeholders, (4) R18. Difficulty in coordination between different design consultants, (5) R31. Unduly long period of design review by owner/ main contractor, and (6) R26. Design changes from different technical disciplines of the design team.

Because design is a multidisciplinary field, working together on some projects can be more advantageous than working alone (Hampton, 2001). Thus, there are virtues in establishing an effective system for communication and coordination among designers. In DB projects, the total period of the employer's design review can be excessive and not conducive to the advancement of the design. Furthermore, design team members from various technical disciplines, such as engineering, architecture, or industrial design, propose changes that can lead to conflicting ideas, differing priorities, and potential inconsistencies in the design. These changes may stem from the unique perspectives, expertise, and requirements of each discipline. However, without effective coordination and integration, these changes can result in delays, budget overruns, or compromises in the overall design quality.

4.6.5. DR5: Risk of change and requested by owner

The risk of change and requested by owner accounted for 12.559% of variance and consisted of five components: (1) R35. Owner requests for design changes, (2) R34. Owner/ main contractor requests to proceed design without signing contract, (3) R33. Payment delays, (4) R37. Changes or improper scope/ work definition in contract, (5) R30. Inaccurate, missing, vague, or illegal information in owner's requirements.

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A project that is not correctly defined from the beginning will affect the entire process later. Additional requirements of the investor, the design-build contractor is responsible for consulting on the design, clarifying the technical parameters of the project, limiting technical errors that are not suitable for the investor as well as state regulations.

4.6.6. DR6: Risk of disagreement and misunderstand by owner

The risk of disagreement and misunderstanding by owner explained 6.048% of total variance and embodied two risk factors: (1) R29. Owner/ main contractor misunderstands designer's proposal, and (2) R36. Owner/ main contractor's disagreement on source of main equipment or materials.

The designer implements their idea but the owner does not clearly understand the function or layout, causing the slowing down of project's progress. Some cases, investors often intervene in construction materials such as paint colors, bricks, equipment, etc. The owner often changes materials or equipment suppliers to suit the purpose of use, finances, or preferences. This poses a high risk of delay or lack of resources for construction, delaying the progress of the project and increasing costs incurred by the contractor.

4.7. Chapter summary

Through Chapter 4, data analysis of the questionnaire has been done, and the several findings have been discussed.

First, after calculation and scoring the level of impact and possibility of risk factors, 37 design risk factors were ranked, and critical factors have been discussed to find out the

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reasons why those factors affect the design phase of Design-Build power plant projects in Vietnam.

Second, these design risk factors were categorized into 6 groups through exploratory factor analysis: DR1: Risk of design team lack of capacity and experience, DR2: Risk of improper design scheme, DR3: Risk of design team lack of responsibility, DR4: Risk of inefficient document review and poor cooperation between stakeholders, DR5: Risk of change and requested by owner, and DR6: Risk of disagreement and misunderstand by owner.

Third, ANOVA analysis has been conducted to find out the different point of views of surveyed respondents, who represent different stakeholders participating in Design-Build power plant projects. In general, among 37 design risk factors, there were 6 factors that caused a different trend. R10 “Design behind schedule”, R12 “Original design was flawed, and later designers continued to rely on original results”, R24 “Team leader lacks experiences and management skills”, R25 “Inexperienced design team”, R33 “Payment delays” and R34 “Owner/ main contractor requests to proceed design without signing contract” have a difference in the opinions of survey participants regarding to the current expertise and organization of respondents.

Therefore, specific design risk management activities should be taken to minimize risks and achieve better project results. The details of risk management activities would be presented in Chapter 5 of this thesis.

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Chapter 5. Management activities of design risks

This chapter summarizes several solutions to minimize the design risk factors when designing Design-Build power plant projects specified in the previous chapter. By interviewing with experts, reviewing literature and adopting management activities by a case study of Design-Build power plant project in Vietnam, this chapter would attempt to suggest some tactic management activities and strategies. Those would help the stakeholders reduce the effects of risk factors in practicing DB power plants in Vietnam.

5.1. Management activities

5.1.1. Literature review of risk management

As mentioned in Chapter 2 of this thesis, there are several types of responses to manage risk. In the literature review, it is clear about the theory of design risk management, what action should be taken towards the identified risks and threats. The response strategy and approach chosen depends on the kind of risks concerned. However, when encountering a specific situation or risk for the design phase, only a few studies provide specific risk management activities.

A case study demonstrated the project management issues involved in procuring a large and complex power plant in East Asia. The practicality and usefulness of this case study are the demonstration of how the large and complex project can be successfully implemented using a multi contract DB system. The case study shows that domestic contractors, with limited DB capability, can also be involved by adopting the develop and construct form. To ensure project success, DB contractors would need to choose a suitable organization form to

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discharge their design and construction responsibilities. For unsophisticated domestic contractors, an integrated approach may give a better chance of project success (Y.Y. Ling and B.S.Y. Lau, 2001). Furthermore, through this case study, a number of risk management activities have been drawn from the project's lesson learned report, summarized in Table 5.1.

Another study identified and analyzed the critical risk factors and activities to manage during OSC (Off-site construction) project execution, including production, transportation, assembly, and integration, and 50 management activities were derived from the existing literature. Poor human resources management had the highest importance, whereas lifting error had the highest performance. Production planning error ranked lowest in both importance and performance. (SeungYeon Lee et al., 2023). Hence, OSC projects need to improve performance further, and intensive management should be used to minimize the performance–importance imbalance. From the project management activities of such large and complex projects, when implementing power plant project design, stakeholders could refer for application. The management activities are summarized in Table 5.1.

5.1.2. Description of expert interview for management activities

This second expert interview has the main purpose of discovering more management activities to minimize risks when designing a power plant project in the Design-Build format. At the same time, when conducting expert interviews, experts will be invited to comment on the results of the previous survey, to consider whether the results and discussion of design risks are reasonable or not. The interview was conducted with 5 experts who have at least 15 years of experience in the construction industry with different roles to get an overview of the issue, and also represent the views of the different participating units in the design phase.

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Among five experts, two of them who are from CTCI Vietnam Corporation, participated in the design phase of the case study as a chief designer and leader of the design team. The interview was an online meeting via the internet to present to them about the results, then send an excel file and ask interviewees to write down their opinions. The details of second interviews were attached in Appendix C. After collecting all their opinions, the results are combined in Table 5.1.

5.1.3. Management activities of power plant projects in design phase

After reviewing literature and interviewing with experts, risk management activities are summarized in Table 5.1 below.

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Table 5.1. Risk management activities in literature review and interview with experts

No	Design risks	Management activities	Risk management method	References
R1	Inadequate design standard/specification adopted	Ask project managers to follow the ITB (Instruction to Bidders) documentation	Risk Avoidance	Interview
R2	Unproven design solutions adopted	Follow common or international codes/ standards	Risk Avoidance	Interview
R3	Poor constructability of design	- Use BIM to minimize design variations - Main contractor needs strict control so that the design can be delivered to the construction site without any errors	Risk Mitigation/ Reduction	Interview
R4	Budget overrun in design	- Limit project's budget at the beginning step	Risk Mitigation/ Reduction Risk Avoidance	Interview
R5	Concept of design is not clear	Study many options and meeting with owner, construction party to come up with solutions	Risk Transfer	Interview
R6	Defective or omission in design	Have a process of planning and checking of results to ensure that complex issues are properly assessed	Risk Mitigation/ Reduction	Interview

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R7	Designer's unfamiliarity with requirements of codes/standards	Follow common or international codes/ standards	Risk Avoidance	Interview
R8	Conflicting because of lack of norms and standards, specifications	Follow common or international codes/ standards	Risk Avoidance	Interview
R9	Separation of design and site supervision	- Use BIM to minimize design variations - General/ Main contractor needs strict control so that the design can be delivered to the construction site without any errors	Risk Mitigation/ Reduction	Interview
R10	Design behind schedule	- WBS-based design planning - Design schedule feedback through periodic reporting - Immediate response and update to design changes - Production monitoring with software - Schedule coordination linked to cost expenditure	Risk Mitigation/ Reduction	JeongWook Son et al. (2023)
R11	Dispute about design responsibility	Assign specific responsibility for the results of the product	Risk Avoidance	Interview
R12	Original design was flawed, and later designers continued to rely on original results	Have a clear process of designing and controlling results	Risk Avoidance	JeongWook Son et al. (2023)

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R13	Insufficient geological investigation or unknown geological conditions	Geotechnical investment also requires a large safety factor to avoid affecting the results later	Risk Avoidance	Interview
R14	Incomplete check on input documents	Human factor, need management process of result's checking	Risk Avoidance	Interview
R15	Inconsistency among core designers	Conduct a meeting to find out solutions	Risk Share	Interview
R16	Differences between designers' work habits and local practice	Follow common or international codes/ standards	Risk Avoidance	Interview
R17	Frequent substitutions of design team members	HR management and managing responsibilities, rewards and punishments policies need to be clear	Risk Mitigation/ Reduction	Interview
R18	Difficulty in coordination between different design consultants	Divide into small groups for discussion	Risk Transfer	Interview
R19	Teamwork ability is not effective	- Establishing a clear communication process - Planning and collaboration between preceding and following steps - Coordination of details among participants in the execution phase	Risk Mitigation/ Reduction	JeongWook Son et al. (2023); Y.Y. Ling and B.S.Y. Lau (2002)

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R20	Designers's distraction/ not reached high performance	- Create a design process and ensure workers follow procedure	Risk Mitigation/ Reduction	Interview
R21	Designers lack of technical software handling skills	Need a training programme, especially for newbie	Risk Mitigation/ Reduction	Interview
R22	Designers lack of documents management skills	Need a training programme, especially for newbie	Risk Mitigation/ Reduction	Interview
R23	Lack of professional designers	Recruit qualified personnel and experts to carry out power plant projects because this is a complex project	Risk Mitigation/ Reduction	Interview
R24	Team leader lacks experiences and management skills	Recruit qualified personnel and experts to carry out power plant projects because this is a complex project	Risk Mitigation/ Reduction	Interview
R25	Inexperienced design team	Choose the qualified design consultants before finalizing the bid	Risk Avoidance	Interview
R26	Design changes from different technical disciplines of design team	- Establish clear roles and responsibilities - Use BIM to minimize design variations - Use common tools and formats - Communicate frequently and effectively - Participate in design reviews and meetings periodically - Learn from other design disciplines (keep updated	Risk Mitigation/ Reduction	JeongWook Son et al. (2023); Y.Y. Ling and B.S.Y. Lau (2002); Interview

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		and informed on the latest trends, technologies, and innovations in the other design disciplines)		
R27	Delay of resolving matters between all of involved stakeholders	- Add a condition to set a deadline for the issue documents to move forward - Make detailed plans and timelines for participating parties	Risk Share Risk Mitigation/Reduction	Interview
R28	Inaccurate information from involved stakeholders	While receiving information, do carefully to get early feedback	Risk Share	Interview
R29	Owner/ main contractor misunderstands designer's proposal	Establishing a clear communication process	Risk Share	JeongWook Son et al. (2023)
R30	Inaccurate, missing, vague, or illegal information in owner's requirements	Require owners to provide appropriate and accurate information for design	Risk Transfer	Interview
R31	Unduly long period of design review by onwer/ main contractor	Add conditions about setting up a deadline for issue documents to move forward if it takes too long to receive feedback.	Risk Mitigation/ Reduction	Interview

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R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers	- Single contract would certainly reduce the number of project participants - Project participants should make the commitment to comply with the agreed format for information flow and interaction. - Establishing a clear communication process - Planning and collaboration between preceding and following steps - Coordination of details among participants in the execution phase	Risk Mitigation/ Reduction	JeongWook Son et al. (2023); Y.Y. Ling and B.S.Y. Lau (2002); Interview
R33	Payment delays	- Request advance payment before proceeding with design - Require the investor to split payments by stages or by the amount of work completed - Actively tracking short path and implement appropriate measures - Rapid reaction such as decreasing speed of activities and increasing follow-ups of nonpayments.	Risk Mitigation/ Reduction	JeongWook Son et al. (2023)
R34	Owner/ main contractor requests to proceed design without signing contract	Only start project implementation after signing a principle or official contract	Risk Avoidance	Interview

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R35	Owner requests for design changes	- Consider about the degree of client's involvement in the design; check and comply with the terms and conditions in the signed contract - Appoint a client’s representative who is vested with power and authority to make final decisions and sign-off drawings. - Requirements should be determined and finalized at the pre-bid stage to avoid excessive change orders.	Risk Mitigation /Reduction	Y.Y. Ling and B.S.Y. Lau (2002); Interview
R36	Ower/ main contractor's disagreement on source of main equipment or materials	Clients should specify their requirements comprehensively in the bid documents	Risk Mitigation/ Reduction	Y.Y. Ling and B.S.Y. Lau (2002)
R37	Changes or improper scope/ work definition in contract	Clients should specify their requirements comprehensively in the bid documents	Risk Mitigation/ Reduction	Y.Y. Ling and B.S.Y. Lau (2002)

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5.2. Case study of a power plant in Vietnam

5.2.1. Introduction of case study

Project name: Nhon Trach 3&4 Combined-Cycle Power Project

The perspective of Nhon Trach 3&4 Combined-Cycle power plant project is shown as Figure 5.1 below.

The Nhon Trach combined-cycle power plant (CCPP) in Vietnam is proposed to be expanded with the addition of two more units, namely Nhon Trach 3 and Nhon Trach 4. This mega project will be developed in Ong Keo Industrial Park, Nhon Trach District, in Dong Nai province, Vietnam.

The two new units will be located on a total area of 34.5ha, with Nhon Trach 3 and Nhon Trach 4 occupying 16.6ha and 17.4ha, respectively. The two new units will have a combined capacity of 1500 MW and make Nhon Trach the first power project in the country to be fuelled by liquefied natural gas (LNG). Vietnam is now dependent on coal-based power, which accounts for about a third of the country's total electricity production. The project will contribute to Vietnam's commitment to achieving net-zero carbon emissions by 2050. Two new units are expected to be operational by May 2025.

The total estimated investment in the project is $1.4bn. The capital required for the development of the two power plants will be sourced through 25% equity and 75% debt. The loan component of the project financing includes an export credit of $600m, $300m in foreign commercial loans and approximately $174.7m in domestic loans.

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Regarding the involved stakeholders, the CCPP is owned by PetroVietnam Power (PV Power), a leading power producer in Vietnam. A consortium of South Korean engineering and construction company Samsung C&T and Taiwanese engineering and construction company CTCI Corporation received a contract to provide engineering, procurement and construction (EPC) services for Nhon Trach 3 and Nhon Trach 4 in March 2022. In particular, Samsung C&T acts as the general contractor/ main contractor of the project, and CTCI provides design-build services. Besides, General Electric (GE) was awarded the contract to supply the gas turbines and associated equipment for the project in May 2022. PV Gas also received a contract to supply LNG for the project in 2019.

Figure 5.1. Nhon Trach 3&4 CCPP's project perspective

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5.2.2. Risk in design phase of case study

When designing the Nhon Trach 3 and 4 Combined-Cycle Power Project in Vietnam, several challenges and difficulties may arise. First of all is the environmental considerations. Ensuring compliance with environmental regulations and mitigating the project's impact on the surrounding ecosystem can be challenging. Next is the technical complexity. Combined-cycle power projects involve intricate engineering and technical considerations. Designing the power plant layout, selecting appropriate equipment, and optimizing the energy generation process require expertise in various disciplines. Besides that, infrastructure and site constraints such as transmission lines, gas pipelines, and water supply networks can also impact the project's design. Furthermore, stakeholder engagement is also an issue that needs to be concerned. Engaging with diverse stakeholders, including local communities, government agencies, and non-governmental organizations, is crucial for project success. As mentioned above, the project is involved by several contractors from different countries. So communication and cooperation between contractors is a big deal. Last but not least, project financing is also a problem when designing this project. Securing adequate funding and managing project finances can be a significant challenge, because this power plant is 75% debt from ODA. Therefore, right from the design stage, it is necessary to have the most optimal design to reduce project costs. Thus, addressing these challenges often requires collaboration among various stakeholders, good risk planning, and comprehensive risk assessments can help navigate these difficulties and ensure the successful design and implementation of the Nhon Trach 3 and 4 Combined-Cycle Power Project in Vietnam.

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In fact, when designing this power plant, in the early stages of the project, there were some problems with the investor's input information, so as a result, the design progress of the project was delayed 2 months compared to the original plan. The project began its design phase in October 2022, and was completed by August 2023. The design progress of this project is described in Figure 5.2 below. However, by using the form of Design-Build project, this did not greatly affect the overall progress of the entire project, because the main items of the power plant have all been designed and sent to the construction site for construction.

Figure 5.2. Design progress of Nhon Trach 3&4 CCPP project

Table 5.2 below is a summary of risk management activities when designing Nhon Trach 3&4 CCPP

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Table 5.2. Risk management activities in Nhon Trach 3&4 CCPP

No.	Design risks	Responsibility	Risk management activities of the case study
R1	Inadequate design standard/specification adopted	Design consultant	Apply American standards
R2	Unproven design solutions adopted	Design consultant	Apply American standards
R3	Poor constructability of design	Design consultant	- Conduct meetings with construction contractor and PCM, owner to find out solutions - Use BIM to minimize design variations
R4	Budget overrun in design	Design consultant	- Try to run other design options to reduce construction costs - Limit project's budget at the beginning step
R5	Concept of design is not clear	Owner	Study many options and meeting with owner, construction party to come up with solutions

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R6	Defective or omission in design	Design consultant	- Study lessons learnt reports of previous projects or similar scale projects to avoid design errors - Have a process of planning and checking of results to ensure that complex issues are properly assessed
R7	Designer's unfamiliarity with requirements of codes/standards	Design consultant	Apply American standards
R8	Conflicting because of lack of norms and standards, specifications	Design consultant	Apply American standards
R9	Separation of design and site supervision	Design consultant	- Assign at least 2 designers and 1 checker too improve document's quality - Use BIM to minimize design variations
R10	Design behind schedule	Design consultant	- Make a personnel list and keep the team stable - Apply overtime for employees - WBS-based design planning

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			- Design schedule feedback through periodic reporting - Immediate response and update to design changes - Production monitoring with software - Schedule coordination linked to cost expenditure
R11	Dispute about design responsibility	Design consultant	Assign specific responsibility for the results of the product
R12	Original design was flawed, and later designers continued to rely on original results	Design consultant	Have a clear process of designing and controlling results
R13	Insufficient geological investigation or unknown geological conditions	Design consultant Main contractor	- Refer to data of adjacent construction works - Geotechnical investment also requires a large safety factor to avoid affecting the results later
R14	Incomplete check on input documents	Design consultant	Leader need to check the input documents before assigning tasks to designers

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R15	Inconsistency among core designers	Design consultant	Conduct a meeting with PCM and owner and present to them the options, let them pick the best solution
R16	Differences between designers' work habits and local practice	Design consultant	- Apply American standards - Open and transparent communication to understand and respect the local practices and cultural norms.
R17	Frequent substitutions of design team members	Design consultant	HR management and managing responsibilities, rewards and punishments policies need to be clear
R18	Difficulty in coordination between different design consultants	Design consultant PCM	Invite the PCM to run the meeting if the consultants cannot communicate with each other
R19	Teamwork ability is not effective	Design consultant	- Double check frequently for each party - Join more member to design and confirm information sooner - Establishing a clear communication process - Planning and collaboration between preceding and

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			following steps - Coordination of details among participants in the execution phase
R20	Designers's distraction/ not reached high performance	Design consultant	- Assign at least 2 designers and 1 checker to improve quality - Create a design process and ensure workers follow procedure
R21	Designers lack of technical software handling skills	Design consultant	Need a training programme, especially for newbie
R22	Designers lack of documents management skills	Design consultant	Need a training programme, especially for newbie
R23	Lack of professional designers	Design consultant	- Recruit qualified personnel and experts to carry out power plant projects because this is a complex project

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			- Provide support and resources to foster the growth and development of design talent.
R24	Team leader lacks experiences and management skills	Design consultant	Provide leadership development programs, mentorship opportunities, and ongoing training to enhance the team leader's management skills and support their growth in the role
R25	Inexperienced design team	Owner	- Do not accept bidding packages that are beyond design capabilities - Choose the qualified design consultants before finalizing the bid
R26	Design changes from different technical disciplines of design team	Design consultant	- Join more member to design and confirm information sooner - Establish clear roles and responsibilities - Use BIM to minimize design variations - Use common tools and formats

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			- Communicate frequently and effectively - Participate in design reviews and meetings periodically - Learn from other design disciplines (keep updated and informed on the latest trends, technologies, and innovations in the other design disciplines)
R27	Delay of resolving matters between all of involved stakeholders	All stakeholders	- Add a condition to set a deadline for the issue documents to move forward - Make detailed plans and timelines for participating parties
R28	Inaccurate information from involved stakeholders	All stakeholders	Double check frequently for each party
R29	Owner/ main contractor misunderstands designer's proposal	Owner Main contractor	Establishing a clear communication process

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R30	Inaccurate, missing, vague, or illegal information in owner's requirements	Owner	Require owners to provide appropriate and accurate information for design
R31	Unduly long period of design review by owner/ main contractor	Owner Main contractor	Add conditions about setting up a deadline for issue documents to move forward if it takes too long to receive feedback.
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers	Owner Main contractor Design consultant	- Single contract would certainly reduce the number of project participants - Project participants should make the commitment to comply with the agreed format for information flow and interaction. - Establishing a clear communication process - Planning and collaboration between preceding and following steps - Coordination of details among participants in the execution phase

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R33	Payment delays	Owner	- Request advance payment before proceeding with design - Require the investor to split payments by stages or by the amount of work completed - Actively tracking short path and implement appropriate measures - Rapid reaction such as decreasing speed of activities and increasing follow-ups of nonpayments.
R34	Owner/ main contractor requests to proceed design without signing contract	Owner	Only start project implementation after signing a principle or official contract
R35	Owner requests for design changes	Owner	- Request signing a contract of arised workload - Consider about the degree of client's involvement in the design; check and comply with the terms and conditions in the signed contract - Appoint a client's representative who is vested with power and authority to make final decisions and sign-off

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			drawings. - Requirements should be determined and finalized at the pre-bid stage to avoid excessive change orders.
R36	Ower/ main contractor's disagreement on source of main equipment or materials	Owner Main contractor	Clients should specify their requirements comprehensively in the bid documents
R37	Changes or improper scope/ work definition in contract	Owner Main contractor	Clients should specify their requirements comprehensively in the bid documents

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5.2.3. Discussion of management activities between literature review and case study

From the results of literature review and case study, following key points can be observed when managing risks in the design phase of DB power plants:

First of all, using international design standards, in the case of the Nhon Trach 3 & 4 CCPP is American design standards, will reduce the risk of conflicts during the design process. According to the experience of designers in Vietnam, with specific types of structures in power plants such as pipeline supports, factories, warehouses, operating houses, pipe racks, and so on, all are steel structures. Therefore, using American standards for power plants in Vietnam is completely possible. Furthermore, the use of international design standards also helps contractors from different countries around the world to access more quickly, helping to minimize unnecessary errors compared to using Vietnamese design standards.

Secondly, a useful and highly effective method in designing a DB project is to use Building Information Modeling (BIM). It enables stakeholders to collaborate by integrating design and construction processes. Besides, BIM enables clash detection and coordination, allowing for the early identification and minimizing conflicts through visualization and simulation tools, which help to understand project's design intent. Especially for a large-scale and complex project such as a power plant, using BIM also help to minimize collisions between different disciplines when designing. Furthermore, BIM also enables the optimization of building systems, which improves energy efficiency and performance. Real-time quantity takeoffs and cost calculations ensure accurate cost estimation and control.

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Thirdly, a clear design process is crucial for the successful execution of a Design-Build power plant project. It provides clarity and consistency in project objectives, facilitating effective communication and streamlined decision-making among stakeholders. By identifying and mitigating risks early on, it helps prevent costly design errors and delays during construction. The design process ensures quality assurance, compliance with standards, and efficient resource allocation, leading to a safe and reliable power plant.

Fourthly, the most important factor of the design phase is human resource management. During the design phase, strategic management and coordination of human resources are referred to as human resource management. Planning, selecting, developing, motivating, managing performance, training, and retaining professionals involved in hiring for the design aspects of construction projects are all part of it. Human resource management in the construction design industry seeks to guarantee that the right people with the necessary abilities, know-how, and experience are found and added to the project team. It entails assessing the need for staffing, outlining job duties and responsibilities, and luring competent experts with efficient hiring and selection procedures. Once the team is assembled, human resource management focuses on providing the necessary training and development opportunities to enhance the skills and capabilities of the team members. This can include technical training, software proficiency, industry standards, and project-specific requirements. Additionally, human resource management plays a role in monitoring and evaluating the performance of the design team, providing feedback, and ensuring that project objectives are being met. It also involves fostering collaboration, effective communication, and problem-solving among team members to ensure smooth coordination and successful design outcomes. Motivation and retention of talented professionals in the construction

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design field are also important aspects of human resource management. Providing competitive compensation packages, recognition programs, career development opportunities, and a positive work environment contribute to attracting and retaining skilled individuals. Furthermore, human resource management in construction design involves ensuring compliance with labor laws, regulations, and safety standards. This includes promoting a safe working environment and implementing measures to protect the health and well-being of design professionals.

5.3. Chapter summary

This chapter has outlined risk management activities after reviewing literature, interviewing with experts and especially risk management activities that were carried out in a case study: Nhon Trach 3&4 CCPP. Thereby, some important points drawn are: (1) using international design standards, (2) using Building Information Modeling (BIM) in designing phase, (3) having a clear design process, and (4) having an effective human resource management strategy.

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Chapter 6. Conclusion

6.1. Conclusions

Through reviewing related studies and interviewing experts, this study identified a total of 37 design risk factors in a Design-Build power plant project and its ranking in the Vietnamese market. Besides, this research also categorized these factors into 6 groups through exploratory factor analysis. In addition, several management activities are also suggested to overcome design risk factors in Design-Build power plant projects. Some conclusions of the research could be drawn in accordance with the survey results as follows:

Firstly, the study utilized scoring and ranking based on the Importance index (IMP.I.). Top ten critical risks include: (1) Owner requests for design changes, (2) Defective or omission in design, (3) Design changes from different technical disciplines of design team, (4) Budget overrun in design, (5) Design behind schedule, (6) Separation of design and site supervision, (7) Owner/ main contractor requests to proceed design without signing contract, (8) Poor constructability of design, (9) Payment delays, (10) Inaccurate information from involved stakeholders.

Secondly, six groups created from design risk factors through exploratory factor analysis (EFA) respectively as follows: DR1: Risk of design team lack of capacity and experience, DR2: Risk of improper design scheme, DR3: Risk of design team lack of responsibility, DR4: Risk of inefficient document review and poor cooperation between stakeholders, DR5: Risk of change and requested by owner, DR6: Risk of disagreement and misunderstand by owner.

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Thirdly, ANOVA analysis has been conducted to find out the different point of views of surveyed respondents, who represent different stakeholders participating in Design-Build power plant projects. In general, among 37 design risk factors, there were 6 factors that caused a different trend. R10 “Design behind schedule”, R12 “Original design was flawed, and later designers continued to rely on original results”, R24 “Team leader lacks experiences and management skills”, R25 “Inexperienced design team”, R33 “Payment delays” and R34 “Owner/ main contractor requests to proceed design without signing contract” have a difference in the opinions of survey participants regarding to the current expertise and organization of respondents. Therefore, base on that differences, project parties should execute more discussion, collaboration, and informed decision-making rather than solely relying on it as the sole determinant of risk prioritization and mitigation.

Fourthly, several management activities are also suggested to overcome design risk factors after reviewing literature and interviewing experts. Especially the risk management activities that were carried out in a case study: Nhon Trach 3&4 CCPP have been discussed: (1) using international design standards, (2) using Building Information Modeling (BIM) in designing phase, (3) having a clear design process, and (4) having an effective human resource management strategy.

The findings contribute to the body of knowledge in risk analysis of the design phase of design-build power plant projects in Vietnam, and more fundamentally, the findings enhance design-build participants' understanding and awareness of the level of impact and possibility of risk factors during the design phase. This research also provides stakeholders with a checklist and analysis of risks during the design process, enriching research on risk analysis

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and management. Thereby, while designing a power plant, stakeholders could take specific design risk management activities to minimize risks and achieve better project results.

6.2. Recommendations to stakeholders

Several managerial implications can be inferred from the study. First, risk factors are often interrelated; building a model of risk management activities by risk group can better reflect the complex nature of risk's impact on project target. Second, based on the interaction between factors, contractors (design consultants, construction units, project management units) and investors can apply for reference and provide feedback with these risk factors in a systematic and comprehensive way. Project owners need to have specific and clear implementation plans and information to avoid design interruptions. Besides, project owners also need to implement stringent construction selection procedures, thoroughly assessing their experience and capacities to avoid design risks from the designers. In addition, design consultants could refer to the design risk factors and risk management activities mentioned in this thesis to improve design efficiency and increase the success of power plant projects. Because of the complexity of Design-Build power plant projects, construction contractors and project management units can contribute comments and feedback earlier while the design is underway to prevent errors that may arise in design drawings, also shortening the design time and implementation time of the entire project. Third, a consistent design plan is critical to the success of a design-build project, requiring designers to carefully examine design inputs and outputs. Finally, Design-Build contractors should assemble a team of experienced and highly motivated design staff, apply modern technologies to the design phase (using BIM), and develop communication and coordination systems among project participants.

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6.3. Limitations and future research

The research process has limitations. First, the study relies on respondents' subjective perceptions of design risk factors. Second, for the exploratory factor analysis, the more people participating in the survey, the more accurate the results. The ratio of sample size to number of variables is suggested at 5.00. Nevertheless, the research still provides results that can serve as a reference.

The study expands understanding of risk management of power plant design-build projects and creates opportunities and foundations for future research. Future research can be conducted to explore integrated risk management in connection with the design, procurement, and construction of DB projects. In addition, the related investigation into the extent to which this study's findings compare with other integrated procurement modes (e.g., public–private partnership) and separate modes (e.g., more traditional design-bid-build) will be of great benefit to the construction industry. More fundamentally, because human resource management is the key factor to the success of the design phase, further exploration into ways to improve this is suggested. Besides, future research is encouraged to study other types of projects other than power plants, such as transportation projects, infrastructure projects, offshore projects, and so on. Last but not least, future research can analyze and compare risk factors when designing in different countries, such as comparison between Vietnam and Taiwan, giving international project contractors a more general view of risks in different countries and regions.

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Appendices

Appendix A: Expert's background

Interviewee	Current organization	Position	Type of current company	Year of experience	Number of DB power plant project participated
Bui Thanh Chung	Coninco JSC	Project manager, Deputy director	Supervision consultants	23	3
Le Khac Hien	CTCI Vietnam	Civil design leader	Design consultant	14	15
Le Hoang	CTCI Vietnam	Civil design leader	Design consultant	8	7
Ha Manh Thuan	South MeKong Group JSC	Site manager	Contractor	15	3
Pham Duc Manh	Xuan Phu Hai JSC	Project manager	Owner	20	5

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Appendix B: Interview report

B.1. Interview report 1 for adjusting design risk factors

I. Interview with expert 1

1. Interview participants:

- Student: Bui Duc Thang

- Expert: Le Khac Hien, Structural team leader – Civil Dept., CTCI Vietnam

2. Interview time and location:

- Time: 10:00~10:30, December 4th 2023.

- Location: CTCI Vietnam’s office, 6th floor, Charmvit tower, Tran Duy Hung st., Cau Giay dist., Ha Noi, Viet Nam.

3. Interview main content

Q: This is the risk factors from literature review, please give your comment, and let me know if which factors and groups are illogical?

A:

- Remove “G5.4 Designers’ incompetency” because it has the same meaning and overlapping with “G5.3 Inexperienced design consultant”.

- Combine the “G5 Risk of designer's lack of experience” with “G4 Risk of an improper design team” because these two groups seem like both have the same patterns.

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- Move “G7.1 Construction permit has not been approved” and “G7.2 Payment delays” to “G3 Risk from other party”, because these works are responsible of the owner.

- Delete the Possibability, because all of the factors will appear due to literature review.

Q: Are there any risk factors not included in the questionnaire that you feel is important?

A: No more factors, those factors abovementioned are quite enough.

II. Interview with expert 2

1. Interview participants:

- Student: Bui Duc Thang

- Expert: Bui Thanh Chung, Project manager, Deputy director, Coninco JSC.

2. Interview time and location:

- Time: 20:00~20:40, December 24th 2023.

- Location: Online meeting via Google Meet.

3. Interview main content

Q: This is the risk factors from literature review, please give your comment, and let me know if which factors and groups are illogical?

A:

- Adding introduction part.

- Move G3.2 to group 2; G3.3 to group 4; G3.6 to group 1; G3.11 to group 5.

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- Rearrange the risk factors of group 3 respectively: investor, subcontractor, supplier, etc.

- Combine the “G5 Risk of designer's lack of experience” with “G4 Risk of an improper design team” because these two groups seem like both have the same patterns.

Q: Are there any risk factors not included in the questionnaire that you feel is important?

A: No, those factors abovementioned are quite enough.

B.2. Interview report 2 for adjusting management activities

1. Interview participants:

- Student: Bui Duc Thang

- Expert:

Le Khac Hien, Structural team leader – Civil Dept., CTCI Vietnam (representative of Design consultant)

Le Hoang, Structural team leader – Civil Dept., CTCI Vietnam (representative of Design consultant)

Bui Thanh Chung, Project manager - Coninco JSC (representative of PCM)

Pham Duc Manh, Project manager – Xuan Phu Hai investment and construction JSC (representative of Owner)

Ha Manh Thuan, Site manager – South MeKong Group JSC (representative of Contractor)

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2. Interview method

Present research results online via the internet, then send a excel file and ask interviewees to write down their opinions.

3. Interview main content

After presenting the research survey results and risk management activities, conduct interviews and ask for expert opinions on the reasonableness of the survey results and actual risk management activities when they design a construction project. Among them, 2 out of 5 experts have participated in designing the project that research use as a case study for analysis. These two people were asked about the project's situation and the risk management activities performed during the design to compare with the literature review. After collecting all their opinions, the results are combined in a table in the attachment.

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Appendix C: Questionnaire survey form

Questionnaire survey

Dear valuable respondents,

My name is Bui Duc Thang and I am a graduate student at National Taiwan University. My master thesis title is “Risk Management in Design Phase of Design-Build Power Plant Projects”. I would like to focus on investigating the risk factors that are encountered and its probability when designing a power plant project in the Design-Build delivery method. Up to now, I have investigated the risk factors by reviewing literature and interviewing some specialists. The purpose of this questionnaire survey is to receive more opinions from different points of views that would help to find out critical risk factors that could affect the projects and its probability to occur. Therefore, please give your opinion about these risk factors by choosing the answer in the answer sheet.

All your filled answers and information are confidential. You will need only 10-15 minutes to fill the whole set of questionnaires. The conclusion will be drawn based on your survey answers, so please take time and answer all questions genuinely.

Thank you for your consideration in regards to this. If you have any questions to clarify don’t hesitate to contact me at the number listed below.

Sincerely,

Bui Duc Thang

MSc 2nd Year Student,

Department of Civil Engineering, National Taiwan University

doi:10.6342/NTU202402214

Email: thangbd.vncc@gmail.com | r11521734@ntu.edu.tw

Research supervisor

Assistant Prof. Lin Szu Yun

Department of Civil Engineering, National Taiwan University

Email: szuyunlin@ntu.edu.tw

Section A. General questions

I. Personal questions

1. What is your nationality?

- ☐ Vietnamese
- ☐ Taiwanese
- ☐ Other (please specify) ____

2. How long have you worked in the construction industry?

- ☐ Below 5 years
- ☐ 5 – 9 years
- ☐ 10-14 years
- ☐ 15-19 years
- ☐ Above 20 years

2. What is your current expertise?

- ☐ Architect
- ☐ Structural engineer

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- ☐ Quantity surveyor
- ☐ Project manager
- ☐ Site engineer
- ☐ Other (please specify) ____

3. What type of your current organization?

- ☐ Private owner
- ☐ Design consultant
- ☐ Contractor
- ☐ Public authority
- ☐ PCM - Project and Construction Management
- ☐ Other (please specify) ____

4. What is your highest education level?

- ☐ High school
- ☐ Bachelor
- ☐ Master
- ☐ PhD

II. Project related questions

1. Have you ever participated in any Design-Build project?

- ☐ Yes
- ☐ No

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2. How many DB projects did you participate in? ______________________

3. Type of project you have participated in? (Multiple choice)

- ☐ Power plant
- ☐ Building
- ☐ Infrastructure
- ☐ Industrial factory
- ☐ Other (please specify) ____________________________________

4. Largest capacity power plant project that you have participated in? ________________

(If you haven't participated in the DB power plant project, please skip this question).

5. Source of capital to implement the project in which you have participated?

- ☐ Government
- ☐ Private
- ☐ ODA (Official Development Assistance)
- ☐ Other (please specify) ____________________________________

Section B. Risk factors that affect to the design phase of design-build project and its probability to occur

Please choose and mark "X" in one of the following boxes depending on the level of impact and level of probability of risk factors when implementing a design-build power plant project, as follows:

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Level	Level of impact	Level of probability
1	Very low	Very low
2	Low	Low
3	Moderate	Moderate
4	High	High
5	Very high	Very high

No.	Design risks	Level of impact					Level of probability				
		1	2	3	4	5	1	2	3	4	5
R1	Inadequate design standard/specification adopted										
R2	Unproven design solutions adopted										
R3	Poor constructability of design										
R4	Budget overrun in design										
R5	Concept of design is not clear										
R6	Defective or omission in design										
R7	Designers' unfamiliarity with requirements of codes/standards										
R8	Conflicting because of lack of norms and standards, specifications										
R9	Separation of design and site supervision										
R10	Design behind schedule										
R11	Dispute about design responsibility										
R12	Original design was flawed, and later designers continued to rely on original results										
R13	Insufficient geological investigation or unknown geological conditions										

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R14	Incomplete check on input documents										
R15	Inconsistency among core designers										
R16	Differences between designers’ work habits and local practice										
R17	Frequent substitutions of design team members										
R18	Difficulty in coordination between different design consultants										
R19	Teamwork ability is not effective										
R20	Designers's distraction/ not reached high performance										
R21	Designers lack of technical software handling skills										
R22	Designers lack of documents management skills										
R23	Lack of professional designers										
R24	Team leader lacks experiences and management skills										
R25	Inexperienced design team										
R26	Design changes from different technical disciplines of design team										
R27	Delay of resolving matters between all of involved stakeholders										
R28	Inaccurate information from involved stakeholders										
R29	Owner/ main contractor misunderstands designer's proposal										
R30	Inaccurate, missing, vague, or illegal information in owner's requirements										

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R31	Unduly long period of design review by onwer/ main contractor										
R32	Communication gap or misinterpretation on exchange information between owner/ main contractor and designers										
R33	Payment delays										
R34	Owner/ main contractor requests to proceed design without signing contract										
R35	Owner requests for design changes										
R36	Ower/ main contractor's disagreement on source of main equipment or materials										
R37	Changes or improper scope/ work definition in contract										

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Appendix D: One-way ANOVA descriptives statistics

Descriptives statistics of working experience

Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
R1	Below 5 years	43	3.23	1.130	0.172	2.88	3.58
	5-9 years	35	3.06	1.349	0.228	2.59	3.52
	10-14 years	28	2.43	1.260	0.238	1.94	2.92
	Total	106	2.96	1.272	0.124	2.72	3.21
R2	Below 5 years	43	3.23	1.192	0.182	2.87	3.60
	5-9 years	35	3.00	1.260	0.213	2.57	3.43
	10-14 years	28	2.32	1.219	0.230	1.85	2.79
	Total	106	2.92	1.266	0.123	2.67	3.16
R3	Below 5 years	43	3.49	1.032	0.157	3.17	3.81
	5-9 years	35	3.49	1.121	0.190	3.10	3.87
	10-14 years	28	2.93	1.184	0.224	2.47	3.39
	Total	106	3.34	1.120	0.109	3.12	3.56
R4	Below 5 years	43	3.86	1.014	0.155	3.55	4.17
	5-9 years	35	3.46	1.245	0.210	3.03	3.88
	10-14 years	28	3.32	1.188	0.225	2.86	3.78
	Total	106	3.58	1.154	0.112	3.36	3.81
R5	Below 5 years	43	3.35	1.089	0.166	3.01	3.68
	5-9 years	35	3.14	1.192	0.201	2.73	3.55
	10-14 years	28	2.79	1.197	0.226	2.32	3.25
	Total	106	3.13	1.164	0.113	2.91	3.36
R6	Below 5 years	43	4.00	1.175	0.179	3.64	4.36
	5-9 years	35	3.54	1.462	0.247	3.04	4.05
	10-14 years	28	3.21	1.500	0.283	2.63	3.80

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	Total	106	3.64	1.388	0.135	3.37	3.91
R7	Below 5 years	43	3.05	1.174	0.179	2.69	3.41
	5-9 years	35	2.69	1.430	0.242	2.19	3.18
	10-14 years	28	2.32	1.124	0.212	1.89	2.76
	Total	106	2.74	1.275	0.124	2.49	2.98
R8	Below 5 years	43	2.72	1.120	0.171	2.38	3.07
	5-9 years	35	2.40	1.143	0.193	2.01	2.79
	10-14 years	28	2.32	0.983	0.186	1.94	2.70
	Total	106	2.51	1.098	0.107	2.30	2.72
R9	Below 5 years	43	3.70	0.914	0.139	3.42	3.98
	5-9 years	35	3.11	1.278	0.216	2.68	3.55
	10-14 years	28	2.86	1.297	0.245	2.35	3.36
	Total	106	3.28	1.193	0.116	3.05	3.51
R10	Below 5 years	43	3.79	1.206	0.184	3.42	4.16
	5-9 years	35	3.09	1.579	0.267	2.54	3.63
	10-14 years	28	3.14	1.407	0.266	2.60	3.69
	Total	106	3.39	1.418	0.138	3.11	3.66
R11	Below 5 years	43	2.65	0.870	0.133	2.38	2.92
	5-9 years	35	2.14	1.216	0.206	1.73	2.56
	10-14 years	28	2.36	1.062	0.201	1.95	2.77
	Total	106	2.41	1.058	0.103	2.20	2.61
R12	Below 5 years	43	3.40	1.116	0.170	3.05	3.74
	5-9 years	35	2.71	1.384	0.234	2.24	3.19
	10-14 years	28	2.89	1.257	0.238	2.41	3.38
	Total	106	3.04	1.272	0.124	2.79	3.28
R13	Below 5 years	43	3.00	1.175	0.179	2.64	3.36
	5-9 years	35	2.54	1.197	0.202	2.13	2.95
	10-14 years	28	2.75	1.041	0.197	2.35	3.15
	Total	106	2.78	1.155	0.112	2.56	3.01
R14	Below 5 years	43	2.93	0.985	0.150	2.63	3.23
	5-9 years	35	2.57	1.378	0.233	2.10	3.04

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	10-14 years	28	2.75	1.005	0.190	2.36	3.14
	Total	106	2.76	1.134	0.110	2.55	2.98
R15	Below 5 years	43	2.53	1.008	0.154	2.22	2.85
	5-9 years	35	2.20	1.106	0.187	1.82	2.58
	10-14 years	28	2.57	0.997	0.188	2.18	2.96
	Total	106	2.43	1.042	0.101	2.23	2.63
R16	Below 5 years	43	2.49	1.334	0.203	2.08	2.90
	5-9 years	35	2.03	1.248	0.211	1.60	2.46
	10-14 years	28	2.18	1.188	0.225	1.72	2.64
	Total	106	2.25	1.273	0.124	2.01	2.50
R17	Below 5 years	43	2.60	1.158	0.177	2.25	2.96
	5-9 years	35	2.26	1.146	0.194	1.86	2.65
	10-14 years	28	2.46	1.170	0.221	2.01	2.92
	Total	106	2.45	1.156	0.112	2.23	2.68
R18	Below 5 years	43	3.07	0.985	0.150	2.77	3.37
	5-9 years	35	2.74	1.172	0.198	2.34	3.15
	10-14 years	28	2.64	0.989	0.187	2.26	3.03
	Total	106	2.85	1.058	0.103	2.65	3.05
R19	Below 5 years	43	3.07	1.009	0.154	2.76	3.38
	5-9 years	35	2.60	1.193	0.202	2.19	3.01
	10-14 years	28	2.93	1.184	0.224	2.47	3.39
	Total	106	2.88	1.127	0.109	2.66	3.09
R20	Below 5 years	43	2.84	0.949	0.145	2.55	3.13
	5-9 years	35	2.77	1.003	0.169	2.43	3.12
	10-14 years	28	2.57	1.069	0.202	2.16	2.99
	Total	106	2.75	0.996	0.097	2.55	2.94
R21	Below 5 years	43	3.74	0.848	0.129	3.48	4.01
	5-9 years	35	2.74	1.172	0.198	2.34	3.15
	10-14 years	28	3.04	1.347	0.254	2.51	3.56
	Total	106	3.23	1.181	0.115	3.00	3.45

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R22	Below 5 years	43	3.49	1.077	0.164	3.16	3.82
	5-9 years	35	2.97	1.224	0.207	2.55	3.39
	10-14 years	28	2.79	1.166	0.220	2.33	3.24
	Total	106	3.13	1.180	0.115	2.90	3.36
R23	Below 5 years	43	3.47	0.882	0.135	3.19	3.74
	5-9 years	35	2.86	1.216	0.206	2.44	3.27
	10-14 years	28	2.93	1.215	0.230	2.46	3.40
	Total	106	3.12	1.119	0.109	2.91	3.34
R24	Below 5 years	43	3.58	0.957	0.146	3.29	3.88
	5-9 years	35	2.83	1.248	0.211	2.40	3.26
	10-14 years	28	2.86	1.079	0.204	2.44	3.28
	Total	106	3.14	1.142	0.111	2.92	3.36
R25	Below 5 years	43	3.77	1.250	0.191	3.38	4.15
	5-9 years	35	2.91	1.401	0.237	2.43	3.40
	10-14 years	28	3.14	1.353	0.256	2.62	3.67
	Total	106	3.32	1.370	0.133	3.06	3.58
R26	Below 5 years	43	3.53	0.935	0.143	3.25	3.82
	5-9 years	35	3.09	1.147	0.194	2.69	3.48
	10-14 years	28	3.00	1.186	0.224	2.54	3.46
	Total	106	3.25	1.094	0.106	3.03	3.46
R27	Below 5 years	43	3.23	0.996	0.152	2.93	3.54
	5-9 years	35	2.91	1.067	0.180	2.55	3.28
	10-14 years	28	2.82	1.124	0.212	2.39	3.26
	Total	106	3.02	1.060	0.103	2.81	3.22
R28	Below 5 years	43	3.60	0.877	0.134	3.33	3.87
	5-9 years	35	2.94	1.083	0.183	2.57	3.31
	10-14 years	28	2.82	1.219	0.230	2.35	3.29
	Total	106	3.18	1.094	0.106	2.97	3.39
R29	Below 5 years	43	3.30	1.036	0.158	2.98	3.62
	5-9 years	35	2.69	1.367	0.231	2.22	3.16

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	10-14 years	28	3.18	1.335	0.252	2.66	3.70
	Total	106	3.07	1.252	0.122	2.82	3.31
R30	Below 5 years	43	3.44	0.983	0.150	3.14	3.74
	5-9 years	35	3.03	1.294	0.219	2.58	3.47
	10-14 years	28	2.86	1.177	0.223	2.40	3.31
	Total	106	3.15	1.161	0.113	2.93	3.37
R31	Below 5 years	43	3.07	0.799	0.122	2.82	3.32
	5-9 years	35	2.54	1.120	0.189	2.16	2.93
	10-14 years	28	2.93	0.940	0.178	2.56	3.29
	Total	106	2.86	0.970	0.094	2.67	3.05
R32	Below 5 years	43	3.09	0.921	0.140	2.81	3.38
	5-9 years	35	3.00	1.372	0.232	2.53	3.47
	10-14 years	28	2.68	1.156	0.219	2.23	3.13
	Total	106	2.95	1.150	0.112	2.73	3.17
R33	Below 5 years	43	3.74	0.954	0.145	3.45	4.04
	5-9 years	35	3.06	1.162	0.196	2.66	3.46
	10-14 years	28	3.21	1.287	0.243	2.72	3.71
	Total	106	3.38	1.150	0.112	3.16	3.60
R34	Below 5 years	43	3.70	1.013	0.154	3.39	4.01
	5-9 years	35	3.29	1.363	0.230	2.82	3.75
	10-14 years	28	3.25	1.236	0.234	2.77	3.73
	Total	106	3.44	1.204	0.117	3.21	3.68
R35	Below 5 years	43	3.74	1.093	0.167	3.41	4.08
	5-9 years	35	3.29	1.178	0.199	2.88	3.69
	10-14 years	28	3.29	1.243	0.235	2.80	3.77
	Total	106	3.47	1.173	0.114	3.25	3.70
R36	Below 5 years	43	3.30	0.964	0.147	3.01	3.60
	5-9 years	35	2.97	1.150	0.194	2.58	3.37
	10-14 years	28	3.04	0.999	0.189	2.65	3.42
	Total	106	3.12	1.039	0.101	2.92	3.32

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R37	Below 5 years	43	3.28	0.908	0.139	3.00	3.56
	5-9 years	35	2.89	1.051	0.178	2.52	3.25
	10-14 years	28	3.04	1.105	0.209	2.61	3.46
	Total	106	3.08	1.015	0.099	2.89	3.28

Descriptives statistics of expertise

Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
R1	Architect	11	2.36	1.027	0.310	1.67	3.05
	Structural engineer	28	2.61	1.197	0.226	2.14	3.07
	Quantity surveyor	10	3.00	1.333	0.422	2.05	3.95
	Project manager	33	3.30	1.287	0.224	2.85	3.76
	Site engineer	24	3.17	1.308	0.267	2.61	3.72
	Total	106	2.96	1.272	0.124	2.72	3.21
R2	Architect	11	2.45	0.934	0.282	1.83	3.08
	Structural engineer	28	2.75	1.005	0.190	2.36	3.14
	Quantity surveyor	10	2.80	0.919	0.291	2.14	3.46
	Project manager	33	3.33	1.339	0.233	2.86	3.81
	Site engineer	24	2.79	1.587	0.324	2.12	3.46
	Total	106	2.92	1.266	0.123	2.67	3.16
R3	Architect	11	3.55	0.688	0.207	3.08	4.01
	Structural engineer	28	3.54	1.071	0.202	3.12	3.95
	Quantity surveyor	10	3.10	0.738	0.233	2.57	3.63
	Project manager	33	3.39	1.171	0.204	2.98	3.81
	Site engineer	24	3.04	1.367	0.279	2.46	3.62
	Total	106	3.34	1.120	0.109	3.12	3.56
R4	Architect	11	4.00	0.894	0.270	3.40	4.60

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	Structural engineer	28	3.75	1.295	0.245	3.25	4.25
	Quantity surveyor	10	3.60	0.843	0.267	3.00	4.20
	Project manager	33	3.48	1.034	0.180	3.12	3.85
	Site engineer	24	3.33	1.341	0.274	2.77	3.90
	Total	106	3.58	1.154	0.112	3.36	3.81
R5	Architect	11	3.00	1.000	0.302	2.33	3.67
	Structural engineer	28	3.00	1.122	0.212	2.56	3.44
	Quantity surveyor	10	3.10	1.101	0.348	2.31	3.89
	Project manager	33	3.39	1.144	0.199	2.99	3.80
	Site engineer	24	3.00	1.351	0.276	2.43	3.57
	Total	106	3.13	1.164	0.113	2.91	3.36
R6	Architect	11	4.27	1.191	0.359	3.47	5.07
	Structural engineer	28	3.93	1.438	0.272	3.37	4.49
	Quantity surveyor	10	3.70	1.059	0.335	2.94	4.46
	Project manager	33	3.58	1.415	0.246	3.07	4.08
	Site engineer	24	3.08	1.381	0.282	2.50	3.67
	Total	106	3.64	1.388	0.135	3.37	3.91
R7	Architect	11	2.18	1.079	0.325	1.46	2.91
	Structural engineer	28	2.50	1.139	0.215	2.06	2.94
	Quantity surveyor	10	3.20	0.919	0.291	2.54	3.86
	Project manager	33	2.94	1.197	0.208	2.51	3.36
	Site engineer	24	2.79	1.641	0.335	2.10	3.48
	Total	106	2.74	1.275	0.124	2.49	2.98
R8	Architect	11	2.36	1.027	0.310	1.67	3.05
	Structural engineer	28	2.29	1.013	0.191	1.89	2.68
	Quantity surveyor	10	3.00	1.054	0.333	2.25	3.75
	Project manager	33	2.88	1.139	0.198	2.47	3.28
	Site engineer	24	2.13	1.035	0.211	1.69	2.56
	Total	106	2.51	1.098	0.107	2.30	2.72
R9	Architect	11	3.64	0.674	0.203	3.18	4.09
	Structural engineer	28	3.39	1.197	0.226	2.93	3.86

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	Quantity surveyor	10	3.70	0.675	0.213	3.22	4.18
	Project manager	33	3.18	1.236	0.215	2.74	3.62
	Site engineer	24	2.96	1.429	0.292	2.35	3.56
	Total	106	3.28	1.193	0.116	3.05	3.51
R10	Architect	11	4.36	0.809	0.244	3.82	4.91
	Structural engineer	28	3.75	1.578	0.298	3.14	4.36
	Quantity surveyor	10	4.00	0.943	0.298	3.33	4.67
	Project manager	33	3.52	1.149	0.200	3.11	3.92
	Site engineer	24	2.08	1.100	0.225	1.62	2.55
	Total	106	3.39	1.418	0.138	3.11	3.66
R11	Architect	11	3.09	1.136	0.343	2.33	3.85
	Structural engineer	28	2.46	0.962	0.182	2.09	2.84
	Quantity surveyor	10	2.90	0.876	0.277	2.27	3.53
	Project manager	33	2.45	0.905	0.157	2.13	2.78
	Site engineer	24	1.75	1.113	0.227	1.28	2.22
	Total	106	2.41	1.058	0.103	2.20	2.61
R12	Architect	11	3.82	0.751	0.226	3.31	4.32
	Structural engineer	28	3.21	1.101	0.208	2.79	3.64
	Quantity surveyor	10	3.00	1.155	0.365	2.17	3.83
	Project manager	33	3.42	1.200	0.209	3.00	3.85
	Site engineer	24	1.96	1.197	0.244	1.45	2.46
	Total	106	3.04	1.272	0.124	2.79	3.28
R13	Architect	11	2.82	0.603	0.182	2.41	3.22
	Structural engineer	28	2.61	0.994	0.188	2.22	2.99
	Quantity surveyor	10	3.20	1.033	0.327	2.46	3.94
	Project manager	33	3.27	1.281	0.223	2.82	3.73
	Site engineer	24	2.13	1.076	0.220	1.67	2.58
	Total	106	2.78	1.155	0.112	2.56	3.01
R14	Architect	11	3.09	0.701	0.211	2.62	3.56
	Structural engineer	28	2.75	1.175	0.222	2.29	3.21

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	Quantity surveyor	10	3.40	0.843	0.267	2.80	4.00
	Project manager	33	3.12	0.927	0.161	2.79	3.45
	Site engineer	24	1.88	1.154	0.236	1.39	2.36
	Total	106	2.76	1.134	0.110	2.55	2.98
R15	Architect	11	2.64	1.027	0.310	1.95	3.33
	Structural engineer	28	2.25	1.110	0.210	1.82	2.68
	Quantity surveyor	10	2.70	0.483	0.153	2.35	3.05
	Project manager	33	2.82	0.882	0.154	2.51	3.13
	Site engineer	24	1.92	1.139	0.232	1.44	2.40
	Total	106	2.43	1.042	0.101	2.23	2.63
R16	Architect	11	1.82	1.250	0.377	0.98	2.66
	Structural engineer	28	1.93	1.184	0.224	1.47	2.39
	Quantity surveyor	10	2.70	1.059	0.335	1.94	3.46
	Project manager	33	2.67	1.451	0.253	2.15	3.18
	Site engineer	24	2.08	1.060	0.216	1.64	2.53
	Total	106	2.25	1.273	0.124	2.01	2.50
R17	Architect	11	2.27	1.009	0.304	1.59	2.95
	Structural engineer	28	2.18	1.335	0.252	1.66	2.70
	Quantity surveyor	10	3.00	0.667	0.211	2.52	3.48
	Project manager	33	2.76	1.119	0.195	2.36	3.15
	Site engineer	24	2.21	1.103	0.225	1.74	2.67
	Total	106	2.45	1.156	0.112	2.23	2.68
R18	Architect	11	3.36	0.505	0.152	3.02	3.70
	Structural engineer	28	3.00	1.018	0.192	2.61	3.39
	Quantity surveyor	10	3.30	0.823	0.260	2.71	3.89
	Project manager	33	2.94	1.029	0.179	2.57	3.30
	Site engineer	24	2.13	1.116	0.228	1.65	2.60
	Total	106	2.85	1.058	0.103	2.65	3.05
R19	Architect	11	3.45	0.688	0.207	2.99	3.92
	Structural engineer	28	2.96	1.036	0.196	2.56	3.37

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	Quantity surveyor	10	2.90	0.568	0.180	2.49	3.31
	Project manager	33	3.12	1.193	0.208	2.70	3.54
	Site engineer	24	2.17	1.204	0.246	1.66	2.68
	Total	106	2.88	1.127	0.109	2.66	3.09
R20	Architect	11	3.09	0.831	0.251	2.53	3.65
	Structural engineer	28	2.82	1.020	0.193	2.43	3.22
	Quantity surveyor	10	3.10	0.876	0.277	2.47	3.73
	Project manager	33	2.73	1.069	0.186	2.35	3.11
	Site engineer	24	2.38	0.924	0.189	1.98	2.77
	Total	106	2.75	0.996	0.097	2.55	2.94
R21	Architect	11	3.91	1.136	0.343	3.15	4.67
	Structural engineer	28	3.32	1.278	0.242	2.83	3.82
	Quantity surveyor	10	2.80	0.632	0.200	2.35	3.25
	Project manager	33	3.61	1.088	0.189	3.22	3.99
	Site engineer	24	2.46	0.977	0.199	2.05	2.87
	Total	106	3.23	1.181	0.115	3.00	3.45
R22	Architect	11	4.00	0.894	0.270	3.40	4.60
	Structural engineer	28	3.29	1.272	0.240	2.79	3.78
	Quantity surveyor	10	3.30	0.949	0.300	2.62	3.98
	Project manager	33	2.97	1.212	0.211	2.54	3.40
	Site engineer	24	2.71	1.042	0.213	2.27	3.15
	Total	106	3.13	1.180	0.115	2.90	3.36
R23	Architect	11	3.45	1.036	0.312	2.76	4.15
	Structural engineer	28	3.29	1.213	0.229	2.82	3.76
	Quantity surveyor	10	3.10	0.738	0.233	2.57	3.63
	Project manager	33	3.33	1.164	0.203	2.92	3.75
	Site engineer	24	2.50	0.933	0.190	2.11	2.89
	Total	106	3.12	1.119	0.109	2.91	3.34
R24	Architect	11	3.36	0.809	0.244	2.82	3.91
	Structural engineer	28	3.39	1.227	0.232	2.92	3.87

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	Quantity surveyor	10	3.50	1.269	0.401	2.59	4.41
	Project manager	33	3.39	1.029	0.179	3.03	3.76
	Site engineer	24	2.25	0.847	0.173	1.89	2.61
	Total	106	3.14	1.142	0.111	2.92	3.36
R25	Architect	11	3.91	0.944	0.285	3.27	4.54
	Structural engineer	28	3.57	1.425	0.269	3.02	4.12
	Quantity surveyor	10	3.20	1.135	0.359	2.39	4.01
	Project manager	33	3.85	1.149	0.200	3.44	4.26
	Site engineer	24	2.08	1.100	0.225	1.62	2.55
	Total	106	3.32	1.370	0.133	3.06	3.58
R26	Architect	11	3.73	0.467	0.141	3.41	4.04
	Structural engineer	28	3.18	1.090	0.206	2.76	3.60
	Quantity surveyor	10	3.50	1.179	0.373	2.66	4.34
	Project manager	33	3.45	1.092	0.190	3.07	3.84
	Site engineer	24	2.71	1.122	0.229	2.23	3.18
	Total	106	3.25	1.094	0.106	3.03	3.46
R27	Architect	11	3.64	0.674	0.203	3.18	4.09
	Structural engineer	28	3.18	1.056	0.200	2.77	3.59
	Quantity surveyor	10	3.30	0.823	0.260	2.71	3.89
	Project manager	33	3.06	1.171	0.204	2.65	3.48
	Site engineer	24	2.38	0.875	0.179	2.01	2.74
	Total	106	3.02	1.060	0.103	2.81	3.22
R28	Architect	11	3.36	0.809	0.244	2.82	3.91
	Structural engineer	28	3.18	1.020	0.193	2.78	3.57
	Quantity surveyor	10	3.20	0.919	0.291	2.54	3.86
	Project manager	33	3.33	1.190	0.207	2.91	3.76
	Site engineer	24	2.88	1.227	0.250	2.36	3.39
	Total	106	3.18	1.094	0.106	2.97	3.39
R29	Architect	11	3.36	0.809	0.244	2.82	3.91
	Structural engineer	28	2.82	1.249	0.236	2.34	3.31
	Quantity surveyor	10	3.20	0.919	0.291	2.54	3.86
	Project manager	33	3.64	1.194	0.208	3.21	4.06
	Site engineer	24	2.38	1.279	0.261	1.83	2.92
	Total	106	3.07	1.252	0.122	2.82	3.31
R30	Architect	11	3.09	0.539	0.163	2.73	3.45

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	Structural engineer	28	2.89	1.100	0.208	2.47	3.32
	Quantity surveyor	10	3.30	1.059	0.335	2.54	4.06
	Project manager	33	3.58	1.200	0.209	3.15	4.00
	Site engineer	24	2.83	1.308	0.267	2.28	3.39
	Total	106	3.15	1.161	0.113	2.93	3.37
R31	Architect	11	3.09	0.539	0.163	2.73	3.45
	Structural engineer	28	2.71	0.897	0.169	2.37	3.06
	Quantity surveyor	10	3.40	0.843	0.267	2.80	4.00
	Project manager	33	3.24	0.830	0.145	2.95	3.54
	Site engineer	24	2.17	1.049	0.214	1.72	2.61
	Total	106	2.86	0.970	0.094	2.67	3.05
R32	Architect	11	3.00	0.632	0.191	2.58	3.42
	Structural engineer	28	2.89	1.100	0.208	2.47	3.32
	Quantity surveyor	10	3.40	0.966	0.306	2.71	4.09
	Project manager	33	3.00	0.935	0.163	2.67	3.33
	Site engineer	24	2.75	1.648	0.336	2.05	3.45
	Total	106	2.95	1.150	0.112	2.73	3.17
R33	Architect	11	4.18	0.751	0.226	3.68	4.69
	Structural engineer	28	3.64	1.224	0.231	3.17	4.12
	Quantity surveyor	10	3.30	1.337	0.423	2.34	4.26
	Project manager	33	3.48	1.034	0.180	3.12	3.85
	Site engineer	24	2.58	0.881	0.180	2.21	2.96
	Total	106	3.38	1.150	0.112	3.16	3.60
R34	Architect	11	4.27	0.786	0.237	3.74	4.80
	Structural engineer	28	3.79	1.424	0.269	3.23	4.34
	Quantity surveyor	10	3.10	1.287	0.407	2.18	4.02
	Project manager	33	3.58	0.936	0.163	3.24	3.91
	Site engineer	24	2.63	0.924	0.189	2.23	3.02
	Total	106	3.44	1.204	0.117	3.21	3.68
R35	Architect	11	3.73	1.104	0.333	2.99	4.47
	Structural engineer	28	3.61	1.100	0.208	3.18	4.03
	Quantity surveyor	10	3.40	1.265	0.400	2.50	4.30

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	Project manager	33	3.79	1.166	0.203	3.37	4.20
	Site engineer	24	2.79	1.062	0.217	2.34	3.24
	Total	106	3.47	1.173	0.114	3.25	3.70
R36	Architect	11	3.27	0.467	0.141	2.96	3.59
	Structural engineer	28	3.25	1.076	0.203	2.83	3.67
	Quantity surveyor	10	2.80	1.033	0.327	2.06	3.54
	Project manager	33	3.45	1.175	0.205	3.04	3.87
	Site engineer	24	2.58	0.776	0.158	2.26	2.91
	Total	106	3.12	1.039	0.101	2.92	3.32
R37	Architect	11	3.09	0.701	0.211	2.62	3.56
	Structural engineer	28	3.14	1.113	0.210	2.71	3.57
	Quantity surveyor	10	3.10	0.876	0.277	2.47	3.73
	Project manager	33	3.39	0.998	0.174	3.04	3.75
	Site engineer	24	2.58	0.974	0.199	2.17	2.99
	Total	106	3.08	1.015	0.099	2.89	3.28

Descriptives statistics of organization

Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
R1	Private owner	15	3.00	1.000	0.258	2.45	3.55
	Design consultant	37	2.43	1.144	0.188	2.05	2.81
	Contractor	34	3.18	1.314	0.225	2.72	3.63
	PCM	20	3.55	1.317	0.294	2.93	4.17
	Total	106	2.96	1.272	0.124	2.72	3.21
R2	Private owner	15	2.87	1.125	0.291	2.24	3.49

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	Design consultant	37	2.81	0.908	0.149	2.51	3.11
	Contractor	34	2.74	1.543	0.265	2.20	3.27
	PCM	20	3.45	1.356	0.303	2.82	4.08
	Total	106	2.92	1.266	0.123	2.67	3.16
R3	Private owner	15	3.13	0.915	0.236	2.63	3.64
	Design consultant	37	3.70	0.702	0.115	3.47	3.94
	Contractor	34	2.94	1.369	0.235	2.46	3.42
	PCM	20	3.50	1.235	0.276	2.92	4.08
	Total	106	3.34	1.120	0.109	3.12	3.56
R4	Private owner	15	3.67	0.900	0.232	3.17	4.16
	Design consultant	37	3.92	1.038	0.171	3.57	4.26
	Contractor	34	3.24	1.350	0.231	2.76	3.71
	PCM	20	3.50	1.051	0.235	3.01	3.99
	Total	106	3.58	1.154	0.112	3.36	3.81
R5	Private owner	15	3.07	1.033	0.267	2.49	3.64
	Design consultant	37	3.08	1.090	0.179	2.72	3.44
	Contractor	34	2.91	1.379	0.236	2.43	3.39
	PCM	20	3.65	0.875	0.196	3.24	4.06
	Total	106	3.13	1.164	0.113	2.91	3.36
R6	Private owner	15	3.93	1.438	0.371	3.14	4.73
	Design consultant	37	4.11	1.286	0.211	3.68	4.54
	Contractor	34	3.00	1.393	0.239	2.51	3.49
	PCM	20	3.65	1.182	0.264	3.10	4.20
	Total	106	3.64	1.388	0.135	3.37	3.91
R7	Private owner	15	2.67	0.900	0.232	2.17	3.16
	Design consultant	37	2.49	1.121	0.184	2.11	2.86
	Contractor	34	2.82	1.547	0.265	2.28	3.36
	PCM	20	3.10	1.252	0.280	2.51	3.69

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	Total	106	2.74	1.275	0.124	2.49	2.98
R8	Private owner	15	2.47	0.915	0.236	1.96	2.97
	Design consultant	37	2.43	1.119	0.184	2.06	2.81
	Contractor	34	2.29	1.088	0.187	1.91	2.67
	PCM	20	3.05	1.099	0.246	2.54	3.56
	Total	106	2.51	1.098	0.107	2.30	2.72
R9	Private owner	15	3.27	1.100	0.284	2.66	3.88
	Design consultant	37	3.57	1.042	0.171	3.22	3.91
	Contractor	34	2.97	1.403	0.241	2.48	3.46
	PCM	20	3.30	1.081	0.242	2.79	3.81
	Total	106	3.28	1.193	0.116	3.05	3.51
R10	Private owner	15	4.00	1.195	0.309	3.34	4.66
	Design consultant	37	4.19	1.288	0.212	3.76	4.62
	Contractor	34	2.24	1.130	0.194	1.84	2.63
	PCM	20	3.40	0.883	0.197	2.99	3.81
	Total	106	3.39	1.418	0.138	3.11	3.66
R11	Private owner	15	2.53	0.915	0.236	2.03	3.04
	Design consultant	37	2.78	0.976	0.160	2.46	3.11
	Contractor	34	2.03	1.218	0.209	1.60	2.45
	PCM	20	2.25	0.786	0.176	1.88	2.62
	Total	106	2.41	1.058	0.103	2.20	2.61
R12	Private owner	15	3.47	1.356	0.350	2.72	4.22
	Design consultant	37	3.38	1.010	0.166	3.04	3.72
	Contractor	34	2.21	1.274	0.218	1.76	2.65
	PCM	20	3.50	1.000	0.224	3.03	3.97
	Total	106	3.04	1.272	0.124	2.79	3.28
R13	Private owner	15	2.80	0.941	0.243	2.28	3.32
	Design consultant	37	2.78	1.004	0.165	2.45	3.12

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	Contractor	34	2.29	1.142	0.196	1.90	2.69
	PCM	20	3.60	1.188	0.266	3.04	4.16
	Total	106	2.78	1.155	0.112	2.56	3.01
R14	Private owner	15	3.13	0.834	0.215	2.67	3.60
	Design consultant	37	2.89	1.048	0.172	2.54	3.24
	Contractor	34	2.15	1.282	0.220	1.70	2.59
	PCM	20	3.30	0.733	0.164	2.96	3.64
	Total	106	2.76	1.134	0.110	2.55	2.98
R15	Private owner	15	2.53	0.640	0.165	2.18	2.89
	Design consultant	37	2.41	1.092	0.180	2.04	2.77
	Contractor	34	2.12	1.175	0.201	1.71	2.53
	PCM	20	2.95	0.759	0.170	2.59	3.31
	Total	106	2.43	1.042	0.101	2.23	2.63
R16	Private owner	15	2.27	1.280	0.330	1.56	2.98
	Design consultant	37	2.00	1.202	0.198	1.60	2.40
	Contractor	34	2.24	1.103	0.189	1.85	2.62
	PCM	20	2.75	1.585	0.354	2.01	3.49
	Total	106	2.25	1.273	0.124	2.01	2.50
R17	Private owner	15	2.47	0.990	0.256	1.92	3.02
	Design consultant	37	2.38	1.233	0.203	1.97	2.79
	Contractor	34	2.32	1.147	0.197	1.92	2.72
	PCM	20	2.80	1.152	0.258	2.26	3.34
	Total	106	2.45	1.156	0.112	2.23	2.68
R18	Private owner	15	3.13	0.915	0.236	2.63	3.64
	Design consultant	37	3.24	0.830	0.136	2.97	3.52
	Contractor	34	2.26	1.189	0.204	1.85	2.68
	PCM	20	2.90	0.912	0.204	2.47	3.33
	Total	106	2.85	1.058	0.103	2.65	3.05

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R19	Private owner	15	2.87	1.060	0.274	2.28	3.45
	Design consultant	37	3.19	0.811	0.133	2.92	3.46
	Contractor	34	2.35	1.228	0.211	1.92	2.78
	PCM	20	3.20	1.240	0.277	2.62	3.78
	Total	106	2.88	1.127	0.109	2.66	3.09
R20	Private owner	15	2.53	0.834	0.215	2.07	3.00
	Design consultant	37	3.03	0.957	0.157	2.71	3.35
	Contractor	34	2.41	0.988	0.169	2.07	2.76
	PCM	20	2.95	1.050	0.235	2.46	3.44
	Total	106	2.75	0.996	0.097	2.55	2.94
R21	Private owner	15	3.53	1.187	0.307	2.88	4.19
	Design consultant	37	3.57	1.119	0.184	3.19	3.94
	Contractor	34	2.53	1.051	0.180	2.16	2.90
	PCM	20	3.55	1.050	0.235	3.06	4.04
	Total	106	3.23	1.181	0.115	3.00	3.45
R22	Private owner	15	3.27	1.280	0.330	2.56	3.98
	Design consultant	37	3.59	1.166	0.192	3.21	3.98
	Contractor	34	2.68	1.065	0.183	2.30	3.05
	PCM	20	2.95	1.050	0.235	2.46	3.44
	Total	106	3.13	1.180	0.115	2.90	3.36
R23	Private owner	15	2.93	1.163	0.300	2.29	3.58
	Design consultant	37	3.51	1.070	0.176	3.16	3.87
	Contractor	34	2.62	1.045	0.179	2.25	2.98
	PCM	20	3.40	0.995	0.222	2.93	3.87
	Total	106	3.12	1.119	0.109	2.91	3.34
R24	Private owner	15	3.33	1.047	0.270	2.75	3.91
	Design consultant	37	3.62	1.114	0.183	3.25	3.99
	Contractor	34	2.35	0.950	0.163	2.02	2.68

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	PCM	20	3.45	0.887	0.198	3.03	3.87
	Total	106	3.14	1.142	0.111	2.92	3.36
R25	Private owner	15	3.67	1.047	0.270	3.09	4.25
	Design consultant	37	3.76	1.300	0.214	3.32	4.19
	Contractor	34	2.24	1.130	0.194	1.84	2.63
	PCM	20	4.10	0.968	0.216	3.65	4.55
	Total	106	3.32	1.370	0.133	3.06	3.58
R26	Private owner	15	3.47	1.060	0.274	2.88	4.05
	Design consultant	37	3.41	1.040	0.171	3.06	3.75
	Contractor	34	2.71	1.115	0.191	2.32	3.10
	PCM	20	3.70	0.865	0.193	3.30	4.10
	Total	106	3.25	1.094	0.106	3.03	3.46
R27	Private owner	15	2.93	0.961	0.248	2.40	3.47
	Design consultant	37	3.43	0.987	0.162	3.10	3.76
	Contractor	34	2.44	0.960	0.165	2.11	2.78
	PCM	20	3.30	1.031	0.231	2.82	3.78
	Total	106	3.02	1.060	0.103	2.81	3.22
R28	Private owner	15	3.27	0.961	0.248	2.73	3.80
	Design consultant	37	3.24	0.983	0.162	2.92	3.57
	Contractor	34	2.85	1.234	0.212	2.42	3.28
	PCM	20	3.55	1.050	0.235	3.06	4.04
	Total	106	3.18	1.094	0.106	2.97	3.39
R29	Private owner	15	3.33	1.047	0.270	2.75	3.91
	Design consultant	37	2.97	1.093	0.180	2.61	3.34
	Contractor	34	2.56	1.330	0.228	2.09	3.02
	PCM	20	3.90	1.119	0.250	3.38	4.42
	Total	106	3.07	1.252	0.122	2.82	3.31
R30	Private owner	15	3.40	1.183	0.306	2.74	4.06

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	Design consultant	37	2.95	1.026	0.169	2.60	3.29
	Contractor	34	2.82	1.242	0.213	2.39	3.26
	PCM	20	3.90	0.912	0.204	3.47	4.33
	Total	106	3.15	1.161	0.113	2.93	3.37
R31	Private owner	15	3.33	0.724	0.187	2.93	3.73
	Design consultant	37	2.89	0.906	0.149	2.59	3.19
	Contractor	34	2.35	1.098	0.188	1.97	2.74
	PCM	20	3.30	0.571	0.128	3.03	3.57
	Total	106	2.86	0.970	0.094	2.67	3.05
R32	Private owner	15	2.80	0.775	0.200	2.37	3.23
	Design consultant	37	2.89	0.936	0.154	2.58	3.20
	Contractor	34	2.94	1.613	0.277	2.38	3.50
	PCM	20	3.20	0.768	0.172	2.84	3.56
	Total	106	2.95	1.150	0.112	2.73	3.17
R33	Private owner	15	3.73	1.033	0.267	3.16	4.31
	Design consultant	37	3.81	1.244	0.204	3.40	4.23
	Contractor	34	2.65	0.917	0.157	2.33	2.97
	PCM	20	3.55	0.826	0.185	3.16	3.94
	Total	106	3.38	1.150	0.112	3.16	3.60
R34	Private owner	15	3.73	0.961	0.248	3.20	4.27
	Design consultant	37	3.86	1.417	0.233	3.39	4.34
	Contractor	34	2.71	0.938	0.161	2.38	3.03
	PCM	20	3.70	0.733	0.164	3.36	4.04
	Total	106	3.44	1.204	0.117	3.21	3.68
R35	Private owner	15	3.87	1.125	0.291	3.24	4.49
	Design consultant	37	3.62	1.187	0.195	3.23	4.02
	Contractor	34	2.88	1.066	0.183	2.51	3.25
	PCM	20	3.90	1.021	0.228	3.42	4.38
	Total	106	3.47	1.173	0.114	3.25	3.70

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R36	Private owner	15	3.07	1.100	0.284	2.46	3.68
	Design consultant	37	3.30	0.996	0.164	2.97	3.63
	Contractor	34	2.62	0.853	0.146	2.32	2.92
	PCM	20	3.70	1.031	0.231	3.22	4.18
	Total	106	3.12	1.039	0.101	2.92	3.32
R37	Private owner	15	3.33	0.900	0.232	2.84	3.83
	Design consultant	37	3.08	1.064	0.175	2.73	3.44
	Contractor	34	2.68	1.007	0.173	2.33	3.03
	PCM	20	3.60	0.754	0.169	3.25	3.95
	Total	106	3.08	1.015	0.099	2.89	3.28

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