FINANCIAL RISK ASSESSMENT FOR A CONSTRUCTION PROJECT

By

Mrs. Qing ZANG

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Engineering ENGINEERING MANAGEMENT
Department of INDUSTRIAL ENGINEERING AND MANAGEMENT
Silpakorn University
Academic Year 2024

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Mrs.Qing Zang

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Field of Study	ENGINEERING MANAGEMENT
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650920065 : Major ENGINEERING MANAGEMENT
Keyword : Construction industry, multi-criteria decision making, DEMATEL, financial risk

Mrs. Qing ZANG : FINANCIAL RISK ASSESSMENT FOR A CONSTRUCTION PROJECT Thesis advisor : Associate Professor Choosak Pornsing, Ph.D.

This study illustrates the application of a multi-criteria decision analysis tool known as the Decision-making Trial and Evaluation Laboratory (DEMATEL) with the extension of the Interpretative Structure Model (ISM). Due to the complexity of financial risk elements in a construction project, where one component may influence others to varying degrees, traditional decision analysis tools that overlook the interrelationships among risk factors will need to be more robust to identify significant risks systematically. This study selected a building project in China, with twenty-six staff people as decision-makers. Twenty-eight risk variables from nine categories in the literature should be examined. The findings indicate that DEMATEL can identify causal and effectual factors. The ISM shows us the risk factors in eight levels. The first level is the direct affect risk factors; the second is the indirect affect risk factors; and the third is the fundamental risk factors. The hierarchical structure model from the ISM is very useful for management in allocating its limited resources to manage risk factors. Finally, DEMATEL-ISM shows us its powerful decision-making technique for the complicated system.

ACKNOWLEDGEMENTS

Multiple individuals played a significant role in my achievement, and I would like to express my gratitude to them.

I am deeply grateful for my advisor's amazing assistance and great tolerance, Associate Professor Dr. Choosak Pornsing. His expertise and counsel have been absolutely useful to me. I am also grateful to my thesis chair, Assistant Professor Dr. Noppakun Sangkhiew and the entire Industrial Engineering and Management Department staff. They provided crucial practical assistance and pleasant gestures. All department's supplies were ranging properly for graduate students.

I would also like to express my gratitude to my family and the divine entity for their unwavering support and presence in my life.

Qing ZANG

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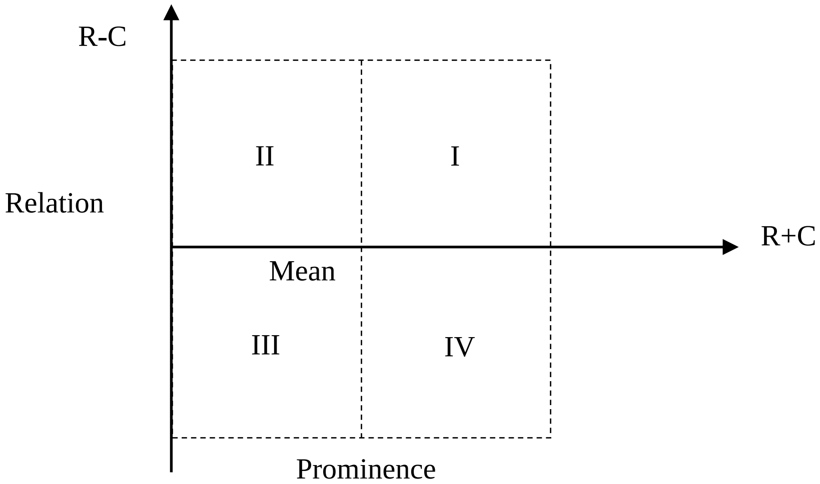

CHAPTER 1
INTRODUCTION

1.1 Motivation

The construction business is a multifaceted, efficient, and highly demanding sector in the expanding global economy. Successfully achieving the key aims and objectives of the industry demands careful attention to resource management, labor requirements, equipment, processes, contract management, and expert advice (Kumar, 2018; Antón et al., 2011). In addition to the multitude of intricate duties inherent in construction, the presence of risks and uncertainties throughout multiple processes is an anticipated aspect of this expansive and essential business. The economic development is contingent upon expanding the construction industry while effectively addressing risks (Akomea-Frimpong et al., 2021; Srinivasan et al., 2022).

The risk that harms the project is considered from the beginning of the investment process, namely when the contract is awarded after winning the bidding (Dziadosz et al., 2015; Purnus and Bodea, 2015a; Gad et al., 2022). The risk level associated with a specific construction contract is a significant determinant in deciding whether to accept or decline the contract. The primary concern revolves around accurately identifying contract risk. The risk factors that substantially influence the project's success and are commonly encountered are further examined. The verification method is contingent upon the company's level of expertise in the construction sector (Liu et al., 2017; Singh et al., 2019; Shibani et al., 2022).

In the last years, China has been suffering from a severe economic crisis, which has affected a large number of businesses and industries, specifically the construction industry (Jiao, 2021). Inevitably, the construction industy is suffering from this factor. Nevertheless, the industry must continue to lead the economic and must be conducted cautiously. To do so, we need to identify, classify, and analyze the most significant risks inherent in a construction project; specifically, on the financial and economic risk category (Brookfield and Boussabaine, 2009; Kolhatkar and Dutta, 2013; Purnus and Bodea, 2015b).

This study aims to mitigate financial risk by identifying and analyzing the factors that influence the financing of a building project, including their sequences and relationships. The study contributes to mitigating the financial risk associated with a project and enhancing operational efficiency in the future. It examines the traditional way of evaluating project financing risks and its application to a current building project. Firstly, the DEMATEL-ISM approach is employed to conduct data analysis to produce project finance risk and evaluate the index system (Song and Hao, 2022). Next, we conduct a thorough and systematic examination of the connections within the data to create a scientifically valuable guidance tool for funding a construction project.

1.2 Research Objectives

1. To identify and classify financial risk factor of a sample construction project in Kunming.

2. To examine the relationship among financial risk factors of a construction project using an interpretative structural model.

1.3 Research Contributions

1. This study yields a practical framework for construction financial risk management.

2. An application to a case study can illustrate as a referenced case model to construction projects about risk assessment and management.

3. This study shows how to apply mathematical thechnique and decision science in practical engineering management, which is helpful for other solving engineering problems.

1.4 Scopes and Limitations

1. This study is a combination of survey research and quantitative research; however, the primary one is the quantitative research that attempts to propose a practical tool and the case is about collecting data from the case study.

2. The survey research has a specific manner. Thus, the result from the case study cannot guarantee other cases in general.

3. The data is collected between March 2024 and May 2024.

4. This study neglects uncertainty of variables.

1.5 Glossary

Application programming interface (API) is a collection of regulations or protocols that enable software programs to interact and share data, characteristics, and capabilities. APIs can also specify how a developer can solicit services from an operating system (OS) or another program and make data available through various routes.

Building information model is a computerized depiction of a building's tangible and operational attributes and plays a crucial role in digital construction. The approach is model-based and aims to provide professionals in the architecture, engineering, and construction sectors with valuable insights to assist them in planning, designing, constructing, and managing buildings and infrastructure. BIM applies to new construction projects and renovating and refurbishing existing buildings.

Decision-making trial and evaluation laboratory is a methodology used to analyze intricate systems and determine causal linkages. It is a decision-making method that considers multiple factors and entails constructing a structural model while also considering experts' opinions. DEMATEL has been employed to address intricate issues in science, politics, and economics.

Engineering management is a distinct area of management that integrates technical proficiency with commercial acumen and leadership abilities to oversee intricate projects and organizations within the engineering industry. Engineering managers serve as intermediaries between technical teams and business departments, facilitating the coordination of workflows and decision-making processes to promote collaboration among organization members in pursuit of shared objectives.

Financial management is the deliberate and systematic process of strategizing, coordinating, and overseeing financial resources. Financial management oversees all incoming and outgoing funds inside a business, including any cash or assets held in reserve. Financial management encompasses applying management principles to an organization's financial assets and involvement in fiscal management.

Financial risk management involves the identification and mitigation of potential financial hazards in order to safeguard a company's economic worth. The process entails assessing the potential hazards and determining whether to embrace them or implement measures to reduce their impact. Financial risk management is a continuous activity, as risks have the potential to evolve.

Information Systems Manager is a specialized professional overseeing an organization's technological infrastructure. These individuals are called IT managers, project managers, functional managers, service delivery managers, or systems managers.

Interpretative structural model is a computerized approach that assists groups in creating visual depictions of intricate systems by discerning and condensing connections between variables. It is an interactive educational technique that can help identify the sequence and objective of intricate connections between components in a system. ISM can be applied to tasks such as evaluating technology and examining barriers to implementing Total Productive Maintenance (TPM).

Risk management is the potential for ineffective, harmful, or underperforming management, which can have negative consequences. This risk can encompass financial, ethical, or other types of risks. It has the potential to impact investors who possess shares in a company, as well as the administration of an investment fund.

CHAPTER 2
LITERATURE REVIEW

This chapter reviews the related theories and topics from trusted literature. Section 2.1 examines whole picture of the construction industry and its significance in the economy; however, we would like to focus on China's construction industry. The relationship between finance and engineering management is reviewed in section 2.2. This section highlights the responsibility of engineers in a company's finance function. Section 2.3 examines the financial risk analysis in complex and multi-function engineering projects. Section 2.4 concludes the background of an analysis tool, the Integrated Decision-Making and Trial Evaluation Laboratory (DEMATEL), which we choose to use in this study. Furthermore, section 2.5 examines the Interpretative Structural Model (ISM), another analysis tool chosen for this study. Section 2.6 tries to conclude some research related to our study. It could not be reviewed as a whole but could portray the financial risk in construction projects to an interested reader.

2.1 Construction Industry

The construction industry constituted around 6.8 percent of China's total domestic GDP in 2023. A substantial portion of the nation's economy is dependent on the real estate sector and the construction of infrastructure. During periods of economic decline, authorities often rely on infrastructure improvements as a means to stimulate economic growth (Zhang, 2024).

In 2023, the China construction industry was worth USD 2,734.90 Billion. It is expected to grow at a Compound Annual Growth Rate (CAGR) of 5.4% from 2024 to 2030, reaching USD 4,107.20 Billion by 2030. The construction market, often known as the infrastructure sector, plays a crucial role in the economy by managing the whole lifespan of various physical assets, such as infrastructure, buildings, and amenities. This sector comprises a broad spectrum of projects, including residential, commercial, and industrial developments, as well as civil engineering and institutional real estate activities.

The operation relies on the collaboration of various parties, including architects, engineers, contractors, suppliers, developers, investors, and government authorities. The business is set to expand due to a growing focus on environmentally sustainable practices, such as incorporating green construction materials and energy-efficient designs. Moreover, the increasing per capita income in emerging economies and the low interest rates in established nations are expected to boost the growth of the infrastructure industry (Next MSC., 2024).

2.1.1 Government support on construction industry

China's construction industry is currently undergoing substantial expansion, driven by several government-supported initiatives that focus on infrastructure development, specifically in railway and road transportation projects. In a 2023 analysis by ITA, it was revealed that the Chinese government made significant investments in infrastructure, with a projected total investment of USD 4.2 Trillion for the 14th Five-year plan period (2021-2025). The main focus is on implementing new infrastructure initiatives in transportation, energy, water systems, and urban development, with a particular emphasis on sustainable construction and energy conservation.

In addition, the government wants to issue USD 137 billion in sovereign debt to help with disaster relief and infrastructure projects. Local governments are working to quickly implement plans to use this money. China's focused endeavors highlight its dedication to infrastructural development, environmental sustainability, and courting foreign investment.

2.1.2 The growth of China's construction market

The infrastructure sector in China is seeing significant expansion, fuelled by increasing investments in infrastructure projects throughout the region. According to data from the Global Infrastructure Hub, investments in the infrastructure sector reached a significant amount of USD 942 billion in 2023. The road transport sector receives a substantial amount of investment, at USD 356 billion, with the energy sector closely following at USD 281 billion. The current trend of investment is projected to persist, promoting consistent expansion and progress in the building industry.

In addition, the decrease in inflation rates strengthens consumer preference and purchasing power, potentially increasing demand for new projects, such as residential and commercial constructions. China's inflation rate in 2024 was 0.97%, which is considerably lower than that of other countries like India and Japan. This positive economic indicator contributes to the growth of the infrastructure sector, attracting more investment and promoting overall economic development in the country.

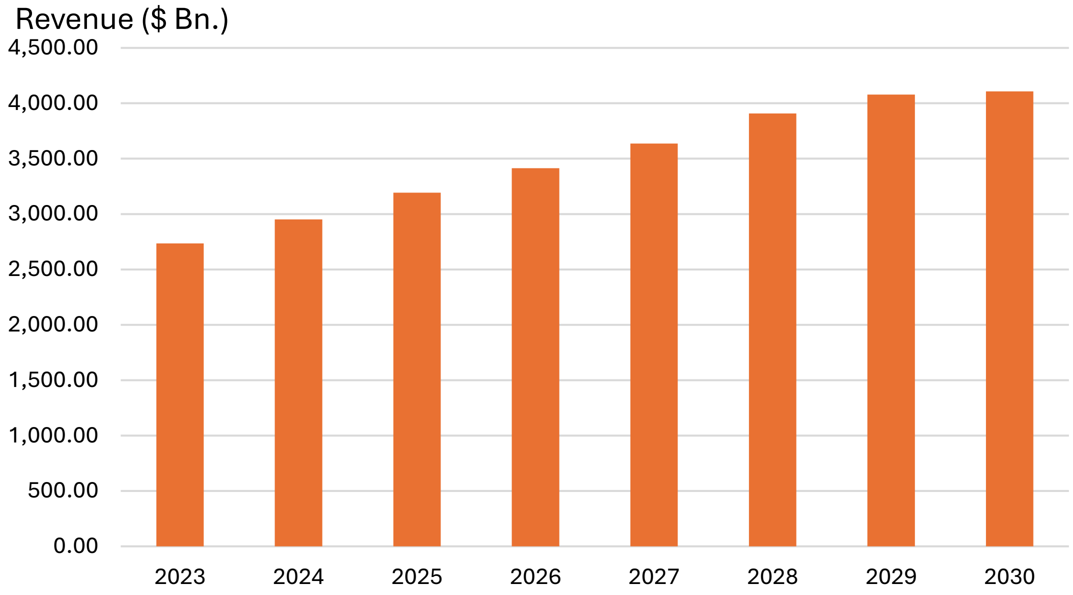

Figure 2.1 China's construction industry growth forecasting.

2.1.3 The barriers of construction industry

Overcoming regulatory complications presents a substantial difficulty in the building business. Infrastructure projects frequently face challenges as a result of the complex network of government rules and permitting procedures. Infrastructure projects require many permissions and approvals from government entities at the local, regional, and national levels. These duties include following zoning restrictions, conducting environmental assessments, complying with building codes, meeting safety standards, and adhering to numerous regulatory requirements. The protracted process of obtaining permits, bureaucratic inefficiencies, and discrepancies in rules across many jurisdictions can significantly extend project timeframes and escalate prices. Moreover, variations in rules or unforeseen policy modifications can interrupt ongoing projects and discourage new investors.

2.1.4 Digitization in China's construction industry

The building sector is currently experiencing a significant change as it incorporates digitalization and embraces the use of Building Information Modelling (BIM). The utilization of sophisticated technology like BIM improves efficiency, accuracy, and collaboration across many projects. BIM, an advanced 3D modeling tool, enables stakeholders to create and oversee digital representations of structures and infrastructure, enhancing collaboration and communication among project teams.

2.2 Financial and Engineering Management

Unsurprisingly, the most frequent response to the question, "What is the role of an engineering leader?" is working on technology. The main responsibility of numerous engineering executives is indeed to take ownership and lead the implementation of product development, architecture, and infrastructure. This entails collaborating with their teams to make strategic decisions regarding architecture and technology, developing and constructing novel products, designing and constructing platforms and APIs, formulating implementation plans, overseeing delivery schedules, coordinating with other departments to establish priorities, providing work estimates, and addressing customer escalation requests (Shepperd, 2019).

Furthermore, engineers frequently observe their managers establishing objectives for their department, mentoring members of the engineering team, coordinating and allocating tasks, fostering a sense of unity and a positive team environment, recruiting fresh engineers, delivering evaluations on performance, and aiding individual engineers in advancing their professional development.

Often, people fail to recognize the significant amount of time that technical executives dedicate to financial matters. This encompasses the tasks of budget preparation, continuous control of departmental spending, and additional broader responsibilities. Now, let us examine some of the non-technical engineering duties necessary for a successful leader.

2.2.1 Project bugetting

Understanding that the budget process is not a singular annual event is crucial. It is continuous, with regular budgeting assessments occurring monthly, quarterly, and annually. Aside from the yearly plan, consistent evaluations are necessary to ensure the continuous achievement of departmental, financial, and business objectives.

As engineering leaders, your role in conducting a monthly assessment of expenditures with your executive manager and/or the finance team is crucial. This regular check ensures that the engineering budget is in line with the stated goals and that the team is not exceeding the allocated funds, giving you a sense of responsibility and control over the budget.

A budget is formulated after a year for execution in the subsequent year. It represents the most accurate projection of expected programs, expenditures, and objectives. Consequently, it is imperative that an engineer consistently assess his financial status to determine if he is exceeding or falling short of the budget. In such cases, promptly inform his boss and other relevant officials.

A budget is dynamic and subject to change. The fluctuations occur regularly due to many circumstances, and these fluctuations might directly influence other teams. For instance, when there is an increase or decrease in revenue or when expenditures in other departments rise or fall, planned projects are routinely reassessed. Departmental executives often adjust their budgets periodically in response to the evolving needs of the business. Understanding this dynamic nature will help you feel prepared for potential changes.

2.2.2 Project budgetting's components

An engineering leader's budget generally consists of:

1) Compensation for Employees: This encompasses the remuneration of all permanent engineers and other team members, as well as part-time staff, compensated interns, and other individuals.

2) Bonuses: Although the specific sorts of bonuses differ among companies, they may encompass a signing bonus and supplementary bonuses based

on performance, patent creation, and successfully finishing a design within budget constraints.

3) Software and licenceses maintenance costs: Software licenses refer to legal agreements that grant individuals or organizations the right to use a specific software program. Maintenance costs are incurred to keep the software functioning correctly and up to date. Historically, software license charges have been associated with traditional boxed software. Currently, this encompasses the original situation and the recurring charges for apps, platforms, and other subscription-based SaaS tools. These tools may include development and deployment tools, monitoring software, communication tools, business applications, and more.

4) Costs related to the development and maintenance of infrastructure: Infrastructure expenditures encompass a broader range of expenses beyond acquiring server hardware. In addition, it is imperative to factor in expenses such as storage, networking, HVAC, electricity, and the costs connected with the selected data storage site. These options may encompass an engineer's personal data center located on the engineer's premises, a colocation provider, or a cloud provider like Liquid Web, Amazon, Microsoft, Google, or other similar providers.

5) Payment of vendors and contractors: Developing and implementing a technology solution that aligns with the company's sales, financial, and business objectives necessitates collaboration with multiple partners. External IT consultants, freelance workers, third-party service providers, and a network of resellers can all contribute. Establishing initial commercial ties, signing financial agreements, and making regular payments to these business partners is necessary, which requires consistent management.

6) Discretionary funds: Discretionary funds include travel costs, purchasing new computers, recruitment charges, attending conferences, enrolling in training courses, organizing team trips, and providing employee lunches. Although each component may only account for a small fraction of the total budget, their cumulative effect on discretionary spending can rapidly escalate unless effectively managed.

2.3 Financial Risk Analysis in Construction Projects

2.3.1 Construction project risk management

Risk management refers to the collective mindset, methods, and systems employed to generate advantages while mitigating adverse outcomes proactively. Befrouei and Taghipour (2015) defined risk management in the context of construction project management as a thorough approach to recognizing, evaluating, and dealing with risks in order to accomplish the project's goals and objectives. As to the British Standards BS31100 (2011), risk management is making decisions to address known or quantified risk and taking actions to reduce the impact or likelihood of its occurrence.

Risk management is a crucial responsibility for project managers. Neglecting this job can lead to a range of problems and financial setbacks. Effective dynamic risk management necessitates a meticulous approach and the acquisition of pertinent information, extensive knowledge, and practical experience (Serpella et al., 2014). The primary rationale behind risk management in construction projects is to provide a secure work environment for the labor force and enhance the achievement of objectives. According to Sehat and Alavi (2010), risk management is a thorough procedure involving identifying and evaluating risks to determine the necessary measures for effective risk mitigation.

Moreover, it enables a system to effectively manage the typical risks in its daily operations and maintain its processes in a comprehensive and suitable environment, facilitating cost-effective outcomes. Risk management involves proactively preparing for future incidents for the same reason. Nevertheless, the neglect of risk management in the building industry has resulted in unfavorable consequences and substandard workmanship. For instance, the lack of effectiveness in managing and the inaccurate assessment of two essential project factors, namely cost and time, which are difficult to measure accurately, can result in project delays and increased expenses (Befrouei & Taghipour, 2015).

Project risk management is closely intertwined with other project elements, and implementing a practical risk management approach enhances the likelihood of achieving the project objectives. Figure 2.2 illustrates the integration of project risk management with the other project components. Rezakhani (2012) state that when it comes to dealing with risk, the concept of probability is crucial. However, estimating probability has been a topic of study for a significant amount of time. Definitions of probability deviate from the standard deterministic premise by emphasizing that it is not simply the proportion of an occurrence to the total number of equally likely outcomes but rather a more subjective and judgment-based interpretation. The expected outcomes are typically predictable, while the estimation of building costs may be less straightforward.

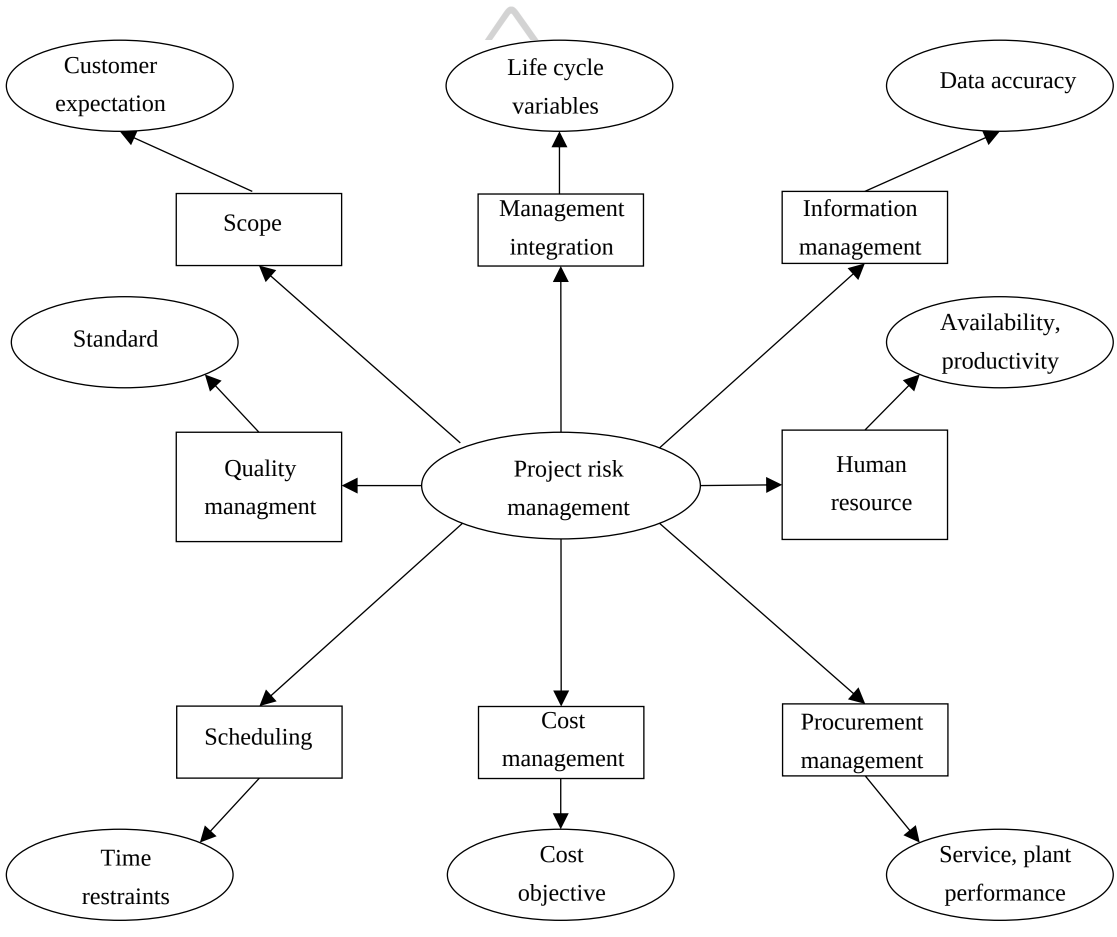

Figure 2.2 Project risk management functions.

Source: Shibani et al. (2022).

2.3.2 Project risk classification

1) Risks inside: Identifying and managing internal hazards is crucial in major construction projects. As Aleshin (2001) points out, these risks are inherent to the project itself, while external hazards arise from the macro level. The classification includes the following categories: owner's responsibility, architects, suppliers, designers, contractors, and subcontractors. Specifically, identifying and managing these risks is essential to limit the owner's obligation and ensure project success.

2) Risks outside: External hazards do not significantly impact the construction process, but they are crucial in terms of project efficiency. They can be classified into political, socio-cultural, economic, natural, and miscellaneous categories (El-Sayegh, 2008). The political risks can be categorized as hazards of armed conflicts, legislative changes, corruption, bribery, and delays in obtaining clearances. These risks are associated with the country's credit risk, frequently arising when the home country cannot meet its financial obligations due to economic difficulties. Authors have increasingly focused on political risk in international construction projects, particularly factors such as labor charges, supply, raw materials, administrative costs, foreign currency, and exchange rates (Baloi & Price, 2003). Corruption has been pervasive in Lebanon in various manifestations, such as nepotism, favoritism, bribery, and embezzlement. Its consequences have intensified since the conclusion of the civil war in 1990. Political corruption in Lebanon has been widely regarded as the most extensive form of corruption, as evidenced by the perceptions of the Lebanese population regarding corruption. The potential for conflict poses a significant external threat to the country and the construction industry. Lebanon has seen a series of conflicts over the past twenty years. The first war took place from 1975 to 1990 and resulted in severe damage to the economy and pollution of the environment. Another war happened in 2006. The persistent risk of conflict in Lebanon persists to this day due to a multitude of economic and political factors.

3) Pandemic risk: It refers to the potential for a widespread disease outbreak that affects many people across different regions or even globally. The “pandemic risk” is a significant and unforeseen threat that will impact the efficiency

and duration of construction projects. Pandemics are characterized as widespread outbreaks of infectious diseases that can cause a considerable increase in mortality rates across a wide geographical area and lead to significant disruptions in the economy, society, and politics. Evidence indicates that the likelihood of pandemics has grown over the last century due to heightened global travel, integration, urbanization, land use changes, and greater natural environment exploitation (Jones et al., 2008). The new coronavirus was identified on January 9th in the Wuhan area of China. Companies worldwide have started to reduce their expansion, regardless of the advice they receive from foreign sources based on company size. International travel and transportation have been restricted and hindered, impacting the economic growth of countries worldwide (Shibani et al., 2020). COVID-19 has adversely impacted the global transportation of construction materials. Construction containment methods are being implemented by the World Health Organization (WHO) rules to provide maximum protection for construction crews, implement adequate preventive measures, and manage the spread of the virus. Moreover, the crisis would significantly affect the construction industry due to a sudden decrease in global demand and supply caused by social distancing measures. It is estimated that if the crisis persists for six months, approximately 1.76 million workers in the construction sector will be at risk (Shibani et al., 2021).

4) Economic risks: They refer to potential threats or uncertainties that can negatively impact a situation or entity's financial aspects. El-Sayegh (2008) asserts that in nations like the UAE, inflation and sudden price hikes are the primary economic hazards, taking into account the economic and financial context. Nevertheless, Kuwait and China express similar perspectives (Kartam & Kartam, 2001). Hence, regarding inflation, contend that employing exact projections to adjust future expenses effectively is crucial. Furthermore, they assert that the lender, possessing more excellent expertise, is more adept at conducting these precise forecasts than the project's promoters. Builders also perceive a significant risk of inflation (Kartam & Kartam, 2001). When strategizing for a substantial building endeavor, it is crucial to consider the primary economic peril, which is the volatility of the currency, particularly in the context of overseas projects. Many countries have recently prioritized attracting foreign capital for privately funded infrastructure

projects, which carries the potential danger of devaluing the native currency. Historically, public corporations and governments have acknowledged the existence of currency risk. However, with the growing demand for private funding, the burden of currency depreciation now falls on the project promoter and, ultimately, on the customers. The investor is unwilling to take this risk. In 1997, Lebanon's central bank established a fixed exchange rate of 1507 Lebanese lira to 1 US dollar. Subsequently, the economy's stabilization has been contingent upon maintaining a consistent exchange rate with the USD throughout the past two decades. Moreover, Lebanon relies on imports for 80 percent of its commodities and resources due to the government's failure to build self-sufficient domestic firms, primarily due to bureaucratic inefficiency and corruption (Koffman, 2020). As per Koffman's (2020) findings, the devaluation of the Lebanese lira began due to corruption and the severe economic catastrophe that struck Lebanon in early 2020. The Lebanese lira nearly reached a value of 10,000 Lebanese lire per dollar. Furthermore, due to the escalating demand for USD, banks implemented increasingly stringent measures, initially limiting USD withdrawals to 300 USD and prohibiting them entirely. This resulted in financial difficulties within the construction industry, as the owners postponed their payments to contractors and suppliers, causing project completion delays.

2.3.3 Financial risk analysis

Financial risk analysis involves evaluating the probability of a potential danger occurring and its potential consequences. Therefore, it is significant in the field of risk management. Financial risk management involves assessing the probable impact and level of exposure to a risk (Mashrur et al., 2020).

Performing this estimate is a complex endeavor, as a particular risk has the potential to initiate numerous consequences. For instance, malfunctioning equipment causes mechanical harm that necessitates repair, disrupts production, incurs financial losses, causes delivery delays, and tarnishes the company's reputation.

The assessment of a company's financial risk begins with the identification of all potential risk occurrences. This article explains the process of identifying them. The analysis not only estimates potential losses but also proactively prevents them. For instance, credit risk analysis, a prominent form of financial risk assessment, evaluates the likelihood that a borrower may be unable to meet their obligations. Armed with this information, the bank proactively takes measures to prevent such incidents or minimize their consequences. Therefore, it is imperative for financial risk management to consider both the internal and external elements that give birth to potential hazards (Mihoci et al., 2020).

Internal factors refer to the factors generated as a result of the company's business operations. Inadequate cash management or production issues pose hazards that can negatively influence a company's financial accounts and market valuation. External variables are political, economic, or social situations that impact a company's performance. These influences can include economic crises, fluctuations in exchange rates, industry changes, or government policy shifts. An efficient approach to performing a financial risk analysis at a company involves integrating the likelihood of a risk event with the potential economic damages it may induce. After identifying the risks and selecting the most suitable instrument to manage them, the organization can determine whether to avoid or accept them based on risk appetite and tolerance level. Risk exposure is quantitatively measured. To evaluate the possible impact of an incident that affects only a specific organization region, we can calculate it by multiplying the chance of the risk occurring by the approximate financial loss. The outcome can provide a graphical representation of functions indicating acceptable and hazardous risks.

Undoubtedly, while making decisions, it is imperative to take into account market trends as well as macroeconomic and financial elements. The financial risk manager can utilize real-time risk detection techniques to effectively manage and proactively address various conditions, hence minimizing potential financial risks. Risk management software is a specific technology used for managing and mitigating risks. Risk management software minimizes the need for manual transaction duties and, as a result, reduces the subjective nature of analysis. Consequently, it serves as a proficient and user-friendly instrument in the realm of financial risk management.

Basic five step of finanacial risk analysis (Calle, 2022):

Step 1: Identifying the primary hazards.

This step is crucial as it sets the foundation for your entire risk management strategy. Commence the financial risk analysis by identifying all the risk elements the firm encounters. The risk factors encompass various elements that impact competitiveness, such as expenses, prices, inventories, and other relevant considerations. Additionally, changes in the company's industry, government regulations, technical advancements, and alterations in staff also contribute to these risk factors.

Step 2: Determine the magnitude of each risk

Efficient resource and effort allocation relies heavily on prioritizing risks. By doing so, we can build a strategy if a potential danger becomes a reality.

Step 3: Establishing a contingency plan

It prepares the company to deal with potential risks effectively. Conduct a thorough analysis of the necessary steps to address the hazards associated with item 1 and develop precise tasks to minimize their effects. It is essential to remember that different dangers require different approaches to dealing with them. Indeed, we may need more ability to influence all of them. Hence, the company's specified risk appetite and tolerance level must be used to design the contingency plan.

Step 4: Allocate duties

While providing specific tasks for every risk may not be feasible, it is advisable to designate an individual to oversee crucial areas and track their progress over time. Refrain from consolidating all duties and obligations in a single individual. Assign responsibilities to the most suitable employees.

Step 5: Establish expiration dates

Mitigation plans have a limited duration as threats have the potential to proliferate and impact additional processes. This factor plays a crucial role in determining the appropriate course of action, necessitating considering the duration required to complete each task.

2.4 DEMATEL

The DEMATEL technique was established in 2012 at the Geneva Research Center of the Battelle Memorial Institute by He and Cheng. It possesses the capacity to address intricate and arduous issues in real-life scenarios. The DEMATEL approach, with its foundation in graph theory and matrix operations, is a collaborative process. By examining the logical links and direct cause-and-effect relationships within a system, we can classify its components into two distinct groups: the group that is influenced and the group that exerts influence. The primary advantage of this technique lies in its ability to incorporate the viewpoints of multiple experts on a certain subject and analyze complex relationships among various parts using a graphical structural model (Mohandes et al., 2022).

The DEMATEL technique can efficiently transform the relationships among the identified components into a tangible structural model of the studied system. This strategy can be executed by classifying the components into cause-and-effect categories. DEMATEL is a method that is very suited and beneficial for evaluating the interwoven relationships between elements in a complex system, as evidenced by this characteristic (Si et al., 2018). In relation to this issue, the identified criteria can be organized in a hierarchical order, and the resulting priority can be utilized for formulating long-term strategic decisions and devising enhancement initiatives. In essence, DEMATEL cannot address decision-making issues; its primary purpose is to assess the interconnectedness of cause-and-effect factors. Figure 2.3 illustrates the initial techniques used in the DEMATEL methodology.

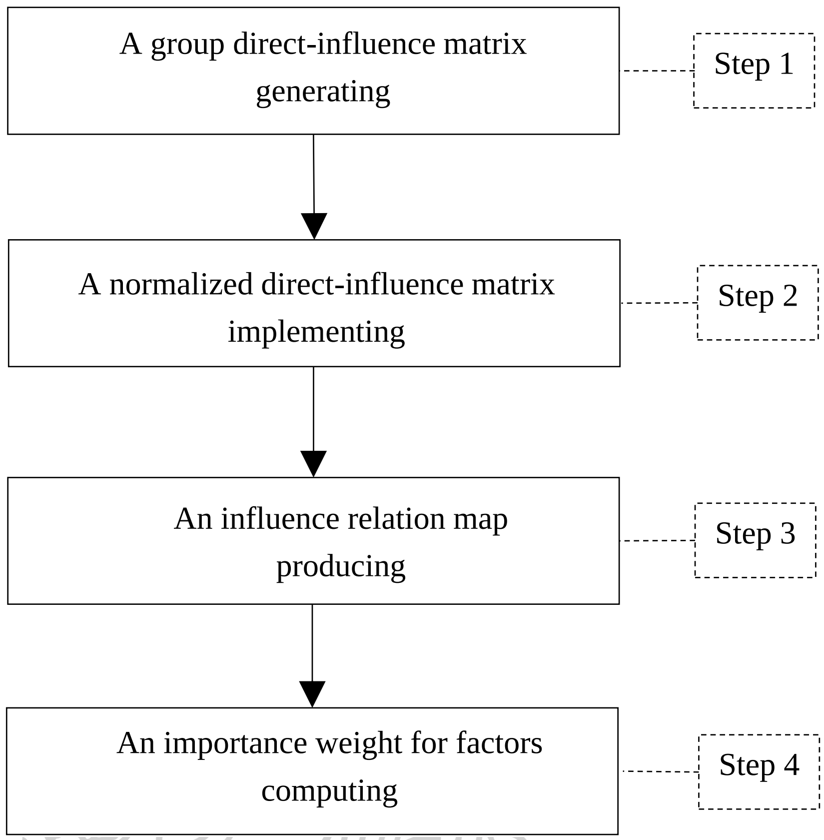

Figure 2.3 DEMATEL procedure.

The four steps of conventional DEMATEL method can be explained as follows:

1) A group direct-influence matrix generating

Suppose that there are n factors, $F = \{F_1, F_2, F_3, \dots, F_n\}$, in a complex system. There are l decision-makers examine the relationship between all factors. They are asked to specify how much factor F_i has a direct influence on F_j by using a five-point Likert scale, i.e., very high (VH) influence (4), high (H) influence (3), moderate (M) influence (2), low (L) influence (1), and no (N) influence (0). Accordingly, suppose that $Z_k = \left[z_{ij}^k\right]_{n\times n}$ as an individual influence matrix, is prepared by kth decision-maker, where the factor's degree to F_i influences F_j. Then, after combining all the l decision-makers data, the group direct-influence matrix can be formulated as Eq. (2.1).

$$Z_{ij} = \frac{1}{l}\sum_{k=1}^{l} z_{ij}^{k}, \quad \forall i, j = 1, 2, \dots, n \tag{2.1}$$

2) A normalized direct-influence matrix implementing

To receive a normalized matrix, Eq. (2.2) is used to calculate $X = \left[x_{ij}\right]_{n\times n}$. It is named the normalized direct-influence matrix.

$$X = \frac{1}{\max\sum_{j=1}^{n} a_{ij}} \times Z, \quad 1 \leq i \leq n \tag{2.2}$$

where all the elements of matrix X are in [0, 1], and $0 \leq \sum_{j=1}^{n} x_{ij} \leq 1$.

Next, the total direct-influence matrix ($T = \left[t_{ij}\right]_{n\times n}$) is calculated using Eq. (2.3).

$$T = X + X^2 + X^3 + \cdots + X^h \tag{2.3}$$

Please note that the direct effect of F_i on F_j is t_{ij}. The total direct-influence matrix now reflexes the relationship between factors. Equeation (2.4) determines the total direct-influence matrix as Eq. (2.3) when $h \rightarrow \infty$.

$$T = X(I - X)^{-1} \tag{2.4}$$

where I is an identity matrix and can be involved with Markov chain theory as: X^h is the power of matrix X, and converges solutions to the inversion of matrix ($\lim_{h\rightarrow\infty} X^h = [0]_{n\times n}$).

The total direct-influence matrix is $\sum_{h=1}^{\infty} X^h$; thus, we have:

$$\sum_{h=1}^{\infty} X^h = X(I + X^1 + X^2 + \cdots + X^{h-1})$$

$$= X \times (I - X)^{-1} \times (I - X) \times (I + X^1 + X^2 + \ \dots + X^{h-1})$$

$$= X \times (I - X)^{-1} \times (I - X^h)$$

$$T \ = X \times (I - X)^{-1}$$

3) An influence relation map producing

The influential relation map is graphical information showing the effects of the factors. It can be drawn by first calculating C and R. Equations (2.5) and (2.6) are the C and R calculation, respectively. They are the summation of T's columns and rows, respectively.

$$R_i = \sum_{i=j}^{n} t_{ij}, \quad \forall i \in \{1,2,\dots,n\} \tag{2.5}$$

$$C_j = \sum_{i=1}^{n} t_{ij}, \quad \forall j \in \{1,2,\dots,n\} \tag{2.6}$$

where R_i is the sum of row ith which can be called the degree of influential impact, C_j is the sum of column jth and which can be called indirect influence received by factor j from all other factors.

It is important to note that in this context, j is equal to i, where i and j are both elements of the set $\{1,2,\dots,n\}$. The term $(R + C)$ is referred to as 'Prominence' and represents a horizontal axis vector that indicates the relative importance assigned to each factor. Likewise, $(R - C)$ known as 'Relation' is then determined for the vertical axis which indicates the net effect. Figure 2.4 shows the $(R + C)$ and $(R - C)$ graphic.

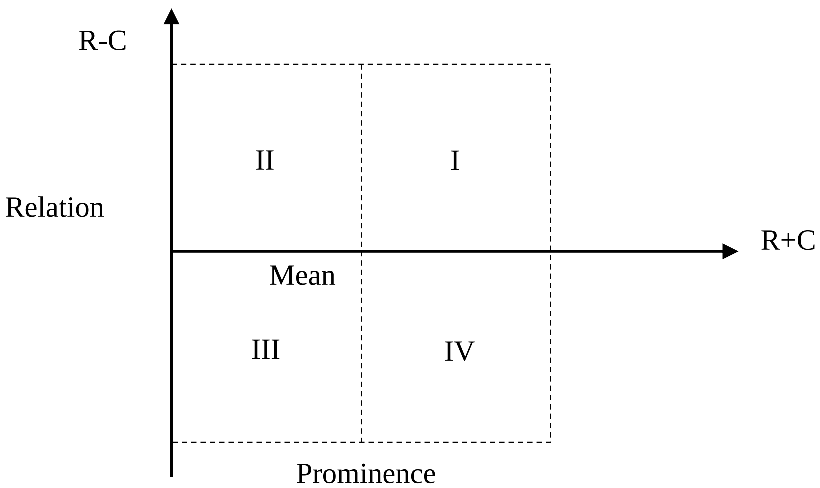

Figure 2.4 Influence relation map.

From Fig. 2.4, all studied factors in the complex problem can be classified into four quadrants which be divided by the means of of $(R + C)$ and $(R - C)$. Four quadrants can be explained as follows:

Quadrant I: The factors in quadrant I are referred to as essential or complex variables due to their substantial correlation value and significance.

Quadrant II: This region comprises autonomous contributors or influential factors since they have a strong correlation but modest importance.

Quadrant III: The factors in this region have little significance and influence, as they are somewhat disconnected from the system being researched and are believed to be independent and separate factors.

Quadrant IV: This quadrant encompasses characteristics with great prominence but low correlation. The term for this is impact factors, which refers to the recipients or individuals affected by something. Other factors influence the elements affecting area IV and do not have a direct opportunity for change.

4) An importance weight for factors computing

During this stage, the significance weights of all discovered factors are calculated. Usually, the weight of elements is determined by the prominence value $(R + C)$ and can be acquired by the normalization technique outlined below:

$$w_i = \frac{t_{i.} + t_{.j}}{\sum_{i=1}^{n} \sum_{j=1}^{n} (t_{i.} + t_{.j})} \quad (2.7)$$

where $\forall i, j \in \{1,2, \dots, n\}$.

2.5 Interpretative Structural Model

An interpretative structural model (ISM) is a method that involves interpreting an embedded object or representation system through the systematic and iterative application of graph theory (Malone, 1975). This process generates a directed graph representing the complicated system based on the contextual relationship among a collection of pieces. Interpretative structural modeling is a method that converts ambiguous and inadequately expressed mental representations of systems into explicit and well-defined models that have various practical applications.

Within any interpretative structural paradigm, the digraph can be interpreted at two distinct levels: nodes and linkages. An Information Systems Manager (ISM) analyzes the nodes by considering the definition of the elements. However, the ability to understand connections in ISM is quite restricted. It only allows for interpreting the contextual relationship between items and the direction of the relationship in a paired comparison. However, there needs to be more understanding of how the directed link functions (Sushil, 2012). For instance, two objectives, A and B, are interconnected through the contextual relationship that 'will aid in accomplishing'. If there is a directed relationship in an ISM from objective A to objective B, it implies that objective A will contribute to achieving objective B. However, it does not specify how objective A would facilitate the accomplishment of objective B.

2.5.1 Overview

The mathematical underpinnings of the ISM methodology can be found in other reference works, such as Stewart and Tall (2015). Several authors address the applicability of the philosophical foundation for the creation of the ISM approach, as well as the conceptual and analytical intricacies of the ISM process. Malone (1975) examined the utilization of ISM in organizing individual values and addressing obstacles to investment in an urban core. Saxena et al. (2006) have utilized it in combination with other modeling approaches within the framework of energy conservation policies. ISM has various applications in different fields, including decision support systems, waste management, vendor selection, product design, supply chain management, decision making, value chain management, and world-class manufacturing (Lin et al., 2006; Agarwal et al., 2007; Mohammed et al., 2008; Haleem et al., 2012).

ISM is a computer-assisted learning approach that involves producing and studying structural models. Structural models are created to visually represent the organization and arrangement of a complicated subject, system, or field of study using a combination of visuals and words. It is a method via which a modeling group can establish structure in the intricate connections between pieces. The method is interpretative as it relies on the group’s judgment to determine the relationship between elements. It is structural as it extracts an overall structure from a complex set of elements based on these relationships. Additionally, it is modeling as it represents the specific relationships and overall structure using a digraph model. ISM is primarily designed as a collaborative learning process, although it can also be utilized by persons working independently. ISM, or Interpretative Structural Modeling, is a method that uses relational mathematics to convert complex and disorganized mental models of a system into a coherent and interconnected set of system elements.

Initially, a set of elements is created, consisting of aspects that are pertinent to the topic or issue at hand. Various group processes, such as brainstorming and the nominal group technique (NGT), can be employed for this purpose. Next, a subordinate relation that is appropriate to the situation is selected. It should be subordinate in the sense that it should have a directive linked to it. The phrasing should be designed to prompt paired comparisons, such as 'Is objective A more significant than objective B?'

Once the modeling group has chosen an element set and determined the contextual relation, they proceed to conduct all paired comparisons. Two elements are selected, and a pairwise comparison between them is conducted. The group’s decision on the matched comparison is reached through a consensus majority vote following a discussion, emphasizing the value of each member's input. Based on the responses from the pairwise comparisons, it deduces specific responses by considering the transitivity of the contextual relationship and prompts responses for other paired comparisons. The principle of transitivity in the contextual relation is a fundamental assumption in ISM. It asserts that if element A is connected to B and B is connected to C, then A is inevitably connected to C. Once all the required input information is obtained, a structural model is created as a directed graph. This graph is supposed to represent the combined characteristics of the group's thought process. ISM can generate many types of structural models based on the specific demands of the modeling group and the requirements of the problem being addressed.

2.5.2 ISM process

Figure 2.5 visually represents the fundamental procedure of ISM and summarizes it as follows. The ISM example of organizational change demonstrates the application of these processes, together with matrices and other tools. The reachability matrix and its partitions are the main instruments in the ISM process (Attri & Sharma, 2013).

Step 1: The initial stage of structural modeling involves identifying and defining the elements that will be represented and their corresponding relationships. One can accomplish this by employing any technique for generating ideas, either through a small group activity or by utilizing grounded theory. The detected elements may also have connections with previous investigations if there is available information.

Step 2: Constructing the structure model that connects the elements is a crucial step in the ISM process. It is essential to clearly define the contextual link between the elements, as this relationship is the backbone of the specific structure we are addressing. Whether it's intention, priority, attribute enhancement, process, or mathematical reliance, as demonstrated in Table 1, the contextual relationship is key.

Step 3: This step represents the initial advancement beyond the conventional ISM. While the contextual connection can provide insight into the nature of a relationship based on its structure, it offers little explanation of how that relationship functions. It is recommended that the interpretation of the relationship be clarified to understand the ISM further and transform it into ISM. Regarding intent structures, it is essential to gain thorough knowledge by interpreting the relationship: ‘How will A assist in achieving B?’ The interpretation of the relationship would vary depending on the specific objectives of each pair, as it aims to clarify the underlying information by addressing the interpretative query mentioned above.

Step 4: The sole interpretation being made here is the direction of the relationship. To upgrade it to ISM, the proposal suggests utilizing the notion of an Interpretative Matrix to thoroughly understand each paired comparison in connection to how the directional relationship functions in the system being examined by addressing the interpretative query outlined in step 3. In paired comparison, the i^{th}

element is individually compared to each element from the $(i + 1)^{th}$ to the nth element. If there are n elements, the number of paired comparisons will be $n(n - 1)/2$. Due to the existence of two alternative directional links, $i\text{–}j$ and $j\text{–}i$, for each pair of items (i, j), the Knowledge Base will include $n(n - 1)$ rows. Each $i\text{–}j$ link can be labeled as either 'Yes (Y)' or 'No (N)'. If the label is 'Yes', it requires additional interpretation. This will provide the underlying reasoning behind the interconnected linkages in the form of 'Interpretative Logic—Knowledge Base'.

Step 5: The interpretative logic in the knowledge base is represented as paired comparisons. These comparisons are then transformed into a reachability matrix. In this matrix, a value of 1 is put in the $i - j$ column if the corresponding entry in the knowledge base is 'Y'. If the entry in the knowledge base is 'N', a value of 0 is placed in the corresponding cell. The matrix undergoes a verification process to adhere to the transitivity rule. It is continuously modified until complete transitivity is achieved. The Knowledge Base is updated whenever a new transitive link is established. The 'No' entry will be replaced with 'Yes', and the term 'Transitive' in the interpretation column will be inserted. If the transitive relationship can be adequately elucidated, it is included in the logic beside the 'Transitive' element; otherwise, it remains unchanged.

Step 6: It involves doing a level partition, which is similar to ISM, in order to determine the placement of pieces at each level. Compute the accessibility and precursor sets for each of the elements. The elements at the highest level of the hierarchy will not have any influence on elements that are positioned above their level. Consequently, the reachability set for a top-level element will include the element itself and any other elements at the same level the element may access, such as components of a highly connected subset. The antecedent set for a top-level element includes

- the element itself,
- elements that are connected to it from lower levels and
- any element from a highly connected subset at the top level.

If the element is at the top level, the intersection of the reachability set and the antecedent set will be identical to the reachability set. The elements at the highest level that meet the requirement should be deleted from the set of elements. This process should be performed iteratively until all levels have been determined.

Step 7: It involves the graphical arrangement of elements in levels, with directed links constructed based on the relationships indicated in the reachability matrix. A more streamlined version of the original digraph can be achieved by gradually deleting the transitive links through careful analysis of their meaning within the knowledge base. Only the transitive relationships that have a crucial meaning may be kept.

Step 8: The ultimate digraph is converted into a binary interaction matrix, representing all interactions with a single entry. The cells containing a single entry are interpreted by selecting the appropriate interpretation from the knowledge base in the form of an Interpretative Matrix.

Step 9: It involves utilizing the connective and interpretative information included in the interpretative direct interaction matrix and diagraph to obtain the ISM. The nodes in the diagraph are substituted with the representation of items positioned within boxes. The interpretation of the cells in the interpretative direct interaction matrix is shown next to the corresponding links in the structural model. This results in a comprehensive interpretation of the structural model, providing a thorough understanding of its nodes and links.

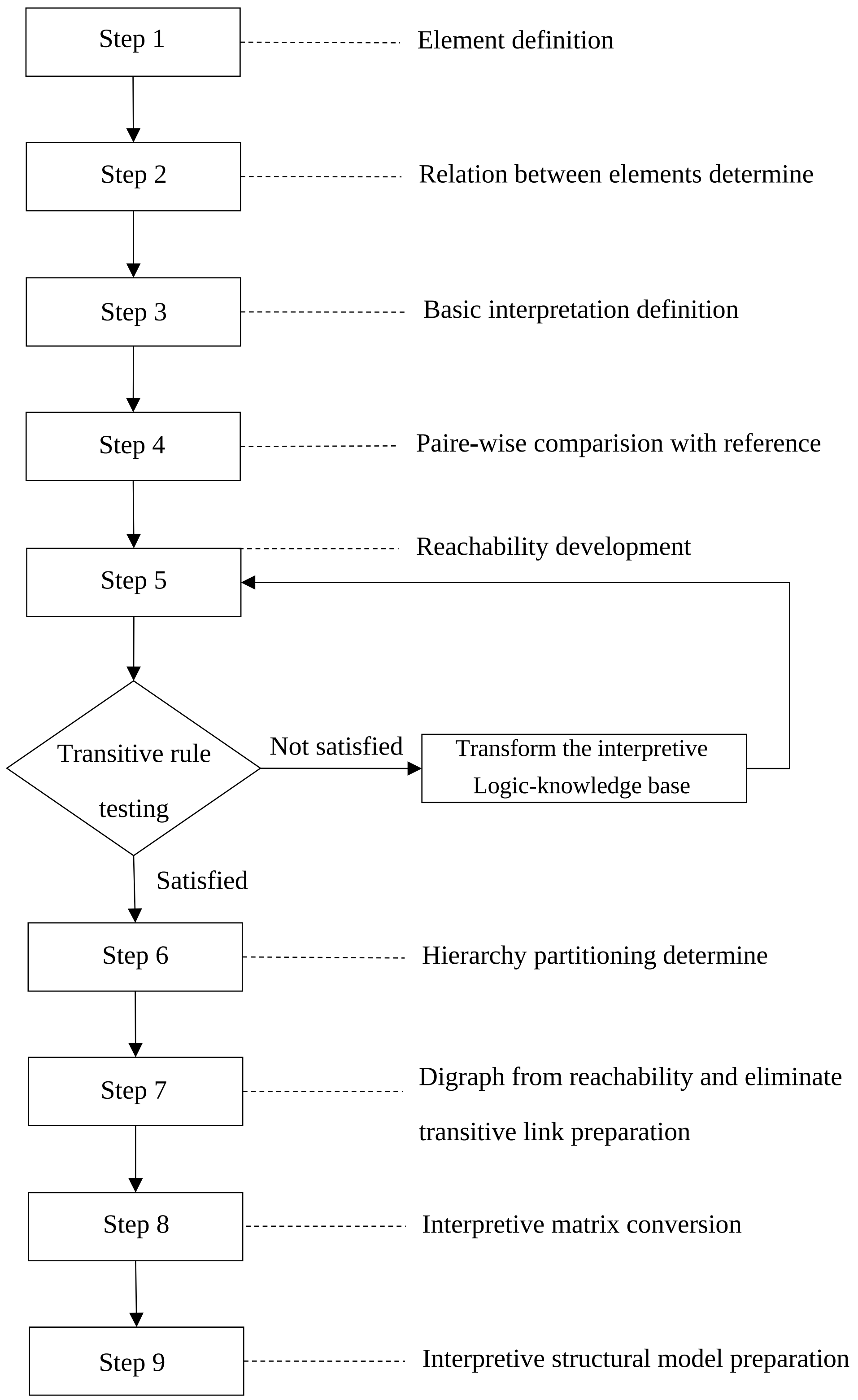

Figure 2.5 Interpretative structural model process.

2.6 Previous Works

Brookfield and Boussabaine (2009) suggested that considering risk as an intricate and emerging entity and utilizing network analysis presents a promising framework for comprehending risk exposure in a broad sense. The methodology focuses primarily on risk and its method of transmission, which is best explained through a network presentation. Our experimental findings suggest that the possibility of risk transmission arises from the combination of established risk identification methods and both intentional and unintentional risk management activities. Our research demonstrates that focusing on areas of risk reception is more crucial for effective risk management than addressing risk propagation. Therefore, it is recommended that project risk management prioritize safeguarding vulnerable areas from the impact of risks rather than attempting to eliminate the sources of risk to those vulnerable areas.

Dziadosz et al. (2015) pointed out that risk, which negatively impacts the project, is considered from the beginning of the investment process, namely when the contract is awarded after winning the bidding. The risk level associated with a specific construction contract is a significant determinant in deciding whether to accept or decline the contract. The primary concern revolves around accurately identifying contract risk. The risk factors that substantially influence the project's success and are frequently encountered are further examined. The verification process relies on the company's expertise in the building business. The purpose of this article is to describe the research findings that have examined the process of identifying and quantifying financial risk factors in construction projects, as well as their influence on the successful execution of these projects. We have analyzed 30 construction projects completed in Poland's northwestern region, including office buildings, factory halls, educational structures, and demolition works. The anticipated and actual risk level for the contract was determined as a percentage relative to the magnitude of the contract (measured in millions of PLN). The study's objective was to validate the correlation between the kind of structure, the magnitude of the contract, and the extent and level of risk. A statistical methodology has been employed. This study serves as a preliminary step in establishing a strategy for identifying contract risks and precisely calculating reserves for unanticipated scenarios. The goal is to enhance the company's competitiveness and give investors a favorable pricing offer.

Srinivasan et al. (2022) stated that the development of a country's infrastructure and economy is contingent upon the growth and progress of the construction sector. The construction industry involves numerous risk variables during the design, execution, and commissioning stages of projects. Managing risk factors in the construction industry is vital to fulfill the sector's overall objectives regarding cost, time, safety, quality, and environmental sustainability. This paper focuses on the financial components directly involved in the sector. The study was conducted with engineers, contractors, and laborers in the northwestern regions of Tamilnadu. The viewpoints of various management levels have been summarized using a standardized questionnaire format that has been examined, and the present circumstances have analyzed their findings. Using surveys and data analysis using the Relative Importance Index (RII), the factors that were most closely associated with the identified components include labor risk, material risk, credit risk, planning risk, execution, and environmental concerns. The suggestions and recommendations have been proposed to address those risk mitigations.

Gad et al. (2022) explained that the distribution of financial risks among project stakeholders is a crucial decision that impacts the project's performance following unforeseen political and economic upheavals in Egypt between 2011 and 2016. Certain financial risks in a project are beyond control and influence project stakeholders. Thus, the research centers on the expertise of implementing financial risk management modeling from many viewpoints. The purpose of this document is to present FRAM. This dynamic model uses many analysis methods to detect and evaluate financial risks related to project stakeholders, including the owner/developer, contractor, financial agencies/banks, and project management organizations. It is used before the construction phase begins.

Shibani et al. (2022) resolved that construction risk refers to the potential occurrence of an event that could negatively impact the viability of a project. Various hazards that pose a risk to enterprises might be encountered in the construction industry, just like in other sectors. Furthermore, construction projects encounter substantial hazards that jeopardize the cost, duration, and quality of execution of building projects. Over the past two years, Lebanon has been grappling with a profound economic crisis that has significantly impacted numerous enterprises and industries, particularly the building sector. This article identifies, categorizes, and analyzes the most significant risks present in the Lebanese construction industry, focusing on the financial and economic risk category. Ultimately, the goal is to conclude this matter. In order to accomplish the objectives of this study, data was gathered through the administration of a questionnaire survey to professionals in the Lebanese construction sector. The findings indicated that the construction sector in Lebanon is vulnerable to numerous sources of internal and external risk. The most significant are financial risks, including currency fluctuations, inflation, and insolvency. This research examines the significance and advantages of adopting risk management and the obstacles that hinder its successful implementation.

Yousri et al. (2023) described that identifying risks is essential in the field of construction management. Enhanced risk management can effectively mitigate the significant impact of identified risk factors on time and cost performance. The identification and development of reactions to risk variables directly and indirectly impact the risk management process. The fluctuations in the exchange rate of the Egyptian pound against foreign currencies in the past year, along with efforts to reduce the importation of engineering materials and equipment, have had a notable impact on the established norms governing buildings in Egypt. Conducting a preliminary survey including experienced engineers is essential to completing research. This research study involved 15 specialists who were requested to examine the gathered risk factors from prior studies to validate these factors' feasibility in the context of Egypt. A total of 35 risk factors were chosen in the pilot survey, which was administered to a sample of 95 participants. In order to streamline the analytic procedure, the data collection was conducted using a five-point Likert scale. Hence, the primary aim of this study is to redefine and organize the risks based on the present circumstances. The suggested model has identified several high-risk elements that have the potential to impact overall performance collectively. These factors include funding issues with contractors, fluctuations in material prices, inaccurate estimations of project activity durations, and shortages of construction materials in the market. In order to facilitate the achievement of project success for stakeholders, it is essential to identify and effectively manage specific components that pose a high risk.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter presents the research procedure and details, including the sample construction projects in Kunming, China. However, the participants are only at middle- to upper-management levels. Thus, 26 staff members participated in this study. The details of the participants are described in section 3.1. The research tool design is explained in section 3.2. The primary research tool is a questionnaire; however, we also need feedback from the participants by setting focus group meetings to report the research results. Section 3.3 describes the data analysis techniques based on the DEMATEL-ISM method. The whole picture of the research process and its agenda is drawn in sections 3.4 and 3.5, respectively.

3.1 Sample and Population

The sample construction project is in Kunming, China. The project size, value, and number of staff are confidential, so we are not allowed to show them to the public. Furthermore, other quantitative data, such as plot size, project location, and construction equipment, are closed.

In this section, we would like to display the research participants and their facts, as shown in Table 3.1.

Table 3.1 Research participants.

No.	Position	Number	Experience (Years)
1	Project manager	1	15
2	Vice project managers	1	13
3	Financial manager	1	7
4	Marketing manager	1	10
5	Personal manager	1	5
6	Supplier manager	1	7

Table 3.1 Research participants. (continued)

No.	Position	Number	Experience (Years)
7	Construction engineers	12	3 - 7
8	Supervisors	8	5 - 10
Total		26	3 - 15

3.2 Research Tool Design

A questionnaire is design to answer the opinion of 26 staff members (decision makers) to quantitfy the risk level with five-point Likert scale (1-5 scale). The meanings and implications are list in Table 3.2.

Table 3.2 A five-point Likert scale.

Point	Definition
1	No influence
2	Very low influence
3	Low influence
4	High influence
5	Very high influence

The key risk factors are retrieved from literature such as Song and Hao (2022), Shibani et al. (2022), Srinivasan et al. (2022), and Yousri et al. (2023). The selected key risk factors in this study are nine classes with twenty-eight factors. The details are shown in Table 3.3.

Table 3.3 Key risk factors.

Class	Elemental description	Code	Short justification
Pandemic, R_1	Pandemic outbreak	x_1	Any pandemic outbreak will occur in the future.
Political, R_2	War and geopolitical conflict	x_2	The conflict occurs during design, procurement, construction, and post-construction phases.
	Political corruption	x_3	Any corruption due to the business and politic situations.
	Regulation and policy changes	x_4	Changes of the regulations during design, procurement, construction, and post-construction phases.
Economy, R_3	Fluctuation of currency exchange rate	x_5	The unstable of currency exchange rate during the project.
	Inflation rate	x_6	Rising of inflation rate which affacts to the project cost.
	Interest rate	x_7	High rising of interest rate that affacts to the project on construction and post-construction phases.
	Household debt	x_8	High household debt affacts to customers' purchasing power.

Table 3.3 Key risk factors. (continued)

Class	Elemental description	Code	Short justification
Credit, R_4	Project's credit risk	x_9	Project credit default and cannot do repayment timely.
	Equity holder's credit risk	x_{10}	Equity credit default and cannot do repayment timely.
Engineering, R_5	Design change	x_{11}	Often desing changes during construction phase.
Engineering, R_5	Lack of material and qualified suppliers	x_{12}	Local vendors cannot supply quality materials to the project.
	Substandard materials	x_{13}	The accepted materials are low quality; however, no choice.
	Substandard equipment	x_{14}	The equipment and tools are low quality and outdated technologies.
	Project delay	x_{15}	The project progress lags behind the project schedule.
Operation, R_6	Counterparty risk	x_{16}	The counterparties are substandard and high risk.
	Rating risk	x_{17}	Project rating from agencies or banks are unreasonable and inaccuracy.
	Tax risk	x_{18}	The appreciation and appraised value are inaccurate, affecting the high property transfer tax.

Table 3.3 Key risk factors. (continued)

Class	Elemental description	Code	Short justification
Market, R_7	Client's financial stability	x_{19}	Due to the market situation, the client has unaccented finance situation.
	Poor finanacial market	x_{20}	The finance institutions are weak and connot support the construction project.
	Poor market research	x_{21}	The project cannot response the customers' needs.
Liquidity, R_8	Lack of cash flow	x_{22}	Poor cash flow management.
	Project's liquidity	x_{23}	Other liquidity except cash flow is poor.
	Delay payment by client	x_{24}	The payment periods are not followed by the client.
Others, R_9	Lack of competent staff	x_{25}	The workforce recruitment cannot response to the project's needs.
	Environmental impacts	x_{26}	There are complains from neighbors and environmental protect agencies.
	Public impacts	x_{27}	Other impacs except environmental impacts such as higher inflation rate, traffic jam in vicinity, and bad building vision.
	Poor construction supply chain management	x_{28}	Uptream and downstream supply chains are poor such as material, debris, workforce, equipment, and tools.

The questionnaire is reviewed its content validity by suing the index of item-objective congruence (IOC). It is a procedure used in test development for evaluating content validity at the item development stage. The formula of IOC is shown below.

$$IOC = \frac{\sum R}{N} \tag{3.1}$$

where IOC = indext of item-objective congruence

R = experts' opinion score

N = number of experts

The score that assigned by the expert has 3 choices as follows.

+1 = The question is congruent with the objective.

0 = It is not sure that the question is congruent with the objective.

-1 = The question is not congruent with the objective.

The criteria of IOC interpretation is as follow.

$IOC \geq 0.50$ is the question being congruent with the objective.

$IOC < 0.50$ is the question being not congruent with the objective.

Three university professors who studied risk analysis, financial management, and construction management over ten years in China. The IOC evaluation is shown in Appendix A and the questionnaire is shown in Appendix B.

Furthermore, the relation among risk factors is also evaluated using the concept of DEMATEL. Thus, the influence level among risk factors is also determined by the decision makers. Table 3.4 shows the influence levels based on five-point Likert scale.

Table 3.4 Five-level influence scale.

Level	Definition
1	No influence
2	Very low influence
3	Low influence
4	High influence
5	Very high influence

3.3 Data Analysis

We would like to show the calculation steps below.

3.3.1 Pairwise comparisons for an initial derect-relation matrix (Z)

The initial direct-relation matrix Z is an average $n \times n$ matrix constructed by pairwise comparisons of m decision-makers. Equation (3.1) is $Z = \left[z_{ij}\right]_{n\times n}$ where Z_{ij} is denoted as an average direct-relation value of x_{ij} and all principal diagonal $z_{ij}(i = j)$ equals to zero, $X^k = [x_{ij}^k]$ is a judgement on causal relationship between x_{ij} by the k^{th} decision maker.

$$Z = \left[z_{ij}\right]_{n\times n} = \frac{1}{m}\sum_{k=1}^{m} z_{ij}^{k}, \quad \forall i, j = 1, 2, \dots, n \tag{3.1}$$

3.3.2 Direct-relation matrix normalization (Z)

The normalized direct-relation matrix $D = \left[d_{ij}\right]_{n\times n}$ where the value of each factor in matrix D is $0 \leq d \leq 1$, can be obtained through Eq. (3.2) and (3.3). The maximum value of the sums of each row and column is used to calculate a coefficient s.

$$s = \min\left[\frac{1}{\max\limits_{1\leq i\leq n} \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{\max\limits_{1\leq j\leq n} \sum_{i=1}^{n} |z_{ij}|}\right] i, j = 1,2, \dots, n \tag{3.2}$$

$$D = s \times Z \text{ or } \left[d_{ij}\right]_{n\times n} = s \times \left[z_{ij}\right]_{n\times n}, s > 0 \tag{3.3}$$

3.3.3 Total-relation matrix (T) calculation

The total-relation matrix T is calculated by Eq. (3.4) as matrix operations on D.

$$T = \lim_{m\to\infty}(D^1 + D^2 + \cdots + D^m) = \sum_{m=1}^{\infty} D^i = D(I - D)^{-1} \tag{3.4}$$

where I is an $n \times n$ identity matrix. R_i and C_j in Eq. (3.5) are the sums of rows and columns in the matrix T, respectively, in which t_{ij} denotes the interdependent value of each pair of the investigated factors. Additionally, in Eq. (3.6), the horizontal axis value pr_i^+ denotes how crucial the i^{th} factor is, whilst the vertical axis value pr_i^- classifies the factors into the cause-and-effect group. If the value of pr_i^- is positive, the factor is classified into the cause group. Alternatively, when the value of pr_i^- is negative, the factor is grouped into the effect group.

$$R_i = \sum_{j=1}^{n} t_{ij} \quad , \quad C_j = \sum_{i=1}^{n} t_{ij} \quad (i, j = 1,2, \ldots, n) \tag{3.5}$$

$$pr_i^+ = R_i + C_i \quad , \quad pr_i^- = R_i - C_i \tag{3.6}$$

3.3.4 Threshold value (α) calculation

The threshold value α tends to filter and remove the factors that have trivial relation on others in the matrix T. The threshold value is calculated by the average value of t_{ij}, where N denotes the total number of element ($i \times j$), see Eq. (3.7). Only the factors whose relation values of t_{ij} are higher than the threshold value can be considered interdependency among the risk factors.

$$\alpha = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} t_{ij}}{N} \tag{3.7}$$

3.3.5 Overall influence matrix calculation

A drawback of the comprehensive matrix is the self-influencing is ignored. Thus, we need the overall influence matrix H to fulfill this disadvantage. The overall matrix is calculated by using Eq. (3.8).

$$H = I + T \tag{3.8}$$

$$H = \left(h_{ij}\right)_{n \times n} \tag{3.9}$$

where I is an indentity matrix.

In this step, we need the threshold value $\lambda, \lambda \in [0,1]$. This value indicates the fewer impact factors because it may come from calculations, and any inaccuracy can be discarded. Nevertheless, the analyst’s pre-determined parameter λ is subjective.

$$s_{ij} = 0, \quad a_{ij} < \lambda, \ \forall i,j \in \{1,2,3,\dots,n\} \tag{3.10}$$

$$s_{ij} = 1, \quad a_{ij} \geq \lambda, \ \forall i,j \in \{1,2,3,\dots,n\} \tag{3.11}$$

Theoretically, the large threshold value affects the relatively simple system structure. However, the influence relationship between risk factors is hardly measured. Conversely, the small threshold value affacts the system structre is complicated, and the influence relationship between risk factors is impractical.

3.3.6 Reachable matrix constructing

Next, the reachable matrix is calculated by using Eq. (3.12).

$$S = \left(s_{ij}\right)_{n\times n} \tag{3.12}$$

The reachable set and antecedent set are built as Eq. (3.13) and (3.14).

$$A(x_i) = \{x_j \in S|s_{ij} = 1\} \tag{3.13}$$

$$R(x_i) = \{x_j \in S|s_{ij} = 1\} \tag{3.14}$$

where $A(x_i)$ is the antecedent set and $R(x_i)$ is the reachable set. The layer detection is calculated by using Eq. (3.15).

$$B(x_i) = \{x_i \in S|R(x_i) \cap A(x_i) = R(x_i)\} \tag{3.15}$$

Finally, the interpretative structural model is built.

3.4 Research Procedure

The research process is drawn as show in Fig. 3.1.

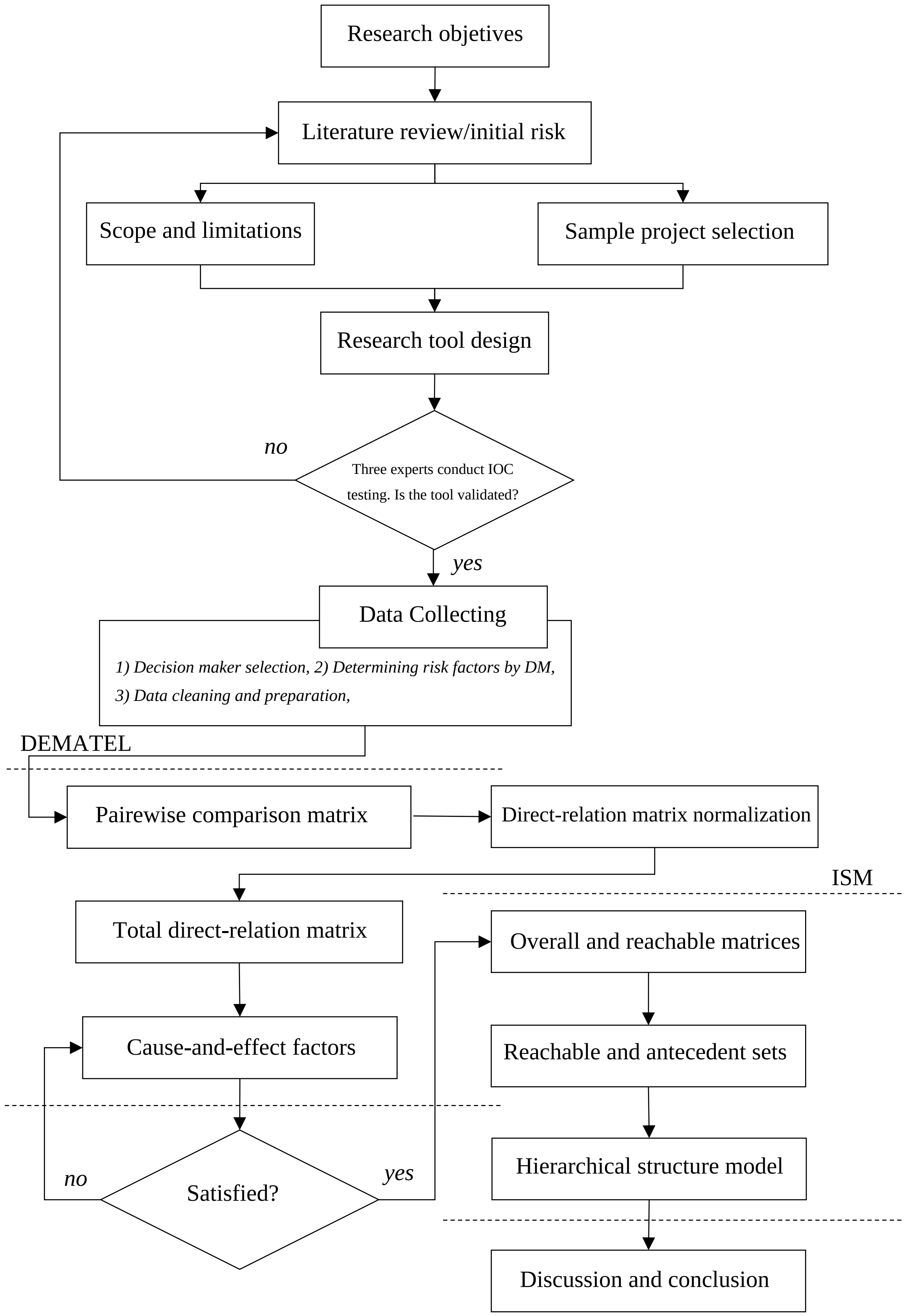

Figure 3.1 Research procedure.

CHAPTER 4
RESULT AND ANALYSIS

This chapter shows the result of each step in DEMATEL-ISE procedure. The name of matrices may different from literature; however, the main idea of matrix in each step is not dissimilar. Sections 4.1 to 4.4 are the details of the decision-making and trial evaluation laboratory technique. Sections 4.5 to 4.8 are the interpretative structural model technique. Section 4.9 is the discussion part of this chapter.

4.1 The Initial Direct-relation Matrix (Z)

The initial direct-relation matrix is shown in Table 4.1.

4.2 The Derect-relation Matrix Normalization (D)

The direct-relation matrix normalization is shown in Table 4.2. The $S = 0.0098$ and the normalized values are $\frac{b_{ij}}{S}$.

4.3 The Total-relation Matrix (T)

The total-relation matrix is shown in Table 4.3. Then, the total direct-relation matrix is calculated using Eq. (3.4), as shown in Table 4.3. Then, pr_i^+ and pr_i^- is calculated using Eq. (3.5) and (3.6). The result and their implication are shown in Table 4.4.

Table 4.1 Direct-relation matrix of twenty-six decision-makers.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	0	1.1	1.5	4.2	3.7	4.5	4.2	4.7	2.7	2.1	1.6	2.9	2.1	2.3	4.5	3.2	2.4	1.6	3.7	4.1	1.3	3.9	3.6	4.1	1.8	1.8	3.4	3.1
X2	1.0	0	2.1	3.7	3.4	4.1	4.1	3.8	3.7	2.2	1.5	3.5	1.5	1.7	2.9	3.9	3.1	2.9	2.8	3.4	1.8	2.6	2.8	3.1	1.9	1.5	2.7	3.4
X3	1.0	2.5	0	4.1	1.9	2.1	1.9	1.7	2.1	2.5	1.9	3.7	3.9	4.1	3.9	3.7	2.7	1.9	2.2	1.4	1.5	2.9	3.4	2.2	1.8	1.5	3.5	2.5
X4	1.0	1.4	2.1	0	3.1	3.7	3.1	3.7	3.5	3.5	2.6	2.1	2.1	2.5	3.4	1.9	2.1	3.2	3.3	3.7	1.8	3.1	3.3	2.7	1.8	1.5	2.7	3.1
X5	1.0	1.3	1.5	3.4	0	4.5	4.3	4.5	2.7	3.3	2.6	2.2	3.9	4.1	4.1	3.7	3.2	2.4	3.6	4.2	2.1	3.8	3.9	3.1	2.1	1.7	2.3	3.9
X6	1.0	1.1	1.3	2.1	3.1	0	3.7	3.9	3.5	3.3	3.1	2.9	3.1	3.1	3.5	3.4	3.6	2.1	3.4	3.7	1.6	2.9	3.3	3.6	1.9	1.1	1.6	3.4
X7	1.0	1.0	1.0	1.4	2.1	2.9	0	1.8	2.1	2.4	1.6	1.4	3.1	1.7	1.4	1.6	4.1	1.9	3.8	4.1	1.9	3.3	3.6	3.9	1.4	1.5	1.4	2.7
X8	1.0	1.0	1.0	2.1	2.5	2.1	3.8	0	2.1	2.1	2.9	2.1	2.1	2.1	2.9	1.9	1.8	1.5	4.2	4.4	1.6	3.9	3.7	4.4	1.6	1.5	1.5	2.4
X9	1.0	1.0	1.0	2.2	2.1	1.8	3.3	1.8	0	4.1	3.2	3.6	3.5	3.4	4.1	3.3	4.2	2.1	2.1	2.5	3.4	4.1	4.2	1.9	3.1	2.4	2.9	3.4
X10	1.0	1.0	1.0	1.8	1.9	2.2	3.7	1.7	4.4	0	3.9	3.2	3.2	3.3	3.7	2.9	4.1	2.2	1.9	2.5	3.1	4.1	4.1	2.1	3.2	2.4	2.7	3.3
X11	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.5	0	3.3	3.5	3.7	4.1	3.9	3.1	2.4	2.1	1.8	2.7	3.9	4.1	3.9	3.4	2.5	2.6	3.9
X12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.1	2.1	4.1	0	3.9	2.8	4.1	3.5	2.1	2.0	1.6	2.1	3.1	3.3	2.5	1.9	2.2	2.4	2.3	2.8
X13	1.0	1.0	1.0	1.2	1.0	2.2	2.5	1.4	1.7	1.5	4.1	2.2	0	1.7	4.2	1.3	3.1	1.4	1.4	2.5	1.7	2.1	1.7	1.7	2.1	1.6	1.6	3.4
X14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.2	1.7	2.1	0	3.9	1.5	2.2	2.1	2.2	2.1	1.8	2.1	2.1	1.5	2.1	2.5	2.2	3.1
X15	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.1	3.1	2.7	1.9	1.8	0	2.4	3.1	2.1	1.9	3.7	2.1	3.8	3.9	4.2	2.2	3.1	3.4	2.2
X16	1.0	1.0	1.0	1.0	1.0	1.0	2.2	1.0	3.4	3.2	3.5	3.9	4.0	3.7	4.1	0	3.2	2.1	2.1	2.5	2.8	3.1	3.1	1.9	2.2	2.2	2.1	3.7
X17	1.0	1.0	1.0	1.0	2.1	1.9	4.2	2.1	4.1	3.9	3.3	2.7	2.7	2.4	3.9	3.3	0	2.1	2.1	3.9	1.7	3.7	3.9	2.0	2.1	2.1	2.1	3.4
X18	1.0	1.0	1.0	1.3	1.0	2.1	3.9	2.2	3.6	3.5	1.8	2.9	3.1	3.1	3.7	3.3	3.9	0	2.5	3.1	2.1	3.6	3.6	2.1	2.5	2.1	2.1	2.8
X19	1.0	1.0	1.0	1.0	1.0	1.4	3.5	3.1	3.8	3.6	3.4	3.1	2.7	2.7	3.5	3.3	3.1	2.3	0	2.1	1.6	4.1	4.1	4.2	3.5	2.1	2.1	3.3
X20	1.0	1.0	1.0	1.7	1.9	2.3	3.8	1.9	4.2	4.0	3.9	3.9	3.9	3.5	4.2	3.3	4.1	3.3	2.7	0	2.1	4.3	4.3	2.8	3.9	2.7	3.1	3.8
X21	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.2	2.1	3.9	3.6	3.6	3.7	3.9	3.5	3.1	3.0	1.6	0	3.6	3.5	3.8	2.5	2.5	2.3	3.5
X22	1.0	1.0	1.0	1.0	1.0	1.1	1.2	1.0	4.1	3.8	3.4	3.9	3.9	3.9	4.3	3.5	4.1	3.5	2.1	2.0	1.5	0	3.9	2.2	3.5	3.1	3.1	3.5
X23	1.0	1.0	1.0	1.0	1.0	1.1	1.5	1.4	3.9	3.9	3.5	3.5	3.4	3.9	3.9	3.3	3.9	2.9	2.1	2.0	1.8	4.1	0	2.5	3.2	2.8	2.7	3.8
X24	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.2	3.9	3.9	3.3	3.7	3.5	3.3	4.1	3.5	3.7	3.3	3.3	2.5	2.1	4.3	3.8	0	3.7	2.2	2.4	3.6
X25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	2.2	2.1	3.5	3.7	3.7	3.8	4.1	3.7	3.5	3.9	2.7	2.4	3.9	3.7	3.7	2.1	0	2.6	2.5	3.3
X26	1.0	1.0	1.0	3.9	1.0	1.6	3.2	1.5	3.3	3.2	4.1	2.5	2.8	2.8	3.9	3.3	3.6	3.3	2.1	2.2	2.5	3.3	3.5	3.6	1.9	0	4.2	2.7
X27	1.0	1.0	1.0	3.9	1.0	1.4	1.4	1.7	3.2	3.2	4.0	3.3	3.3	3.4	4.1	2.5	3.3	3.1	2.3	2.5	2.2	3.4	3.3	3.6	1.7	3.9	0	3.3
X28	1.0	1.0	1.0	3.8	1.0	1.1	1.2	1.1	3.3	3.3	3.8	4.1	4.0	3.7	3.9	3.1	3.3	3.3	2.6	2.1	1.9	3.5	3.3	3.2	2.2	2.7	2.5	0

Table 4.2 Direct-relation matrix normalization of twenty-six decision-makers.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	0	0.0108	0.0147	0.0412	0.0363	0.0441	0.0412	0.0461	0.0265	0.0206	0.0157	0.0284	0.0206	0.0225	0.0441	0.0314	0.0235	0.0157	0.0363	0.0402	0.0127	0.0382	0.0353	0.0402	0.0176	0.0176	0.0333	0.0304
X2	0.0098	0	0.0206	0.0363	0.0333	0.0402	0.0402	0.0372	0.0363	0.0216	0.0147	0.0343	0.0147	0.0167	0.0284	0.0382	0.0304	0.0284	0.0274	0.0333	0.0176	0.0255	0.0274	0.0304	0.0186	0.0147	0.0265	0.0333
X3	0.0098	0.0245	0	0.0402	0.0186	0.0206	0.0186	0.0167	0.0206	0.0245	0.0186	0.0363	0.0382	0.0402	0.0382	0.0363	0.0265	0.0186	0.0216	0.0137	0.0147	0.0284	0.0333	0.0216	0.0176	0.0147	0.0343	0.0245
X4	0.0098	0.0137	0.0206	0	0.0304	0.0363	0.0304	0.0363	0.0343	0.0343	0.0255	0.0206	0.0206	0.0245	0.0333	0.0186	0.0206	0.0314	0.0323	0.0363	0.0176	0.0304	0.0323	0.0265	0.0176	0.0147	0.0265	0.0304
X5	0.0098	0.0127	0.0147	0.0333	0	0.0441	0.0421	0.0441	0.0265	0.0323	0.0255	0.0216	0.0382	0.0402	0.0402	0.0363	0.0314	0.0235	0.0353	0.0412	0.0206	0.0372	0.0382	0.0304	0.0206	0.0167	0.0225	0.0382
X6	0.0098	0.0108	0.0127	0.0206	0.0304	0	0.0363	0.0382	0.0343	0.0323	0.0304	0.0284	0.0304	0.0304	0.0343	0.0333	0.0353	0.0206	0.0333	0.0363	0.0157	0.0284	0.0323	0.0353	0.0186	0.0108	0.0157	0.0333
X7	0.0098	0.0098	0.0098	0.0137	0.0206	0.0284	0	0.0176	0.0206	0.0235	0.0157	0.0137	0.0304	0.0167	0.0137	0.0157	0.0402	0.0186	0.0372	0.0402	0.0186	0.0323	0.0353	0.0382	0.0137	0.0147	0.0137	0.0265
X8	0.0098	0.0098	0.0098	0.0206	0.0245	0.0206	0.0372	0	0.0206	0.0206	0.0284	0.0206	0.0206	0.0206	0.0284	0.0186	0.0176	0.0147	0.0412	0.0431	0.0157	0.0382	0.0363	0.0431	0.0157	0.0147	0.0147	0.0235
X9	0.0098	0.0098	0.0098	0.0216	0.0206	0.0176	0.0323	0.0176	0	0.0402	0.0314	0.0353	0.0343	0.0333	0.0402	0.0323	0.0412	0.0206	0.0206	0.0245	0.0333	0.0402	0.0412	0.0186	0.0304	0.0235	0.0284	0.0333
X10	0.0098	0.0098	0.0098	0.0176	0.0186	0.0216	0.0363	0.0167	0.0431	0	0.0382	0.0314	0.0314	0.0323	0.0363	0.0284	0.0402	0.0216	0.0186	0.0245	0.0304	0.0402	0.0402	0.0206	0.0314	0.0235	0.0265	0.0323
X11	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0176	0.0147	0	0.0323	0.0343	0.0363	0.0402	0.0382	0.0304	0.0235	0.0206	0.0176	0.0265	0.0382	0.0402	0.0382	0.0333	0.0245	0.0255	0.0382
X12	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0206	0.0206	0.0402	0	0.0382	0.0274	0.0402	0.0343	0.0206	0.0196	0.0157	0.0206	0.0304	0.0323	0.0245	0.0186	0.0216	0.0235	0.0225	0.0274
X13	0.0098	0.0098	0.0098	0.0118	0.0098	0.0216	0.0245	0.0137	0.0167	0.0147	0.0402	0.0216	0	0.0167	0.0412	0.0127	0.0304	0.0137	0.0137	0.0245	0.0167	0.0206	0.0167	0.0167	0.0206	0.0157	0.0157	0.0333
X14	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0314	0.0167	0.0206	0	0.0382	0.0147	0.0216	0.0206	0.0216	0.0206	0.0176	0.0206	0.0206	0.0147	0.0206	0.0245	0.0216	0.0304
X15	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0304	0.0304	0.0265	0.0186	0.0176	0	0.0235	0.0304	0.0206	0.0186	0.0363	0.0206	0.0372	0.0382	0.0412	0.0216	0.0304	0.0333	0.0216
X16	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0216	0.0098	0.0333	0.0314	0.0343	0.0382	0.0392	0.0363	0.0402	0	0.0314	0.0206	0.0206	0.0245	0.0274	0.0304	0.0304	0.0186	0.0216	0.0216	0.0206	0.0363
X17	0.0098	0.0098	0.0098	0.0098	0.0206	0.0186	0.0412	0.0206	0.0402	0.0382	0.0323	0.0265	0.0265	0.0235	0.0382	0.0323	0	0.0206	0.0206	0.0382	0.0167	0.0363	0.0382	0.0196	0.0206	0.0206	0.0206	0.0333
X18	0.0098	0.0098	0.0098	0.0127	0.0098	0.0206	0.0382	0.0216	0.0353	0.0343	0.0176	0.0284	0.0304	0.0304	0.0363	0.0323	0.0382	0	0.0245	0.0304	0.0206	0.0353	0.0353	0.0206	0.0245	0.0206	0.0206	0.0274
X19	0.0098	0.0098	0.0098	0.0098	0.0098	0.0137	0.0343	0.0304	0.0372	0.0353	0.0333	0.0304	0.0265	0.0265	0.0343	0.0323	0.0304	0.0225	0	0.0206	0.0157	0.0402	0.0402	0.0412	0.0343	0.0206	0.0206	0.0323
X20	0.0098	0.0098	0.0098	0.0167	0.0186	0.0225	0.0372	0.0186	0.0412	0.0392	0.0382	0.0382	0.0382	0.0343	0.0412	0.0323	0.0402	0.0323	0.0265	0	0.0206	0.0421	0.0421	0.0274	0.0382	0.0265	0.0304	0.0372
X21	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0216	0.0206	0.0382	0.0353	0.0353	0.0363	0.0382	0.0343	0.0304	0.0294	0.0157	0	0.0353	0.0343	0.0372	0.0245	0.0245	0.0225	0.0343
X22	0.0098	0.0098	0.0098	0.0098	0.0098	0.0108	0.0118	0.0098	0.0402	0.0372	0.0333	0.0382	0.0382	0.0382	0.0421	0.0343	0.0402	0.0343	0.0206	0.0196	0.0147	0	0.0382	0.0216	0.0343	0.0304	0.0304	0.0343
X23	0.0098	0.0098	0.0098	0.0098	0.0098	0.0108	0.0147	0.0137	0.0382	0.0382	0.0343	0.0343	0.0333	0.0382	0.0382	0.0323	0.0382	0.0284	0.0206	0.0196	0.0176	0.0402	0	0.0245	0.0314	0.0274	0.0265	0.0372
X24	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0108	0.0118	0.0382	0.0382	0.0323	0.0363	0.0343	0.0323	0.0402	0.0343	0.0363	0.0323	0.0323	0.0245	0.0206	0.0421	0.0372	0	0.0363	0.0216	0.0235	0.0353
X25	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0137	0.0216	0.0206	0.0343	0.0363	0.0363	0.0372	0.0402	0.0363	0.0343	0.0382	0.0265	0.0235	0.0382	0.0363	0.0363	0.0206	0	0.0255	0.0245	0.0323
X26	0.0098	0.0098	0.0098	0.0382	0.0098	0.0157	0.0314	0.0147	0.0323	0.0314	0.0402	0.0245	0.0274	0.0274	0.0382	0.0323	0.0353	0.0323	0.0206	0.0216	0.0245	0.0323	0.0343	0.0353	0.0186	0	0.0412	0.0265
X27	0.0098	0.0098	0.0098	0.0382	0.0098	0.0137	0.0137	0.0167	0.0314	0.0314	0.0392	0.0323	0.0323	0.0333	0.0402	0.0245	0.0323	0.0304	0.0225	0.0245	0.0216	0.0333	0.0323	0.0353	0.0167	0.0382	0	0.0323
X28	0.0098	0.0098	0.0098	0.0372	0.0098	0.0108	0.0118	0.0108	0.0323	0.0323	0.0372	0.0402	0.0392	0.0363	0.0382	0.0304	0.0323	0.0323	0.0255	0.0206	0.0186	0.0343	0.0323	0.0314	0.0216	0.0265	0.0245	0

Table 4.3 Total direct-relation matrix of twenty-six decision-makers.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	0.0232	0.0351	0.0397	0.0807	0.0702	0.0835	0.0944	0.0868	0.0925	0.0882	0.0883	0.0973	0.0922	0.0914	0.1281	0.0983	0.0980	0.0734	0.0929	0.1019	0.0621	0.1171	0.1136	0.1044	0.0746	0.0701	0.0893	0.1031
X2	0.0315	0.0230	0.0439	0.0737	0.0653	0.0773	0.0906	0.0757	0.0979	0.0850	0.0825	0.0989	0.0825	0.0818	0.1079	0.1011	0.1001	0.0820	0.0808	0.0913	0.0642	0.0999	0.1012	0.0903	0.0718	0.0638	0.0791	0.1015
X3	0.0292	0.0446	0.0213	0.0731	0.0470	0.0539	0.0630	0.0509	0.0756	0.0801	0.0798	0.0938	0.0974	0.0971	0.1095	0.0921	0.0885	0.0669	0.0683	0.0656	0.0565	0.0941	0.0981	0.0748	0.0651	0.0593	0.0814	0.0859
X4	0.0306	0.0355	0.0427	0.0367	0.0606	0.0715	0.0787	0.0726	0.0932	0.0942	0.0902	0.0832	0.0852	0.0867	0.1094	0.0798	0.0882	0.0825	0.0828	0.0911	0.0622	0.1016	0.1030	0.0842	0.0692	0.0621	0.0771	0.0958
X5	0.0336	0.0376	0.0402	0.0734	0.0354	0.0838	0.0965	0.0850	0.0940	0.1006	0.0999	0.0928	0.1110	0.1101	0.1268	0.1046	0.1078	0.0823	0.0929	0.1039	0.0711	0.1179	0.1182	0.0961	0.0792	0.0707	0.0803	0.1128
X6	0.0311	0.0330	0.0355	0.0567	0.0610	0.0367	0.0851	0.0747	0.0943	0.0935	0.0967	0.0920	0.0961	0.0935	0.1122	0.0949	0.1035	0.0732	0.0847	0.0924	0.0615	0.1014	0.1044	0.0936	0.0715	0.0595	0.0677	0.1003
X7	0.0272	0.0280	0.0285	0.0436	0.0459	0.0578	0.0415	0.0486	0.0715	0.0747	0.0710	0.0669	0.0845	0.0693	0.0789	0.0675	0.0963	0.0623	0.0790	0.0856	0.0557	0.0921	0.0943	0.0856	0.0578	0.0546	0.0566	0.0820
X8	0.0283	0.0292	0.0297	0.0519	0.0511	0.0521	0.0792	0.0329	0.0740	0.0749	0.0863	0.0766	0.0785	0.0763	0.0966	0.0733	0.0784	0.0615	0.0857	0.0913	0.0554	0.1016	0.0991	0.0940	0.0625	0.0573	0.0605	0.0825
X9	0.0313	0.0322	0.0328	0.0580	0.0512	0.0537	0.0805	0.0544	0.0614	0.1012	0.0988	0.0995	0.1008	0.0973	0.1191	0.0949	0.1100	0.0743	0.0722	0.0810	0.0793	0.1130	0.1132	0.0780	0.0831	0.0730	0.0810	0.1011
X10	0.0310	0.0319	0.0325	0.0538	0.0490	0.0569	0.0836	0.0530	0.1021	0.0618	0.1043	0.0950	0.0972	0.0956	0.1143	0.0905	0.1084	0.0746	0.0698	0.0803	0.0760	0.1122	0.1115	0.0791	0.0834	0.0723	0.0784	0.0993
X11	0.0286	0.0293	0.0298	0.0418	0.0360	0.0405	0.0515	0.0413	0.0709	0.0691	0.0601	0.0890	0.0923	0.0921	0.1095	0.0927	0.0908	0.0707	0.0652	0.0665	0.0667	0.1016	0.1026	0.0886	0.0794	0.0680	0.0717	0.0970
X12	0.0265	0.0272	0.0276	0.0385	0.0334	0.0375	0.0473	0.0380	0.0674	0.0684	0.0922	0.0513	0.0896	0.0774	0.1018	0.0829	0.0749	0.0615	0.0556	0.0640	0.0662	0.0890	0.0810	0.0648	0.0630	0.0622	0.0639	0.0803
X13	0.0248	0.0255	0.0259	0.0377	0.0317	0.0465	0.0582	0.0396	0.0590	0.0581	0.0864	0.0668	0.0470	0.0616	0.0957	0.0573	0.0785	0.0514	0.0502	0.0641	0.0490	0.0722	0.0681	0.0589	0.0576	0.0503	0.0528	0.0802
X14	0.0237	0.0243	0.0247	0.0342	0.0296	0.0331	0.0414	0.0338	0.0494	0.0503	0.0747	0.0590	0.0637	0.0420	0.0891	0.0560	0.0665	0.0555	0.0547	0.0569	0.0475	0.0683	0.0679	0.0538	0.0549	0.0565	0.0560	0.0739
X15	0.0271	0.0278	0.0282	0.0397	0.0343	0.0386	0.0492	0.0393	0.0604	0.0803	0.0849	0.0790	0.0729	0.0701	0.0651	0.0748	0.0864	0.0644	0.0600	0.0804	0.0579	0.0961	0.0963	0.0877	0.0649	0.0702	0.0757	0.0767
X16	0.0285	0.0293	0.0297	0.0418	0.0364	0.0410	0.0634	0.0414	0.0852	0.0844	0.0929	0.0939	0.0966	0.0915	0.1089	0.0553	0.0915	0.0671	0.0649	0.0730	0.0677	0.0940	0.0932	0.0699	0.0679	0.0648	0.0667	0.0948
X17	0.0298	0.0306	0.0311	0.0444	0.0493	0.0524	0.0861	0.0547	0.0963	0.0954	0.0948	0.0866	0.0888	0.0835	0.1113	0.0905	0.0659	0.0703	0.0688	0.0903	0.0601	0.1045	0.1057	0.0749	0.0703	0.0665	0.0698	0.0963

Table 4.3 Total direct-relation matrix of twenty-six decision-makers. (continued)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X18	0.0294	0.0303	0.0307	0.0462	0.0385	0.0535	0.0826	0.0550	0.0906	0.0906	0.0798	0.0873	0.0911	0.0885	0.1081	0.0892	0.1015	0.0492	0.0716	0.0820	0.0630	0.1021	0.1015	0.0746	0.0729	0.0656	0.0687	0.0894
X19	0.0302	0.0310	0.0315	0.0446	0.0392	0.0476	0.0798	0.0643	0.0947	0.0937	0.0972	0.0918	0.0900	0.0875	0.1093	0.0918	0.0965	0.0734	0.0497	0.0743	0.0602	0.1097	0.1089	0.0964	0.0846	0.0676	0.0707	0.0966
X20	0.0333	0.0342	0.0348	0.0566	0.0520	0.0615	0.0898	0.0586	0.1069	0.1061	0.1116	0.1082	0.1107	0.1041	0.1273	0.1007	0.1157	0.0904	0.0825	0.0623	0.0716	0.1217	0.1209	0.0916	0.0956	0.0803	0.0876	0.1110
X21	0.0282	0.0289	0.0294	0.0410	0.0355	0.0401	0.0512	0.0409	0.0626	0.0746	0.0790	0.0932	0.0920	0.0898	0.1042	0.0915	0.0931	0.0760	0.0727	0.0637	0.0400	0.0975	0.0957	0.0866	0.0700	0.0669	0.0677	0.0920
X22	0.0301	0.0309	0.0314	0.0448	0.0386	0.0445	0.0581	0.0443	0.0968	0.0950	0.0974	0.0989	0.1007	0.0984	0.1170	0.0934	0.1052	0.0843	0.0685	0.0727	0.0594	0.0702	0.1062	0.0767	0.0840	0.0771	0.0802	0.0981
X23	0.0297	0.0305	0.0310	0.0441	0.0381	0.0438	0.0599	0.0473	0.0939	0.0948	0.0970	0.0941	0.0949	0.0972	0.1118	0.0904	0.1021	0.0778	0.0678	0.0717	0.0612	0.1075	0.0681	0.0786	0.0804	0.0733	0.0755	0.0996
X24	0.0304	0.0312	0.0317	0.0448	0.0390	0.0439	0.0577	0.0467	0.0962	0.0971	0.0974	0.0984	0.0981	0.0939	0.1163	0.0946	0.1027	0.0834	0.0806	0.0779	0.0656	0.1120	0.1066	0.0566	0.0871	0.0694	0.0744	0.1001
X25	0.0295	0.0303	0.0307	0.0432	0.0374	0.0422	0.0542	0.0468	0.0769	0.0771	0.0958	0.0953	0.0969	0.0956	0.1127	0.0935	0.0974	0.0866	0.0729	0.0745	0.0799	0.1029	0.1020	0.0745	0.0493	0.0709	0.0728	0.0942
X26	0.0306	0.0316	0.0322	0.0730	0.0401	0.0509	0.0782	0.0507	0.0913	0.0914	0.1048	0.0872	0.0919	0.0895	0.1146	0.0928	0.1023	0.0840	0.0708	0.0766	0.0693	0.1035	0.1047	0.0922	0.0703	0.0484	0.0916	0.0924
X27	0.0303	0.0313	0.0319	0.0726	0.0395	0.0483	0.0607	0.0519	0.0894	0.0904	0.1033	0.0937	0.0954	0.0942	0.1157	0.0846	0.0982	0.0814	0.0716	0.0782	0.0658	0.1032	0.1016	0.0911	0.0678	0.0847	0.0514	0.0969
X28	0.0300	0.0309	0.0315	0.0705	0.0388	0.0447	0.0578	0.0455	0.0891	0.0900	0.1003	0.1000	0.1009	0.0958	0.1126	0.0890	0.0969	0.0821	0.0732	0.0734	0.0624	0.1027	0.1001	0.0858	0.0716	0.0726	0.0742	0.0644

Table 4.4 Identification of cause-and-effect factors.

	R	C	pr_i^+	pr_i^-	Identify
X1	2.3903	0.8177	3.2080	1.5726	Cause
X2	2.2446	0.8654	3.1100	1.3792	Cause
X3	2.0130	0.8906	2.9036	1.1224	Cause
X4	2.1507	1.4611	3.6118	0.6897	Cause
X5	2.4586	1.2240	3.6826	1.2345	Cause
X6	2.2008	1.4377	3.6385	0.7630	Cause
X7	1.8076	1.9203	3.7278	-0.1127	Effect
X8	1.9209	1.4745	3.3953	0.4464	Cause
X9	2.2264	2.3336	4.5599	-0.1072	Effect
X10	2.1980	2.3609	4.5589	-0.1630	Effect
X11	1.9430	2.5473	4.4903	-0.6043	Effect
X12	1.7334	2.4696	4.2030	-0.7362	Effect
X13	1.5550	2.5390	4.0940	-0.9840	Effect
X14	1.4413	2.4516	3.8929	-1.0103	Effect
X15	1.7883	3.0339	4.8222	-1.2456	Effect
X16	1.9356	2.4178	4.3534	-0.4823	Effect
X17	2.0692	2.6454	4.7146	-0.5762	Effect
X18	2.0335	2.0425	4.0759	-0.0090	Effect
X19	2.1127	2.0105	4.1233	0.1022	Cause
X20	2.4275	2.1869	4.6144	0.2406	Cause
X21	1.9039	1.7573	3.6612	0.1466	Cause
X22	2.1026	2.8096	4.9123	-0.7070	Effect
X23	2.0622	2.7879	4.8502	-0.7257	Effect
X24	2.1336	2.2836	4.4171	-0.1500	Effect
X25	2.0358	2.0096	4.0454	0.0261	Cause
X26	2.1567	1.8577	4.0145	0.2990	Cause
X27	2.1253	2.0229	4.1482	0.1024	Cause
X28	2.0870	2.5982	4.6852	-0.5113	Effect

The pr_i^+ and pr_i^- are the cartesian x and y, respectively. Thus, Fig. 4.1 illustrates the position of financial risk factors as a diagram, the causal diagram.

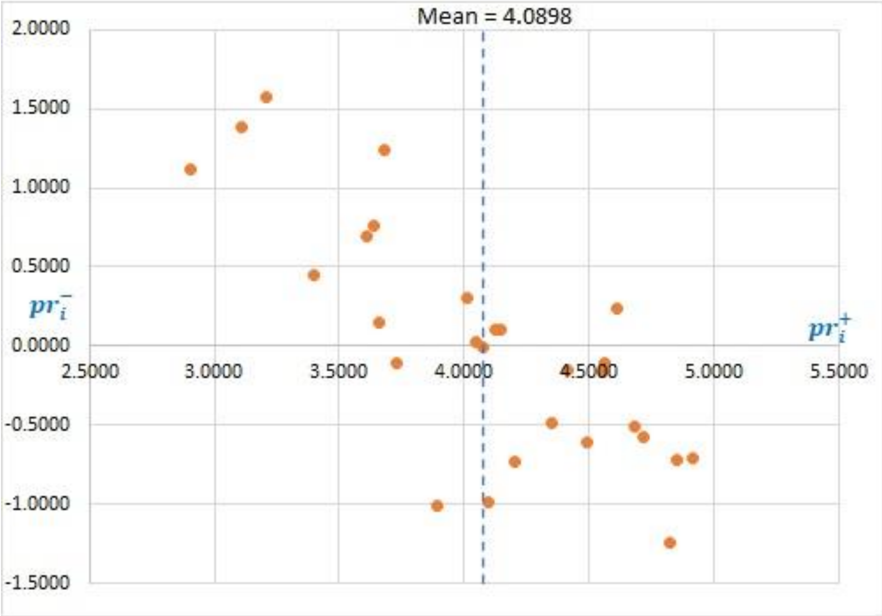

Figure 4.1 The importance and relationships of the factors.

4.4 The Threshold Value (α)

By using Eq. (3.7), the α is equal to 0.0730. That means some relationships are trivial and can be ignored by risk management team. For example, $t_{6,3}$ = 0.0355, which lower than α, see Table 4.3. It implies that even Inflation rate is a cause of financial risk; however, it does not affect to Political corruption. Another example is $t_{4,7}$ = 0.0771. It means Regulation and policy changes affects to Environmental impacts.'

4.5 The Overall Influence Matrix

The overall influence matrix is calculated by using Eq. (3.8). Table 4.5 shows the overall influence matrix of this study.

4.6 The Reachable Matrix

The reachable matrix can be calculated by using Eq. (3.9) and (3.10). Table 4.6 shows the reachable matrix when $\alpha = 0.0730$.

Table 4.5 Overall matrix of twenty-six decision-makers.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	1.0232	0.0351	0.0397	0.0807	0.0702	0.0835	0.0944	0.0868	0.0925	0.0882	0.0883	0.0973	0.0922	0.0914	0.1281	0.0983	0.0980	0.0734	0.0929	0.1019	0.0621	0.1171	0.1136	0.1044	0.0746	0.0701	0.0893	0.1031
X2	0.0315	1.0230	0.0439	0.0737	0.0653	0.0773	0.0906	0.0757	0.0979	0.0850	0.0825	0.0989	0.0825	0.0818	0.1079	0.1011	0.1001	0.0820	0.0808	0.0913	0.0642	0.0999	0.1012	0.0903	0.0718	0.0638	0.0791	0.1015
X3	0.0292	0.0446	1.0213	0.0731	0.0470	0.0539	0.0630	0.0509	0.0756	0.0801	0.0798	0.0938	0.0974	0.0971	0.1095	0.0921	0.0885	0.0669	0.0683	0.0656	0.0565	0.0941	0.0981	0.0748	0.0651	0.0593	0.0814	0.0859
X4	0.0306	0.0355	0.0427	1.0367	0.0606	0.0715	0.0787	0.0726	0.0932	0.0942	0.0902	0.0832	0.0852	0.0867	0.1094	0.0798	0.0882	0.0825	0.0828	0.0911	0.0622	0.1016	0.1030	0.0842	0.0692	0.0621	0.0771	0.0958
X5	0.0336	0.0376	0.0402	0.0734	1.0354	0.0838	0.0965	0.0850	0.0940	0.1006	0.0999	0.0928	0.1110	0.1101	0.1268	0.1046	0.1078	0.0823	0.0929	0.1039	0.0711	0.1179	0.1182	0.0961	0.0792	0.0707	0.0803	0.1128
X6	0.0311	0.0330	0.0355	0.0567	0.0610	1.0367	0.0851	0.0747	0.0943	0.0935	0.0967	0.0920	0.0961	0.0935	0.1122	0.0949	0.1035	0.0732	0.0847	0.0924	0.0615	0.1014	0.1044	0.0936	0.0715	0.0595	0.0677	0.1003
X7	0.0272	0.0280	0.0285	0.0436	0.0459	0.0578	1.0415	0.0486	0.0715	0.0747	0.0710	0.0669	0.0845	0.0693	0.0789	0.0675	0.0963	0.0623	0.0790	0.0856	0.0557	0.0921	0.0943	0.0856	0.0578	0.0546	0.0566	0.0820
X8	0.0283	0.0292	0.0297	0.0519	0.0511	0.0521	0.0792	1.0329	0.0740	0.0749	0.0863	0.0766	0.0785	0.0763	0.0966	0.0733	0.0784	0.0615	0.0857	0.0913	0.0554	0.1016	0.0991	0.0940	0.0625	0.0573	0.0605	0.0825
X9	0.0313	0.0322	0.0328	0.0580	0.0512	0.0537	0.0805	0.0544	1.0614	0.1012	0.0988	0.0995	0.1008	0.0973	0.1191	0.0949	0.1100	0.0743	0.0722	0.0810	0.0793	0.1130	0.1132	0.0780	0.0831	0.0730	0.0810	0.1011
X10	0.0310	0.0319	0.0325	0.0538	0.0490	0.0569	0.0836	0.0530	0.1021	1.0618	0.1043	0.0950	0.0972	0.0956	0.1143	0.0905	0.1084	0.0746	0.0698	0.0803	0.0760	0.1122	0.1115	0.0791	0.0834	0.0723	0.0784	0.0993
X11	0.0286	0.0293	0.0298	0.0418	0.0360	0.0405	0.0515	0.0413	0.0709	0.0691	1.0601	0.0890	0.0923	0.0921	0.1095	0.0927	0.0908	0.0707	0.0652	0.0665	0.0667	0.1016	0.1026	0.0886	0.0794	0.0680	0.0717	0.0970
X12	0.0265	0.0272	0.0276	0.0385	0.0334	0.0375	0.0473	0.0380	0.0674	0.0684	0.0922	1.0513	0.0896	0.0774	0.1018	0.0829	0.0749	0.0615	0.0556	0.0640	0.0662	0.0890	0.0810	0.0648	0.0630	0.0622	0.0639	0.0803
X13	0.0248	0.0255	0.0259	0.0377	0.0317	0.0465	0.0582	0.0396	0.0590	0.0581	0.0864	0.0668	1.0470	0.0616	0.0957	0.0573	0.0785	0.0514	0.0502	0.0641	0.0490	0.0722	0.0681	0.0589	0.0576	0.0503	0.0528	0.0802
X14	0.0237	0.0243	0.0247	0.0342	0.0296	0.0331	0.0414	0.0338	0.0494	0.0503	0.0747	0.0590	0.0637	1.0420	0.0891	0.0560	0.0665	0.0555	0.0547	0.0569	0.0475	0.0683	0.0679	0.0538	0.0549	0.0565	0.0560	0.0739
X15	0.0271	0.0278	0.0282	0.0397	0.0343	0.0386	0.0492	0.0393	0.0604	0.0803	0.0849	0.0790	0.0729	0.0701	1.0651	0.0748	0.0864	0.0644	0.0600	0.0804	0.0579	0.0961	0.0963	0.0877	0.0649	0.0702	0.0757	0.0767
X16	0.0285	0.0293	0.0297	0.0418	0.0364	0.0410	0.0634	0.0414	0.0852	0.0844	0.0929	0.0939	0.0966	0.0915	0.1089	1.0553	0.0915	0.0671	0.0649	0.0730	0.0677	0.0940	0.0932	0.0699	0.0679	0.0648	0.0667	0.0948

Table 4.5 Overall matrix of twenty-six decision-makers. (continued)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X17	0.0298	0.0306	0.0311	0.0444	0.0493	0.0524	0.0861	0.0547	0.0963	0.0954	0.0948	0.0866	0.0888	0.0835	0.1113	0.0905	1.0659	0.0703	0.0688	0.0903	0.0601	0.1045	0.1057	0.0749	0.0703	0.0665	0.0698	0.0963
X18	0.0294	0.0303	0.0307	0.0462	0.0385	0.0535	0.0826	0.0550	0.0906	0.0906	0.0798	0.0873	0.0911	0.0885	0.1081	0.0892	0.1015	1.0492	0.0716	0.0820	0.0630	0.1021	0.1015	0.0746	0.0729	0.0656	0.0687	0.0894
X19	0.0302	0.0310	0.0315	0.0446	0.0392	0.0476	0.0798	0.0643	0.0947	0.0937	0.0972	0.0918	0.0900	0.0875	0.1093	0.0918	0.0965	0.0734	1.0497	0.0743	0.0602	0.1097	0.1089	0.0964	0.0846	0.0676	0.0707	0.0966
X20	0.0333	0.0342	0.0348	0.0566	0.0520	0.0615	0.0898	0.0586	0.1069	0.1061	0.1116	0.1082	0.1107	0.1041	0.1273	0.1007	0.1157	0.0904	0.0825	1.0623	0.0716	0.1217	0.1209	0.0916	0.0956	0.0803	0.0876	0.1110
X21	0.0282	0.0289	0.0294	0.0410	0.0355	0.0401	0.0512	0.0409	0.0626	0.0746	0.0790	0.0932	0.0920	0.0898	0.1042	0.0915	0.0931	0.0760	0.0727	0.0637	1.0400	0.0975	0.0957	0.0866	0.0700	0.0669	0.0677	0.0920
X22	0.0301	0.0309	0.0314	0.0448	0.0386	0.0445	0.0581	0.0443	0.0968	0.0950	0.0974	0.0989	0.1007	0.0984	0.1170	0.0934	0.1052	0.0843	0.0685	0.0727	0.0594	1.0702	0.1062	0.0767	0.0840	0.0771	0.0802	0.0981
X23	0.0297	0.0305	0.0310	0.0441	0.0381	0.0438	0.0599	0.0473	0.0939	0.0948	0.0970	0.0941	0.0949	0.0972	0.1118	0.0904	0.1021	0.0778	0.0678	0.0717	0.0612	0.1075	1.0681	0.0786	0.0804	0.0733	0.0755	0.0996
X24	0.0304	0.0312	0.0317	0.0448	0.0390	0.0439	0.0577	0.0467	0.0962	0.0971	0.0974	0.0984	0.0981	0.0939	0.1163	0.0946	0.1027	0.0834	0.0806	0.0779	0.0656	0.1120	0.1066	1.0566	0.0871	0.0694	0.0744	0.1001
X25	0.0295	0.0303	0.0307	0.0432	0.0374	0.0422	0.0542	0.0468	0.0769	0.0771	0.0958	0.0953	0.0969	0.0956	0.1127	0.0935	0.0974	0.0866	0.0729	0.0745	0.0799	0.1029	0.1020	0.0745	1.0493	0.0709	0.0728	0.0942
X26	0.0306	0.0316	0.0322	0.0730	0.0401	0.0509	0.0782	0.0507	0.0913	0.0914	0.1048	0.0872	0.0919	0.0895	0.1146	0.0928	0.1023	0.0840	0.0708	0.0766	0.0693	0.1035	0.1047	0.0922	0.0703	1.0484	0.0916	0.0924
X27	0.0303	0.0313	0.0319	0.0726	0.0395	0.0483	0.0607	0.0519	0.0894	0.0904	0.1033	0.0937	0.0954	0.0942	0.1157	0.0846	0.0982	0.0814	0.0716	0.0782	0.0658	0.1032	0.1016	0.0911	0.0678	0.0847	1.0514	0.0969
X28	0.0300	0.0309	0.0315	0.0705	0.0388	0.0447	0.0578	0.0455	0.0891	0.0900	0.1003	0.1000	0.1009	0.0958	0.1126	0.0890	0.0969	0.0821	0.0732	0.0734	0.0624	0.1027	0.1001	0.0858	0.0716	0.0726	0.0742	1.0644

Table 4.6 Reachable matrix of twenty-six decision-makers.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
X2	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1
X3	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	1	1
X4	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1
X5	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
X6	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1
X7	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1
X8	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	0	0	1
X9	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
X10	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
X11	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1
X12	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	1
X13	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
X14	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
X15	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	0	0	1	1
X16	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	1

Table 4.6 Reachable matrix of twenty-six decision-makers. (continued)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X17	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	0	0	1
X18	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	0	1
X19	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1
X20	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
X21	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1
X22	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1
X23	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1
X24	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
X25	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1
X26	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1
X27	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1
X28	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1

The reachable matrix is up to the threshold value (α). It means that the reachable mattix may be changed when the threshold value is changed. Unfortunately, there is no simle rule to set the right threshold value. Table 4.7 reports the node degrees in various threshold values and Fig. 4.2 illustrates it graphically.

Table 4.7 Node degrees with different threshold values.

Factor	α = 0.050	α = 0.073	α = 0.100	α = 0.150
X1	26	23	7	1
X2	26	22	6	1
X3	25	16	2	1
X4	37	24	4	1
X5	32	23	11	1
X6	38	22	6	1
X7	46	24	1	1
X8	39	21	2	1
X9	51	39	10	1
X10	51	42	10	1
X11	48	38	9	1
X12	47	34	4	1
X13	47	30	6	1
X14	45	28	3	1
X15	47	39	24	1
X16	48	37	5	1
X17	50	41	15	1
X18	50	33	5	1
X19	49	28	4	1
X20	52	39	15	1
X21	46	17	2	1

Table 4.7 Node degrees with different threshold values. (continued)

Factor	α = 0.050	α = 0.073	α = 0.100	α = 0.150
X22	48	42	23	1
X23	48	42	22	1
X24	48	41	7	1
X25	48	27	4	1
X26	51	23	6	1
X27	50	31	5	1
X28	49	44	14	1
Total	1242	870	232	28

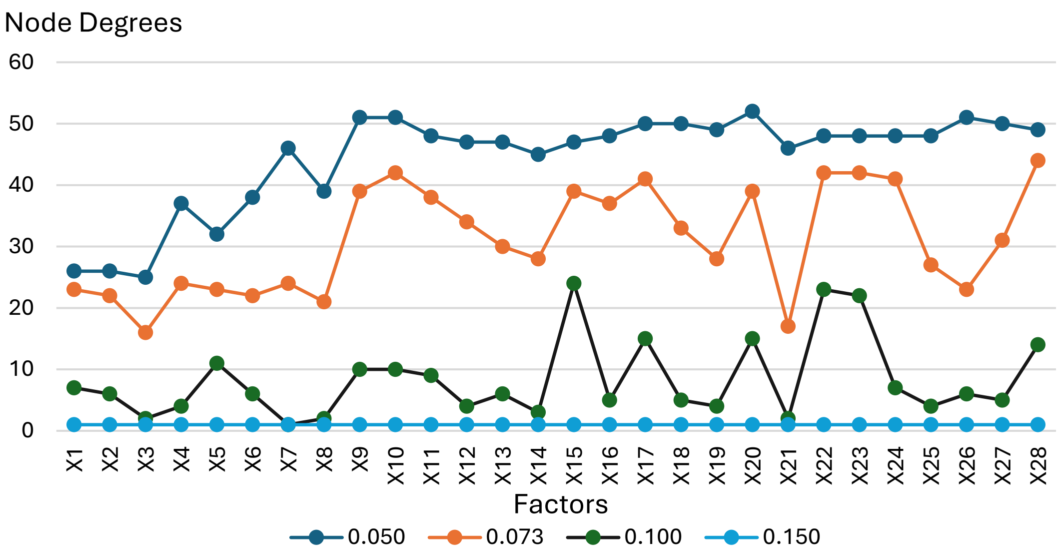

Figure 4.2 Node degrees divergence.

Table 4.7 shows the node degrees according to the various threshold values. The node degrees indicate the relationship between factors. Too many node degrees imply a complex relationship, and the meaning could be undiscovered. On the other hand, too few node degrees imply less relationship between factors, and the true relationships might be looked over.

In this study, we conducted a brainstorming meeting among managers related to the sample company's financial operations. The peer decided to choose the threshold value (α) = 0.073. The total node degrees are 870, which is suitable for the analysis. Table 4.8 shows the reachable matrix according to the threshold, α = 0.10 and Table 4.9 shows the reachable matrix according to the threshold, α = 0.073

Table 4.8 Reachable matrix of twenty-six decision-makers (α = 0.100).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	0	0	0	1
X2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0	0	0	1
X3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
X4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
X5	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	1
X6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	1
X7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
X9	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	1	1	0	0	0	0	1
X10	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
X11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
X12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
X13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
X16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.8 Reachable matrix of twenty-six decision-makers (α = 0.100). (continued)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
X18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	1	0	0	0	0	0
X19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0
X20	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	1
X21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
X22	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
X23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
X24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	1	0	0	0	1
X25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	0
X26	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1	0	0	1	0	0
X27	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0
X28	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1

Table 4.9 Reachable matrix of twenty-six decision-makers (α = 0.073).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
X2	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1
X3	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	1	1
X4	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1
X5	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
X6	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1
X7	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1
X8	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	0	0	1
X9	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
X10	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
X11	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1
X12	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	1
X13	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
X14	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
X15	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	0	0	1	1
X16	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	1

Table 4.9 Reachable matrix of twenty-six decision-makers (α = 0.073). (continued)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X17	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	0	0	1
X18	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	0	1
X19	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1
X20	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
X21	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1
X22	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1
X23	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1
X24	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
X25	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1
X26	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1
X27	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1
X28	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1

4.7 The Reachable and Antecedent Sets

The reachable and antecedent sets when α = 0.073 are shown in Table 4.10. Columns 2 and 3 are the sets. Column 4 is prepared for the next step.

4.8 The Hierarchical Structure Diagram

Figure 4.3 illustrates the financial risk factors of the sample construction company. Please note that the arcs are neglected because the figure is messy. However, it may be referred to Tables 4.9 or 4.10.

Table 4.10 Reachable and antecedent sets of twenty-six decision-makers (α = 0.073).

Factors	$R(x_i)$	$A(x_i)$	$R(x_i) \cap A(x_i)$
X1	1,3,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 22,23,24,25,27.28	1	1
X2	2,3,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 22,23,24,27,28	2	2
X3	3,4,9,10,11,12,13,14,15,16,17,22,23,24,27,28	3	3
X4	4,7,9,10,11,12,13,14,15,16,17,18,19,20,22,23,24 ,27,28	1,2,3,4,5,26	4
X5	4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 22,23,24,25,27.28	5	5
X6	6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 22, 23,24,28	1,2,5,6	6
X7	7,10,13,15,17,19,20,22,23,24,28	1,2,4,5,6,7,8,9,10,17,18,19,20,26	7,10,17,19,20
X8	7,8,9,10,11,12,13,14,15,16,17,19,20,22,23,24,28	1,2,5,6,8	8
X9	7,9,10,11,12,13,14,15,16,17,18,20,21,22, 23,24,25,27,28	1,2,3,4,5,6,8,9,10,16,17,18,19,20,22,23,24,25,26,27,28	9,10,16,17,18,20,22,23,24,25,27,28
X10	7,9,10,11,12,13,14,15,16,17,18,20,21,22, 23,24,25,27,28	1,2,3,4,5,6,7,8,9,10,15,16,17,18,19,20,21,22, 23,24,25,26,27,28	7,9,10,15,16,17,18,20,21,22,23,24, 25,27,28
X11	11,12,13,14,15,16,17,22,23,24,25,28	1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23 ,24,25,26,27,28	11,12,13,14,15,16,17,22,23,24,25, 28
X12	11,12,13,14,15,16,17,22,23,28	1,2,3,4,5,6,8,9,10,11,12,15,16,17,18,19,20,21,22,23,24,25 ,26,27,28	11,12,15,16,17,22,23,28
X13	11,13,15,17,28	1,2,3,4,5,6,7,8,9,10,11,12,13,16,17,18,19,20, 21,22,23,24,25,26,27,28	11,13,17,28
X14	11,14,15,28	1,2,3,4,5,6,8,9,10,11,12,14,16,17,18,19,20,21,22,23,24,25 ,26,27,28	11,14,28

Table 4.10 Reachable and antecedent sets of twenty-six decision-makers (α = 0.073). (continued)

Factors	$R(x_i)$	$A(x_i)$	$R(x_i) \cap A(x_i)$
X15	10,11,12,15,16,17,20,22,23,24,27,28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28	10,11,12,15,16,17,20,22,23,24,27,28
X16	9,10,11,12,13,14,15,16,17,20,22,23,28	1,2,3,4,5,6,8,9,10,11,12,15,16,17,18,19,20,21,22,23,24,25,26,27,28	9,10,11,12,15,16,17,20,22,23,28
X17	7,9,10,11,12,13,14,15,16,17,20,22,23,24,28	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18,19,20,21,22,23,24,25,26,27,28	7,9,10,11,12,13,15,16,17,20,22,23,24,28
X18	7,9,10,11,12,13,14,15,16,17,18,20,22,23,24,28	1,2,4,5,6,9,10,18,19,20,21,22,23,24,25,26,27, 28	7,9,10,18,20,22,23,24,28
X19	7,9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,25,28	1,2,4,5,6,7,8,19,20,24,28	7,19,20,24,28
X20	7,9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,25,26,27,28	1,2,4,5,6,7,8,9,10,15,16,17,18,19,20,24,25,26,27,28	7,9,10,15,16,17,18,19,20,24,25,26,27,28
X21	10,11,12,13,14,15,16,17,18,21,22,23,24,28	9,10,21,25	10,21
X22	9,10,11,12,13,14,15,16,17,18,22,23,24,25,26,27,28	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22,23,24,25,26,27,28	9,10,11,12,15,16,17,18,22,23,24,25,26,27,28
X23	9,10,11,12,13,14,15,16,17,18,22,23,24,25,26,27,28	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22,23,24,25,26,27,28	9,10,11,12,15,16,17,18,22,23,24,25,26,27,28
X24	9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,25,27,28	1,2,3,4,5,6,7,8,9,10,11,15,17,18,19,20,21,22,23,24,25,26,27,28	9,10,11,15,17,18,19,20,22,23,24,25,27,28
X25	9,10,11,12,13,14,15,16,17,18,20,22,23,24,25, 28	1,5,9,10,11,19,20,22,23,24,25	9,10,11,20,22,23,24,25
X26	3,7,9,10,11,12,13,14,15,16,17,18,20,22,23,24,26,27,28	20,22,23,26,27	20,22,23,26,27
X27	9,10,11,12,13,14,15,16,17,18,20,22,23,24,26,27,28	1,2,3,4,5,9,10,15,20,22,23,24,26,27,28	9,10,15,20,22,23,24,26,27,28
X28	9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,27,28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28	9,10,11,12,13,14,15,16,17,18,19,20,22,23,24, 27,28

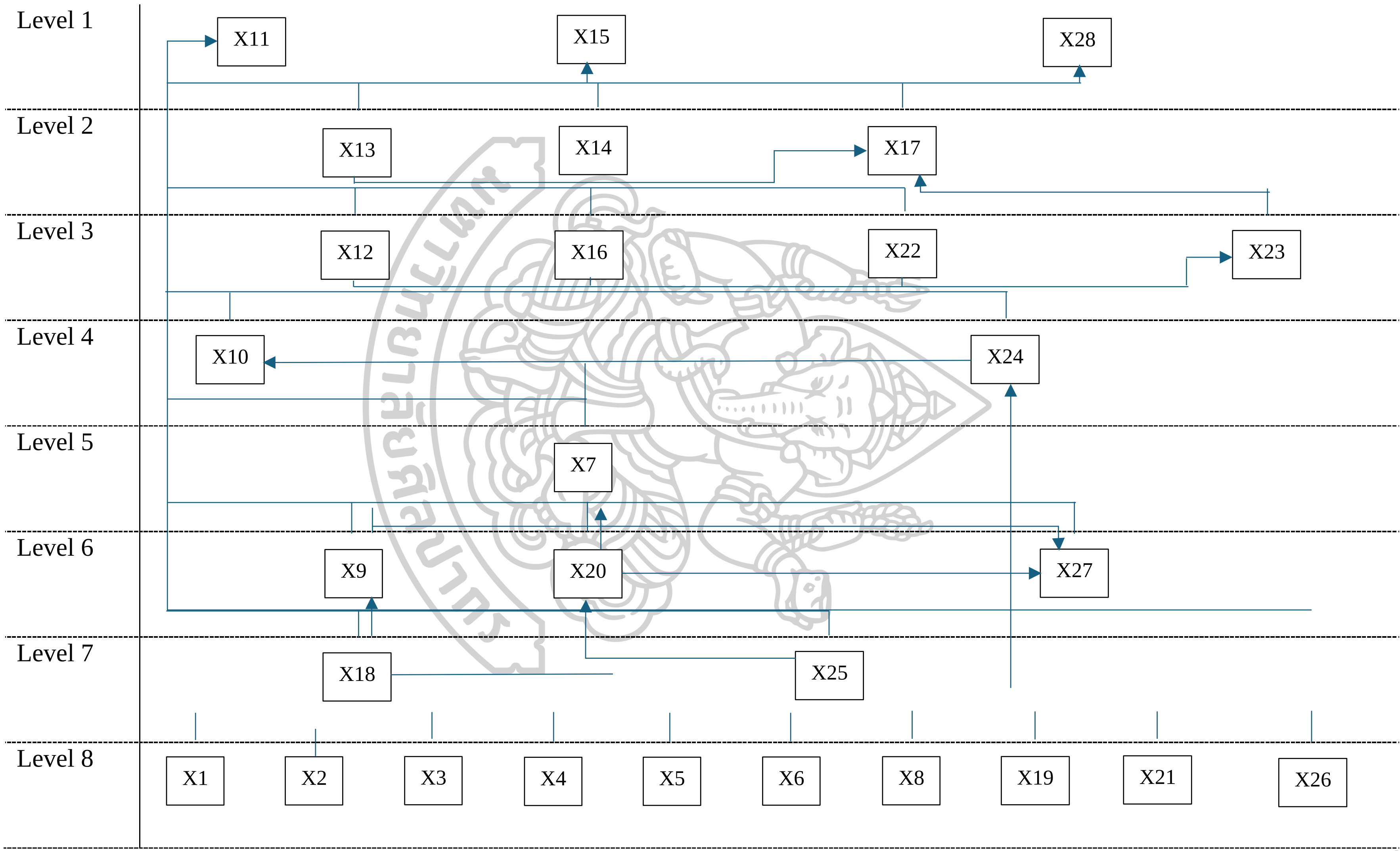

Figure 4.3 Hierarchical structure diagram.

4.9 Discussion

The interpretative structural model (ISM) is deployed to extend the DEMATEL's result. The benefit is that the ISM can give information not only on the factors' significance but also on their relationships. However, the relationships in the hierarchical structure diagram are so complex that they are not easy to interpret as expected (see Fig. 4.3).

To interprete the diagram, we would like to ignor some relation links and focus on significant ones. Three groups of levels are presented in this study. The first group is called the direct risk factors which are in level 1. The second group is called the indirect risk factors which are in levels 2 to 7. The last one is the fundamental influencing risk factors which are in level 8. Their details are discussed in the following sub-sections.

4.9.1 Direct risk factors

The risk factors that affect the construction project's financial situation are 'Design change (X11)', 'Project delay (X15)', and 'Poor construction supply chain management (X28).' These risk factors are re-examined by the peer and accepted that they are essential. The financial situation of the construction project instantly becomes lousy when one of these three risk factors occurs. Design changes always affect construction costs negatively. No matter the causes of the project delay, the project finances will be in a desperate situation. The supply chain is also a critical factor in all operations in the industry. It directly affects every consecutive operation inevitably.

4.9.2 Indirect risk factors

The factors in levels 2 to 7 are between the profound and front-end risk factors. Thus, they are named the indirect risk factors that affect the construction project's financial circumstances. There are fifteen risk factors such as 'Substandard material (X13)', 'Equity holder's credit risk (X10)', 'Interest rate (X7)', and 'Lack of competent staff (X25)'. The peer accepted that these risk factors do not directly affect the project's financial risk. Nevertheless, it may affect other factors. If the management can monitor and control them effectively, the project's financial situation may not be affected.

On the other hand, if the management reviews them and does not understand the relationship among risk factors, they might make a mistake. As a result, direct risk factors may occur inevitably, affecting the construction project's financial situation unavoidably.

4.9.3 Fundamental influencing risk factors

There are several fundamental risk factors in the diagram, such as all political risk factors (X2 to X4), all economy risk factors (X5 to X8), 'Client's financial stability (X19)', 'Poor market research (X21)', and 'Environmental impacts (X26)'. These factors are also important. However, if we consider occurring chances and their impacts, they may fall into fundamental influencing risk factors.

This group notifies us to monitor closely but does not take it too seriously. The limited resources may only be allocated to a little on these factors. They are looked after in the normal degree with some mitigation strategies.

CHAPTER 5
CONCLUSION

This chapter concludes the findings of this study according to the research objectives. A construction project in Kunming is the sample of this study. The participants are only at middle—to upper-management levels. Thus, 26 staff members participated in this study. The findings corresponding to the research objective are arranged in section 5.1. The recommendations and direction for future studies are gathered in section 5.2.

5.1 Conclusion

Twenty-eight risk factors may affect the financial situation of the construction project. They are grouped into nine groups: pandemic, political, economy, credit, engineering, operation, market, liquidity, and others. The risk factors were retrieved from the literature and reviewed by the construction company's management team. The bold risk factor that has never happened before is the pandemic. This risk factor came from the company's experience in the last three years.

This research showed that the risk assessments must start from the risk factor reviewing. There are some factors that never happended before; thus, the reviewing helps us the conduct the assessment cautiously.

This research showed that risk assessments must start with the risk factor review. Some factors never happened before; thus, the reviewing helps us conduct the assessment cautiously.

The DEMATEL and ISM techniques, beyond their role in identifying the significance of risk factors, also categorize them into levels. This categorization aids in understanding the relationships between risk factors, thereby facilitating efficient monitoring and control by management. The direct risk factors, ‘Design change (X11)’, ‘Project delay (X15)’, and ‘Poor construction supply chain management (X28)’, are significant. They must be monitored and controlled effectively. The resources must be allocated reasonably to these factors. The relationships among risk factors in the hierarchical structure diagram also help us understand the influence of the factors. Accordingly, management could mitigate the risks.

5.2 Recommendations and Future Study

The risk-factor review step consumed much time, and there was an argument during the study. The risk factors must be included in the company database so that it has the history and story of the company's review. Furthermore, the new risk factors must always be determined during risk assessment.

Our decision-making tools are designed to promote a scientific approach to decision-making. However, it is undeniable that the key to effective decision-making lies in the hands of our experienced staff. Their expertise is invaluable, especially in navigating the subjective nature of some decision steps. This is why peer review in the final step remains a necessary part of our process.

Some interesting aspects of this study need to be explored. The mitigation strategies were not included in the risk assessment step. Usually, mitigation strategies are considered the next step in risk management. It is good to include mitigation strategies in the risk assessment step. Furthermore, a peer review was required in the final step. Future studies must close the knowledge gap in constructing the peer review framework.

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APPENDIX

APPENDIX A

ICO Evaluation

Evaluation form for experts examining IOC technical research tools

'Financial Risk Assessment for A Construction Project'

I would like the experts to check and consider the consistency between the issues. Are the observations and the observations consistent? Which the researcher has created as a research tool? Before collecting research data, consider the observation issues with things observed. Is there any consistency? Configure the expert's observations as follows:

1: if the item matches the objective(s)

0: if you are not sure

-1: if the item dose not matches the objective(s)

Explanation: this assessment is for experts to answer. Please write ✓ in the level box. Your opinion that the observation issues with what is ordered to be consistent or appropriate.

The questionnaire is divided in to nine risk groups: Pandemic, Political, Economy, Credit, Engineering, Operation, Market, Liquidity, and Others.

Risk Factors	Expert opinion			Remark
Pandemic				
Pandemic outbreak	☐ 1	☐ 0	☐ -1	
Political				
War and geographical conflict	☐ 1	☐ 0	☐ -1	
Political corruption	☐ 1	☐ 0	☐ -1	
Regulation and policy changes	☐ 1	☐ 0	☐ -1	
Economy				
Fluctuation of currency exchange rate	☐ 1	☐ 0	☐ -1	
Inflaction rate	☐ 1	☐ 0	☐ -1	
Household debt	☐ 1	☐ 0	☐ -1	
Credit				
Project's credit risk	☐ 1	☐ 0	☐ -1	
Equity holder's credit risk	☐ 1	☐ 0	☐ -1	
Engineering				
Design change	☐1	☐ 0	☐ -1	
Lack of material and qualified suppliers	☐ 1	☐ 0	☐ -1	
Substandard material	☐ 1	☐ 0	☐ -1	
Substandard equipment	☐ 1	☐ 0	☐ -1	
Project delay	☐ 1	☐ 0	☐ -1	
Operation				
Counterparty risk	☐ 1	☐ 0	☐ -1	
Rating risk	☐ 1	☐ 0	☐ -1	
Tax risk	☐ 1	☐ 0	☐ -1	

Risk Factors	Expert opinion			Remark
Market				
Client’s financial stability	☐ 1	☐ 0	☐ -1	
Poor financial market	☐ 1	☐ 0	☐ -1	
Poor market research	☐ 1	☐ 0	☐ -1	
Liquidity				
Lack of cash flow	☐ 1	☐ 0	☐ -1	
Project’s liquidity	☐ 1	☐ 0	☐ -1	
Delay payment by client	☐ 1	☐ 0	☐ -1	
Others				
Lack of competent staff	☐ 1	☐ 0	☐ -1	
Environmental impacts	☐ 1	☐ 0	☐ -1	
Public impacts	☐ 1	☐ 0	☐ -1	
Poor construction supply chain management	☐ 1	☐ 0	☐ -1	

Other comments and suggestions:

………………………………………………………………………………………

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APPENDIX B

Questionnaire

Questionnaire

This form is the questionnaire for a research project of Mrs. Qing Zhang, a student in the Master Degree of Engineering Program in Engineering Management at Silpakorn University. The topic is "Financial Risk Assessment for A Construction Project"

There is one part. It asks asks the opinion about the factors' influencing to other factors. It is a five-point Likert scale as shown in the table below.

Point	Definition
1	No influence
2	Very low influence
3	Low influence
4	High influence
5	Very high influence

Twenty-eight risk factors are divided into nine groups. The details are shown the table below.

Class	Elemental description	Code
Pandemic, R_1	Pandemic outbreak	x_1
Political, R_2	War and geopolitical conflict	x_2
	Political corruption	x_3
	Regulation and policy changes	x_4
Economy, R_3	Fluctuation of currency exchange	x_5

Class	Elemental description	Code
	rate	
	Inflation rate	x_6
	Interest rate	x_7
	Household debt	x_8
Credit, R_4	Project's credit risk	x_9
	Equity holder's credit risk	x_{10}
Engineering, R_5	Design change	x_{11}
	Lack of material and qualified suppliers	x_{12}
	Substandard materials	x_{13}
	Substandard equipment	x_{14}
	Project delay	x_{15}
Operation, R_6	Counterparty risk	x_{16}
	Rating risk	x_{17}
	Tax risk	x_{18}
Market, R_7	Client's financial stability	x_{19}
	Poor financial market	x_{20}
	Poor market research	x_{21}
Liquidity, R_8	Lack of cash flow	x_{22}
	Project's liquidity	x_{23}
	Delay payment by client	x_{24}
Others, R_9	Lack of competent staff	x_{25}
	Environmental impacts	x_{26}
	Public impacts	x_{27}
	Poor construction supply chain management	x_{28}

Thank you very much for your cooperation. The data are kept secret and unopened to a third-party organization. The purpose of this study is academic only.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28
X1																												
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VITA

NAME Mrs.Qing Zang