A CRITICAL EVALUATION OF RISK ON LARGE SCALE LOGISTICS PROJECTS

by

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Declaration

I declare that the thesis, which I hereby submit for the degree Philosophiae Doctor (Project Management) at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at another University.

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Summary

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As an important basis in decision-making, risk assessment has been applied in many fields. However, most risk analyses of logistics projects are still at their infancy, wherein qualitative methods are applied. Performing further qualitative and quantitative analyses of the risk of logistics projects is meaningful. This thesis aims to thoroughly analyse the effects of risk factors on project objectives to illustrate the economic goals of investment and the possibility of realisation. Hence, it can promote scientific decision-making by investors, which is the main issue in this thesis.

Large-scale logistics projects are characterised by high risk, high investment, and high professionalism. This thesis applies risk assessment to logistics projects and divides the risk assessment of logistics projects into two levels. In the first level, various risk factors in the process of investment, construction and operation of the logistics projects are fully considered, and a set of risk comprehensive evaluation index system for the logistics projects is established. At this level, this thesis assigns light to each factor, judges the degree of risk of each factor in logistics projects and evaluates the risk degree of the logistics projects via fuzzy comprehensive measurement method (FCMM). It proposes a logistic alliance risk identification and analysis method based on the particle swarm optimisation (PSO) algorithm and penalty function method to address the limitation of existing methods, such as FCMM. This proposed method is called PSO–analytic hierarchy process (PSO–AHP). On the basis of the introduced index system and methods, this thesis uses Hanjin Shipping as a novel case to show how risk evaluation is performed. Results show that both methods can be used to predict the risk of Hanjin Shipping, and management risk is the main risk faced by Hanjin Shipping. This finding is consistent with the predicted results. The contents of this thesis provide meaningful results for actual application. Thus, the models and index system applied in this thesis (FCMM and PSO–AHP) can be used to perform risk measurement. In the second level, combined with the results of the overall risk assessment of the logistics projects, this thesis provides several suggestions on risk prevention for these kind of logistics projects. This thesis not only measures the risk of large-scale logistics projects but also provides several strategies to improve the management of logistics projects and reduce the probability of risk in the Chinese context. Moreover, this thesis generates suggestions for the development of Chinese large-scale logistics projects in South Africa.

The main contents of this thesis can be summarised as follows. The first chapter is the introduction. This chapter briefly introduces the background of large-scale logistics projects, explains the purpose and significance of the research and introduces the main research issues and innovations. It also briefly introduces the structure of this thesis. The second chapter comprises a review of previous studies. It mainly reviews and summarizes relevant literature on risk theory and logistics risk to provide a solid background analysis for the remaining part of this thesis. The third and the fourth chapters are about the methodologies and indicators used in this thesis. The third chapter summarises and introduces the main methods used in the risk assessment for the logistics projects. It focuses on the methods used in this thesis. The fourth chapter presents a systematic analysis of the various risks faced in the process of investment, construction and operation of logistics projects. It appropriately enumerates the main analysis of this thesis, namely, the various risks in large-scale logistics projects. An index system is also constructed in this chapter. The fifth and sixth chapters focus on the specific operation process of the models used in this thesis. These chapters focus on the data analysis according to the models proposed in previous chapters, and the results of quantitative analysis are mainly discussed. The seventh chapter is aimed at the risk prevention of large-scale logistics projects. The eighth chapter is the research summary and outlook, where it summarises the conclusions and shortcomings of this research, discusses the innovation of this thesis from the analysis and indicates further research directions.

The main contributions of this thesis are as follows. (1) On the basis of China’s Belt and Road strategy, this thesis pays special interest on the risk analysis of large-scale logistics projects. With the development of Chinese economics and special relationship with South Africa, cooperating in aspects where logistics projects play a great connecting role becomes increasingly important for these countries Thus, ensuring how the risk of China's large-scale logistics projects is sufficiently low becomes increasingly important. The methods and results in this thesis can be applied to the large-scale logistics projects in China and South Africa. (2) Many studies on risk assessment issues obtain risk factors using Delphi method (Dalkey and Helmer, 1963; Fan, 2019; Dufour et al., 2017). This method usually suffers from the fact that the experts' knowledge, ability and experience limit their personal judgement method, and the recognition result is influenced by the subjective factors of the experts. This thesis does not use AHP method on it own but focuses on the usage of work breakdown structure (WBS) method to determine the risk factors of logistics construction projects, which can provide a reasonable risk index system. As WBS can let people carefully build an index system from each aspect of the large-scale logistics projects. (3) This thesis generates a PSO method to PSO–AHP method and applies it in the risk assessment of large-scale logistics projects, in which Hanjin Shipping is taken as an example in a novel way. Many studies primarily use FCMM to perform the risk assessment. However, limited research focuses on the use of PSO–AHP methods on the risk assessment of large-scale logistics projects. This thesis not only uses FCMM to handle risk assessment but also uses PSO–AHP method and then selects the better method on the basis of certain criteria. By doing so, this thesis provides an excellent example for researchers to select between the two models for risk assessment. (4) This thesis not only measures the risk of large-scale logistics projects but also provides several strategies that can improve the management of logistics projects to reduce the chance of risk happening based on actual situations. It also generates suggestions for the development of Chinese large-scale logistics projects in South Africa. As the measurement of risk in terms of large-scale logistics projects is an instrument for people to prevent risk, each method should be used to guide the development in actual situations. Thus, this thesis provides several strategy suggestions that can reduce the risk of large-scale logistics projects in China and South Africa by combining the results obtained from models and actual situations in China and South Africa.

Keywords

Decision-making, Fuzzy Comprehensive Measurement Method, Large-scale logistics project, Measure, Particle Swarm Optimization- Analytic Hierarchy Process, Risk assessment, Suggestion

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List of Acronyms

PSO	Particle Swarm Optimization
FCMM	Fuzzy Comprehensive Measurement Method
AHP	Analytic Hierarchy Process
WBS	Work Breakdown Structure
FDI	Foreign Direct Investment
BP	Back Propagation
EURASIP	European Association for Signal Processing

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Chapter 1：

Introduction

With the rapid development of the global economy, logistics has become the core content for connecting all economic activities, especially for China. China has become the largest global logistics market with the greatest influence after 40 years of rapid development since its reform and opening-up (Fan, 2019). Meanwhile, the Belt and Road Strategy is a global development strategy adopted by the Chinese government in 2013 involving infrastructure development and investments in nearly 70 countries and international organizations in Asia, Europe, and Africa (Xu and Chung, 2018; Yu, 2016 and 2017). To accomplish this strategy, China must increase its investments in the countries involved, which may bring large risks for many logistics projects. Although logistics has become an important industry for Chinese economics, the weak capability to resist risk is still the main problem that makes the Chinese logistic market big but weak. In China, project assessment and management has only recently been introduced to the logistics industry, so little research has been conducted on the risk assessment and management of logistics projects. On this basis, this thesis aims to provide a robust method to assess the risk of logistics projects. This chapter mainly introduces the background and significance of this thesis by focusing on the role of risk evaluation during the entire logistics system. It then introduces the research objectives and main research questions, followed by the introduction of the main methods, namely, fuzzy comprehension measurement method (FCMM; Zadeh, 1965) and particle swarm optimisation–analytic hierarchy process (PSO–AHP; Huang et al., 2011).[1] Finally, it summarises the main expected contributions and highlights of this thesis.

[1]The difference between the method in this thesis and Huang et al. (2011) is that this thesis not only combines AHP and PSO, but also uses WBS together to build the risk indicator system, which is the base of PSO-AHP method, while Huang et al. (2011) focus on the combination of AHP and PSO, and use it to maximize the value of product updating so as to extend the product life cycle.

1.1 Background and Significance

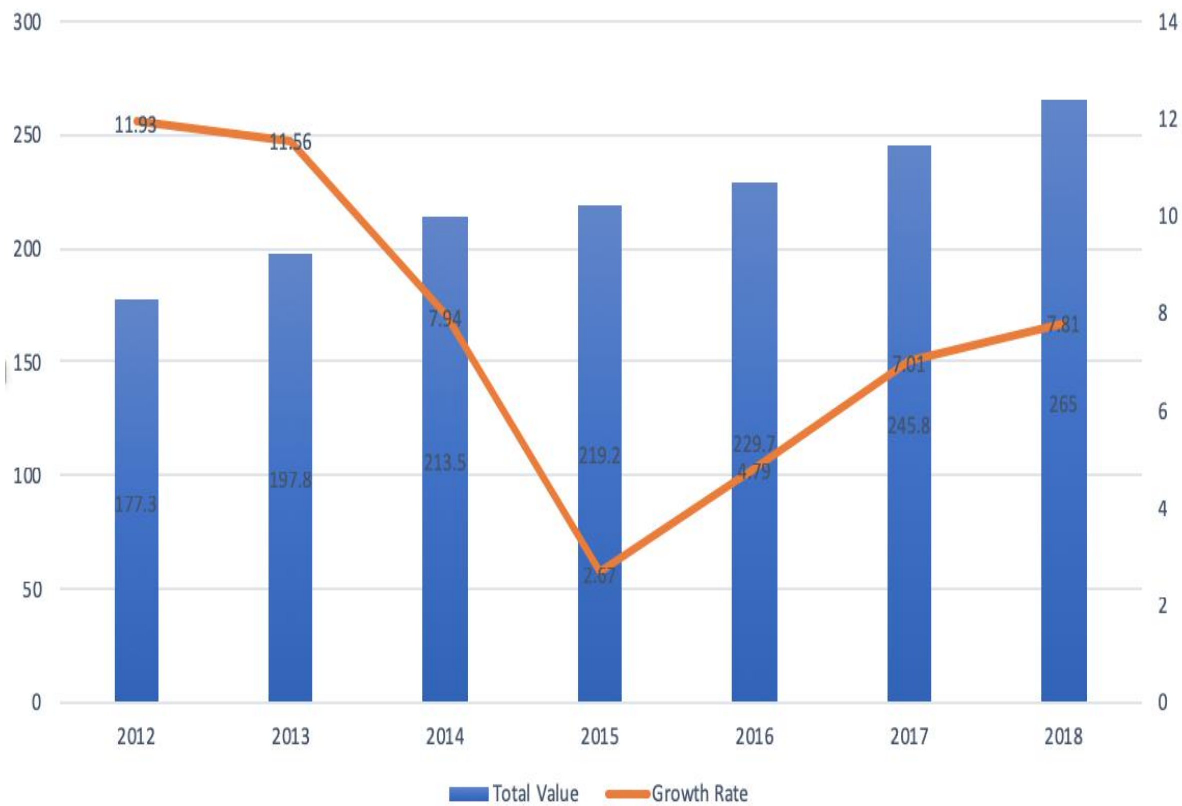
1.1.1 Background

After more than 30 years of development, the logistics industry in China has become a pillar industry of the national economy and an important modern service industry. (**Figure 1-1**).[2] In 2013, the logistics market of China exceeded that of the United States for the first time and became number one in the world. With the rise of the Belt and Road strategy of China, the planning and construction of logistics projects have also prospered. Although the construction of logistics projects has many implications for the logistics development of a city or region, the inherent characteristics of such projects, which include strategic, non-profit, high investment and long investment recovery period, introduce unprecedented management risk to the logistics industry after construction (Ralston et al., 2015; Ricjey et al., 2010). Many of the completed logistics projects in China have failed to achieve the expected results due to poor management, which not only causes excessive waste of manpower, material and financial resources but also brings serious harm to the survival of enterprises (Boyson, 2014; Chen et al., 2013; Fan, 2019). To solve the problems that may exist in the construction of logistics projects, the following are necessary: **(1)** conducting a preliminary feasibility study; **(2)** conducting a comprehensive investigation of the construction projects; and **(3)** performing technical investigations on various situations that may occur in the projects where an important aspect of economic feasibility analysis is the investigation and evaluation of the overall risk of such projects. This approach provides a basis for the formulation of investment

[2]See https://www.iyiou.com/p/88098.html. This citation shows that the total national social logistics in China reached 252.8 trillion yuan in 2017, including 3.689 billion tons of the national railway cargo, 36.869 billion tons of the road freight volume, 6.678 billion tons of the waterway freight volume, and 7.058 million tons of the civil aviation cargo and mail transportation volume. Moreover, China has 2,696.22 billion tons of the national railway cargo turnover, 6,677.15 billion tons of the road cargo turnover, 9,861.13 billion tons of the waterway cargo turnover, and 24.35 billion tons of the civil aviation. The country ranks its first globally in terms of the volumes of railway cargo delivery, railway cargo turnover, road freight volume, port throughput, container throughput, and express delivery rank first in the world. Its volume of civil aviation cargo ranks second worldwide.

decisions and risk prevention measures, which is the main focus of this thesis.

Figure 1- 1 Total Value and Growth Rate of Logistics Market in China (2012-2018)



Note: Data are from Sootoo Institute, 2019 (http://www.sootoo.com/). The unit on the left axis represents Wan Yuan, and that on the right axis denotes percentage. This figure shows that the total value of China's logistics market and the growth rate have been increasing from 2015.

China has initially possessed the economic environment and market conditions for the development of the logistics industry after its reform and opening-up. It then experienced sustained and rapid economic development. The demand for simple warehousing and transportation of major enterprises has gradually developed into a series of integrated logistics, including warehousing and transportation services, due to the continuous improvement of the market economic system and intensification of market competition. Many enterprises pay attention to risk management to improve their competitiveness. Meanwhile, the product storage and transportation of these enterprises have proposed professional management requirements for logistics companies and provide a good environment for the development of logistics project management Buhler et al., 2019; (Bradley, 2014; Chen et al., 2013). On this basis, this thesis motivates from research to provide several strategies that can improve the management of logistics companies to reduce the chance of risk from occurring after building a model to assess the logistics project's risk.

UNIDO Manuals on Preparing Industrial Feasibility Studies and Evaluating Industrial Projects[3] specializes risk analysis methods. However, no attention has been paid to the risk analysis of logistics projects, especially in the case of market, investment and economic benefits that may have various risks (Buhler et al., 2019; Chen et al., 2013; Frankel et al., 2002). Given the insufficient analysis and prediction of the influence of risk on logistics projects, actual data and feasibility study of many projects may change considerably or even become completely inaccurate. The construction of logistics projects requires many valuable resources, such as capital, materials and manpower. Once completed, logistics projects are difficult to change. Therefore, the risk prevention and control of projects are particularly important. To effectively prevent and control risk, a growing number of researchers (Hofer et al., 2014; Fawcett et al., 2012; Frankel, 2002) not only conduct risk analysis and risk countermeasure research in the preliminary work of investment projects but also perform effective risk evaluation during project implementation and operation. Therefore, strengthening the current risk awareness and emphasizing the results of risk analysis are necessary conditions for the smooth development of various constructions under the market economy (Hofer et al., 2014; Fawcett et al., 2012).

At the same time, the Chinese government has provided policy supports for the development of logistics infrastructure and services to promote the rapid development of the logistics industry (Fan, 2019). On the one hand. on the basis of the policy of opening-up to the outside world, foreign investment has encouraged the entry to field of logistics and distribution services rapidly. On the other hand, Chinese domestic enterprises are encouraged to engage in logistics and distribution services to develop

[3]See https://www.unido.org/resources/publications/publications-type/cds.

domestic logistics enterprises and increase employment opportunities. Many transportation and warehousing companies have conducted logistics business during this good development environment (Buzacott et al., 2012; Camuffo et al., 2007; Cantor et al., 2014; Fan, 2019). The choice of professional logistics services has also become important for many of companies to reduce cost and enhance competitiveness. The demand for large-scale logistics[4] enterprises increases with the expansion of the logistics demand market. However, at present, not many companies in China have the strength to be fully responsible for the comprehensive logistics services. Therefore, according to their own needs, several logistics companies are selected to jointly undertake all businesses, such as Yuanyang Logistics Company and Haiyun Logistics Company (https://www.sinooceangroup.com/). Under this circumstance, large-scale logistics enterprises with strong comprehensive strength will have good development prospects. However, the development of large-scale logistics services requires a strong logistics and information networks, which come with large investment and high risk. Although the development of logistic business can form a win–win situation for logistics and financing companies, it also poses various risks. Effectively analysing and controlling these risks is one of the keys to the success of logistics projects.

Many researchers have realised the importance of the risk analysis of logistics projects (Hartmann and de Grahl, 2011; Frankel et al., 2002; Zacharia et al., 2011). The economic evaluation analysis of project risk can usually be summarised into three levels, that is, **(1)** risk analysis based on project financial evaluation; **(2)** risk analysis of cash flow; and **(3)** risk analysis following complete risk analysis method (Stank et al., 2001). However, most risk analyses of logistics projects remain at the first level, which is risk analysis based on project financial evaluation (Cantor et al., 2014; Fan, 2019; Keers and van Fenema, 2018; Min et al., 2005; Zarbakhshnia et al., 2018). Conducting further qualitative and quantitative analyses of the risks of logistics projects is important to comprehensively analyse the influences of various risk factors on the project objectives

[4]In this thesis, we focus on large-scale logistics projects, such as the Hanjing case used in this thesis, which has a large international customer base and manages the flow of raw material through the finishing process and responsible for customer satisfaction. One of the main characteristics of large-scale logistics project is that they are built across different countries. With the development of technology, large-scale logistics projects will become more and more common.

and illustrate the economic goals of investment and the possibility of realisation, which can promote scientific decision making by investors (Dufour et al., 2017; Harker, 1999; Keers and van Fenema, 2018; Panayides, 2007; Singh and Power, 2009). These issues are the main concerns of this thesis. Especially, this thesis aims to thoroughly analyse the effects of risk factors on project objectives to illustrate the economic goals of investment and the possibility of realisation. Hence, it can promote scientific decision-making by investors.

1.1.2 Significance

Logistics projects often refer to projects in which third-party logistics companies provide logistics services in the construction of logistics infrastructure and hardware equipment. The development of large-scale logistics business must be based on a strong logistics system, reflecting the advantages of the low cost and high efficiency of logistics services. In order to conduct logistics business, enterprises must perform a large-scale construction of logistics infrastructure and provide a large amount of capital investment on the basis of the original business and management experience. During the process of investment construction and operation, even after the completion of projects, enterprises face complex and diverse risks (Day, 2000; Kähkönen and Lintugangas, 2012; Lambert et al., 2008). As a venture capital, investors must understand the risk factors of investment projects to make investment and operations decisions, effectively control the risks of investment and decision making and considerably reduce the possibility of investment failure.

This thesis applies risk analysis and management theory to the logistics research and strictly follows the complete risk analysis procedure to conduct risk identification, evaluation and corresponding preventive measures. Risk analysis in the feasibility research of logistics business is usually based on financial project evaluations, such as break-even and sensitivity analyses. The risk analysis and management of logistics projects can improve the content of their feasibility study and the credibility of research results. Following the multi-risk characteristics of logistics projects, the WBS[5] is used in this study to firstly determine the risk factors. Subsequently, this thesis summarises and establishes an overall risk indicator system, evaluates the risk as a whole and a single factor separately and clarifies the risk level of project as a whole and a single factor. A FCMM (Fuzzy Comprehensive Measurement Method) and PSO–AHP methods are also used separately to measure the risks of logistics projects by using examples from Hanjin Shipping. As studies focusing on the use of PSO–AHP method for the risk assessment of large-scale logistics projects are limited, this thesis not only uses the FCMM to deal with risk assessment but also employs the PSO–AHP method and then selects the best one according to some criteria. Generally speaking, the PSO-AHP method has the following advantages: (1) Enabling to develop risk information management; (2) Supporting effective decision-making for risk management; (3) Establishing practical risk organizing for organizations; (4) Providing valuable analysis data for future estimation. To implement the PSO-AHP method illustrated in an integrated novel manner in this thesis, in the first step, AHP is used on people interview records to select the module in a product that needs to be changed with top priority, whereas in the second step, PSO is used to select the best suppliers on the project. AHP is a structured technique used in organizing and analyzing complex decisions; occasionally however, the results obtained from AHP alone are not appropriate enough. The current thesis combines the use of AHP and PSO to overcome this drawback. By doing so, this thesis provides a novel and unique manner for researchers to choose between the two models identified and implemented for conducting risk assessment on the logistics projects.

The scientific comprehensive approach for the risk assessment of logistics projects can help understand the key risk factors affecting project and assist managers in implementing effective risk mitigation measures by scientifically predicting the risks that may arise during the project development process. For the unavoidable risks, the profit balance is based on the company’s own capabilities and the losses possibly attributed to the risks. Effective management measures are also available for decision makers to make choices. Therefore, the results of this study are of great value for venture

[5]See the introduction of WBS https://en.wikipedia.org/wiki/Work_breakdown_structure.

capitalists or corporate decision makers.

According to the principles and methods of risk identification and the characteristics of logistics projects, this thesis , using proper scientific and philosophical resoning, divides the risk of large-scale logistics project into two categories, that is, logistics enterprise risk and logistics environment risk. Based on these, this thesis designs a complete and novel risk assessment risk index system according to the framework of WBS. The newly designed index system built in this thesis can help clarify the nature of the various components of the project and their relationship with one another, as well as the relationship between the project and the environment, thereby reducing the uncertainty in the process of identifying the project structure for logistics projects.

Based on the case of Hanjin Shipping considered and analysed in proper detail in this research, this thesis pays special interest in the risk analysis of large-scale logistics projects. With the development of Chinese economy and special relationship with South Africa, the cooperation of the two countries in terms of many aspects is becoming increasingly important, and logistics projects play a considerable role in their connection. Therefore, ensuring that the risk of China's large-scale logistics projects is sufficiently low is crucial. The methods and results of this thesis provide several novel meaningful and properly evaluated tools to analyse the large-scale logistics projects in South Africa.

1.2 Research Objectives and Main Research Questions

Following the previous discussion, the objectives of this thesis are shown as follows,

1) To determine the risk factors of constructing logistics projects by using WBS following the multi-risk characteristics of large scale logistics projects, where WBS which can transform large systems into small ones, decompose complex things into simple and understandable things and clearly show the hierarchical relationship of risks in risk identification of large-scale logistics projects to group the elements in a project based on the purpose of deliverables. As summarized in Chapter 8, and comparing with the existing method, Delphi method, which is influenced by subjective factors of the experts, the WBS method applied in a novel and integrated manner in this thesis can provide a reasonable new and novel risk index system that can also be used effectively on logistics projects.

2) To measure the risks of large-scale logistics projects in Hanjin Shipping[6] by employing the FCMM and PSO–AHP separately and comparing the effects of the two methods, this thesis generates PSO method to PSO–AHP method and applies it in the risk assessment of large-scale logistics projects, in which Hanjin Shipping is taken as an example in a novel way. Many studies (See summary in Xu et al., 2018) primarily use FCMM to perform the risk assessment. However, limited research focuses on the use of PSO–AHP methods on the risk assessment of large-scale logistics projects (Xu et al., 2018). This thesis not only uses FCMM to handle risk assessment but also uses the PSO–AHP method and then selects the better method on the basis of certain criteria. As indicated in Chapter 8, by doing so, this thesis provides a novel and integrated method for researchers to decide between the two models, identified and used in special and unique logistics projects for risk assessment.

3) To provide several strategies that can improve the management of logistics projects to reduce the chance of risk occurrence. This thesis not only measures the risk of large-scale logistics projects but also provides several strategies that can improve the management of logistics projects to reduce the chance of risk happening based on actual situations. It also generates suggestions for the development of Chinese large-scale logistics projects in South Africa. As the measurement of risk in terms of large-scale logistics projects is an instrument for people to prevent risk, each method should be used to guide the development in actual situations. Thus, this thesis provides several strategy suggestions that can reduce the risk of large-scale

[6]Hanjin Shipping had a long history, with a strong mode of advanced logistics enterprises. The company's bankruptcy took the entire logistics industry in South Korea into market shock and lack of confidence, which spread globally. Therefore, a study of this case by using the theory of project management is necessary. Analysing the reasons through this thesis behind Hanjin Shipping's bankruptcy and management loopholes should provide meaningful experience for contemporary logistics enterprises.

logistics projects in China and South Africa by combining the results obtained from models and actual situations in China and South Africa, such as political risk (See **Chapter 8**).

The main research questions this thesis addresses are subsequently as follows:

a) How can the risks of logistics projects be qualitatively and quantitatively analysed to comprehensively investigate the impact of various risk factors on the project objectives and illustrate the economic goals of investment and the possibility of its realisation?

b) How to choose the better one from the two models which can assess logistic risks and subsequently promote the selected model to other countries apart from China or other logistics objectives?

Note that the research objectives 1) and 2) are aimed to answer the first research question, while the objective 3) is to address the second question. Both two questions are answered in **Chapter 8**, where to achieve the first question, this thesis mainly utilizes the WBS method in a novel and integrated manner to identify risks for logistics projects, which can group project elements based on the purpose of deliverables. Next, this thesis uses the FCMM and PSO–AHP methods separately and in comparison to measure the risks in large-scale logistics projects. In addition, the research of this thesis has provided meaningful new results for actual practical logistics project cases. According to the index system presented in **Chapter 4** and the methods introduced in **Chapter 5**, Hanjin Shipping was used as a case study in **Chapter 6** to demonstrate how risk evaluation is performed. The results show that both methods could be used to predict risks in Hanjin Shipping and that management risks are the main risks faced by the company, which is consistent with predicted results. These indicate that the FCMM and PSO–AHP methods can be used to perform risk measurements well. This thesis gives more comparisons between these two methods in **Chapter 6**. Thus, the second question is also answered, see details in **Chapter 8**.

1.3 Main Methods of This Thesis

To clarify the contribution of this work, Section 1.3 briefly introduces the main methods used in this thesis (Details of the methods will be introduced in **Chapter 3**). Firstly, this thesis establishes various factors that may have a risk effect on large-scale logistics projects to survey the overall risk of large-scale logistics projects in China. This thesis also uses WBS which can transform large systems into small ones, decompose complex things into simple and understandable things and clearly show the hierarchical relationship of risks in risk identification of large-scale logistics projects to group the elements in a project based on the purpose of deliverables. Many studies on risk assessment issues obtain risk factors using a Delphi method (Dalkey and Helmer, 1963; Dufour et al., 2017; Fan, 2019). This method usually suffers from the fact that the experts' knowledge, ability and experience limit their personal judgement method, and the recognition result is influenced by the subjective factors of the experts. This thesis does not use AHP method to build index system but focuses on the usage of work breakdown structure (WBS) method to determine the risk factors of logistics construction projects, which can provide a reasonable risk index system. Secondly, this thesis separately applies the FCMM (Swing et al., 2007; Song, 2003) which can solve the problems with a large amount of fuzzy information in various risk assessment activities and improve the scientific and reliability of risk assessment results and PSO–AHP methods which can achieve better results than PSO algorithm alone to measure the risks of the large-scale logistics projects in China (Tranfield et al., 2003).

The basis of fuzzy theory is the fuzzy set (Zadeh, 1965), which has a certain mathematical foundation. Given that logistics projects have a considerable amount of fuzzy information (Xu et al., 2018), fuzzy theory has criticality and penetration as an approximate mathematical system to solve the issues in logistic projects, especially in various risk assessment activities with a large amount of fuzzy information. Fuzzy theory can solve this problem and improve the reliability of risk assessment results, which can use an indicator to represent the risk level. This is the main reason for selecting FCMM to perform the risk assessment.[7] FCMM is essentially based on the evaluation factors, evaluation criteria and weights of factors and the fuzzy set transformation principle is used to describe the fuzziness of various factors by the degree of membership. The boundary is constructed to establish a fuzzy evaluation matrix, and the level of evaluation object is finally determined by multi-level coincidence operation.

Kennedy and Eberhart developed PSO in 1995 (Kennedy and Eberhart, 1995; Xu et al., 2018). The basic concept of PSO comes from the behaviour of predatory birds and has evolved into an optimisation algorithm for evolutionary computing techniques. The simulation of the PSO model belongs to a group of intelligence algorithms. Each particle in the particle group represents a possible solution to a problem. In an intelligent hypothesis area, a piece of food (that is the optimal solution usually described in the optimisation problem) is solved by the simple behaviour of the individual particles and the information interaction within the group. (Huang et al., 2010). The task of the flock is to find this food source. Birds transmit their position to one another during the entire searching process. Thus, they can determine whether they can find the optimal solution and transmit its information. Eventually, the entire flock of birds can gather around the food source, that is, the optimal solution is found. Therefore, the problem converges. However, PSO cannot use the indicator automatically. To improve the performance of PSO, this thesis uses PSO-AHP (Huang et al., 2011), which combines PSO with AHP to solve the optimal problem.[8] Additional details will be presented in **Chapter 3**. The difference between the method in this thesis and Huang et al. (2011) is that this thesis not only combines AHP and PSO, but also uses WBS together to build the risk indicator system, which is the base of PSO-AHP method, while Huang et al. (2011) focus on the combination of AHP and PSO, and use it to maximize the value of product updating so

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[7]Details of each step will be presented in Chapter 5, where this thesis use FCMM to assess risk for a logistics project. Also, this method has been used by the author as co-author in a published paper "Predict the logistic risk: fuzzy comprehensive measurement method or particle swarm optimization algorithm?" in EURASIP Journal on Wireless Communications and Networking in 2018.

[8]This method has been used in a published paper 'Predict the logistic risk: Fuzzy comprehensive measurement method or particle swarm optimization algorithm?' in EURASIP Journal on Wireless Communications and Networking in 2018. For details about PSO–AHP, this thesis refers to Huang et al. (2011).

as to extend the product life cycle.

1.4 Expected Contributions

Many studies about the risk analysis of projects are available. Leopkey and Parent (2009) identified the risk management issues in large-scale sporting events from the perspective of the organising committee members and stakeholders. Brun and Castelli (2008) considered the value and risk assessment of supply chain management improvement projects (For detail of literature, refer to **Chapter 2**). However, research on the risk assessment for large-scale logistics projects in China is limited. Thus, this thesis makes the following contributions:

a) Based on the case of Hanjin Shipping,[9] this thesis pays special interest in the risk analysis of large-scale logistics projects.[10]

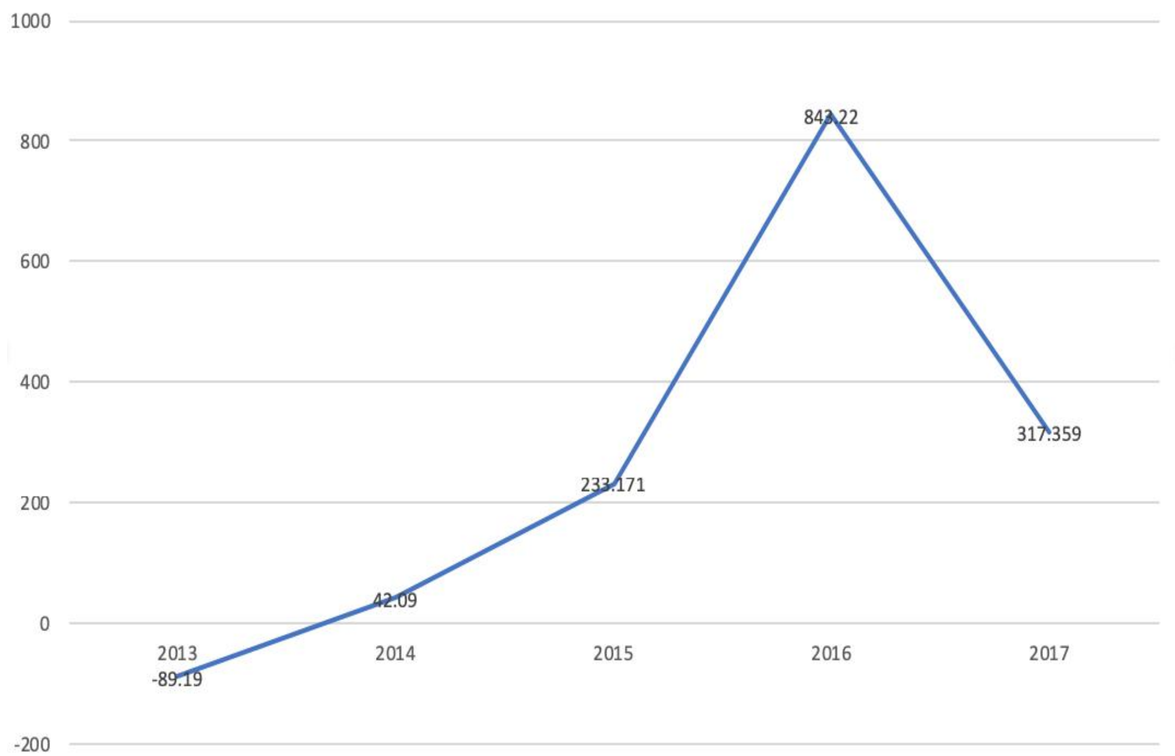
With the development of Chinese economy and special relationship with South Africa, the cooperation of the two countries in terms of many aspects is becoming increasingly important, and logistics projects play a considerable role in their connection. African governments have provided policy supports for the development of logistics infrastructure and services. On the one hand, foreign investment has encouraged to enter in field of logistics and distribution services rapidly; on the other hand, the domestic enterprises are encouraged to engage in logistics and distribution services to develop domestic logistics enterprises and increase employment opportunities. During this good development environment, many transportation and warehousing companies have carried out logistics business. The choice of professional logistics services has also

[9]Hanjin Shipping had a long history, with a strong mode of advanced logistics enterprises. The company's bankruptcy took the entire logistics industry in South Korea into market shock and lack of confidence, which spread globally. Therefore, a study of this case by using the theory of project management is necessary. Analysing the reasons through this thesis behind Hanjin Shipping's bankruptcy and management loopholes should provide meaningful experience for contemporary logistics enterprises.

[10]What should be pointed out here is that although this thesis focuses on large-scale logistics projects, it is obviously to extend to 3 or more cases. For example, three cases could be compared to see which one has the highest risk by using the methods in this thesis, and then according to the ways provided in Chapter 7, people could seek some ways to reduce the risks.

become important way for many of companies to reduce risks and enhance competitiveness. However, the development of large-scale logistics services requires a strong logistics network and information network, which has huge investment and high risks. Therefore, ensuring that the risk of China's large-scale logistics projects is sufficiently low is crucial. The methods and results in this thesis may also possibly be applied to the large-scale logistics projects in South Africa.

Figure 1- 2 FDI of China in Africa



Note: Data are obtained from CEIC. The unit for y axis is millions, whereas that for x axis is year. As illustrated in Figure 1-2, the Foreign Direct Investment (FDI) of China in Africa shows an upward trend in recent years.

b) This thesis applies a method named WBS to determine the risk factors of constructing logistic projects, which can provide a reasonable risk index system.

Several studies on risk assessment prefer obtaining the risk factors by using the Delphi method (Dalkey and Helmer, 1963; Dufour et al., 2017; Fan, 2019). This method usually has a disadvantage in that the personal judgement method of an expert is limited by the individual's knowledge, ability and experience. The recognition result is also influenced by the subjective factors of the expert. Thus, this thesis builds a complete risk assessment risk index system according to the framework of WBS. The new index system built in this thesis can help clarify the nature of the various components of the project and their relationship with one another, as well as the relationship between the project and the environment, thereby reducing the uncertainty in the process of identifying the project structure for logistics projects.

c) This study generates PSO– to- PSO–AHP method in the content of logistics issue, combines it with WBS, and applies it in the risk assessment of large-scale logistics projects.

Considerable research focuses on the use of FCMM to perform risk assessment. Cheng and Xiao (2009) integrated the concepts of AHP and fuzzy consistent matrix method to identify risk factors during bridge construction. Cheng et al. (2008) presented a fuzzy logic-based method, which synthesises the fuzzy AHP method on the basis of a three-point scale, fuzzy set theory and fuzzy logic which are integrated into a single approach to measure the risk of bridges during construction. However, studies focusing on the use of PSO-AHP method for the risk assessment of large-scale logistics projects are limited. Huang et al. (2011) focus on the combination of AHP and PSO and use it to maximize the value of product updating so as to extend the product life cycle, while this thesis combines AHP and PSO and uses WBS together to build the risk indicator system, which is the base of PSO-AHP method. Therefore, the present study not only uses the FCMM to deal with risk assessment but also employs the PSO-AHP method and then selects the best one according to some criteria. By doing so, this thesis provides an excellent example for researchers to choose between the two models for conducting risk assessment.

d) This study measures the risk of large-scale logistics projects in Chapter 5 and 6 and provides several strategies in Chapter 7 that can improve the management of logistics projects to reduce the change of risk occurrence on the basis of the real situation. This thesis also generates suggestions for the development of Chinese large-scale logistics projects in South Africa.

Risk measurement in terms of large-scale logistics projects is not solely an instrument because measurement is not the final objective. Each method should be used to provide guidelines for the development in real situations. Thus, by combining the results obtained from models and real situations in China and South Africa, this thesis s provides several strategies that can improve the management of logistics projects to reduce the chance of risk occurrence on the basis of the real situation. Risk measurement in terms of large-scale logistics projects is not solely an instrument because measurement is not the final objective. Each method should be used to provide guidelines for the development in real situations. Thus, by combining the results obtained from models in this thesis, this thesis will examine risk prevention and consider it from six dimensions according to the risk index system, namely, management, technical, operational, market, fiscal and environment risk, which could be consider as a part of contribution of this thesis, as this chapter provides some ways that can prevent logistic risks. This thesis also generates suggestions for the development of Chinese large-scale logistics projects in South Africa in **Chapter 8**, where this thesis will summarize the main contents and contributions of this thesis.

1.5 Thesis Content and Roadmap

This thesis initially aims to read through the literature, understand previous research results on risk management and then proposes the theoretical model and index system that must be analysed. This study further improves and determines the risk index system of each model on the basis of the criteria summary formed in other research works. In detail, this thesis consolidates opinions from different research works to analyse six types of risks and the corresponding 23 risk factors summarised in the literature to provide scientific and reasonable indicators in the risk analysis framework model. Then on the basis this index system, this thesis discusses and evaluates in some detail for the two methods (FCMM and PSO– AHP). Details of the thesis content are as follows and summarised in **Figures 1-3**:

The **first chapter** presents the introduction, which briefly discusses the study background, explains the research purpose as well as significance and presents the main research issues and main innovations. The research structure is also presented in this chapter.

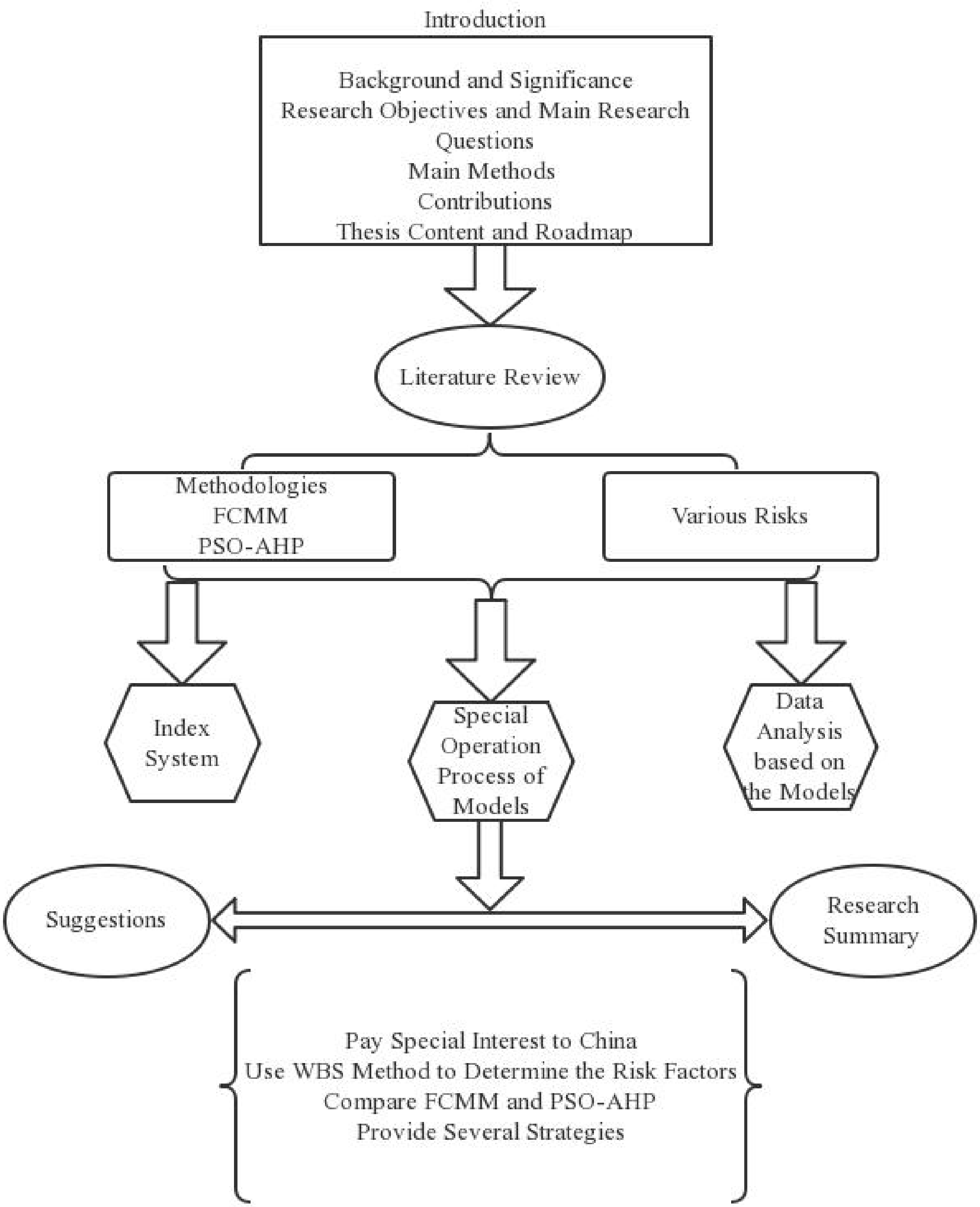
The **second chapter** is a review of relevant previous studies referenced in literature. It mainly reviews relevant literature on risk theories and logistics risks and summarises them to provide a solid background analysis for the remaining parts of this thesis. This chapter also gives a summary on models related to the logistics risk assessment.

The **third and fourth** chapters discuss the methodologies and indicators used in this study. Based on the second chapter, the third chapter summarises and introduces the main methods used during the risk assessment research process for logistic projects as well as specifically large scale logistics projects and then focuses on the methods employed in this thesis. The fourth chapter presents a systematic analysis of the various risks encountered in the investment, construction and operation of logistics projects. This chapter also approximately enumerates the main analysis of this thesis, that is, the various risks in large-scale logistic projects. The index system is also constructed in Chapter 4.

The **fifth and sixth** chapters explain the specific operation processes of the models used in this thesis which focus on the data analysis according to the models proposed in previous chapters. It also introduces and discusses the results of quantitative analysis specifically focused on logistics projects. Specifically, according to the index system presented in Chapter 4 and the methods introduced in Chapter 5, Hanjin Shipping was used as a case study in Chapter 6 to demonstrate how risk evaluation is performed.

The **seventh chapter** discusses the risk prevention of large-scale logistics projects. The **eighth chapter** provides the conclusions of this research, indicates its shortcomings, draws its innovation from the analysis and suggests further research directions.

Figure 1- 3 Thesis Roadmap



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Chapter 2：

Literature Review on Risk and Risk Management of Logistics Projects

With the increasing market competition and continuous development of economic globalization, there is a growing demand for logistics services. Project assessment has been introduced into the logistics industry, which can reach the individual with diversified requirements. As a relatively high-risk service industry, the implementation of project assessment and management in the logistics industry can not only effectively prevent and control risks and improve the level of logistics management, but can also promote the smooth and healthy development of logistics enterprises. The international standard ISO31000[11] for risk management defines the entire process of risk identification, risk analysis and risk assessment. As argued in **Chapter 1**, this thesis is not only about the measurement of risk; the manner in which risk can be reduced to the lowest, is more important and is also related to risk management. Thus, this chapter focuses on the literature related to risk management to clarify the concepts used in this thesis when modelling. At present, the basic idea of risk assessment is to analyse and measure risk, determine the level of risk and provide a reference to subsequent risk control. Following this idea, this chapter introduces the definitions, types and classifications of risk; it provides readers with relevant appropriate and recent knowledge about research in this field; and provides relevant brief diagrams, as well as the process of risk assessment and the risk analysis models that are commonly used in the assessment classification process. Moreover, this chapter presents a new or perhaps more appropriate definition of the risk used in this thesis according to the existing research. The work structure breakdown method is used to divide the project into investment construction stage,

[11]According to Lalonde and Boiral (2012), ISO 31000 is a family of standard related to risk management codified by the International Organization for Standardisation, which aims to provide principles and guidelines on risk management. It includes ISO 31000: 2009—Principles and Guidelines on Implementation, ISO/IEC 31010: 2009—Risk Management—Risk Assessment Techniques, and ISO Guide 73: 2009—Risk Management—Vocabulary. For details, this thesis refers readers to www.iso.org.

operation stage and continuous development stage, and the risk existing on each stage is identified. Finally, after introducing several models that can be used to perform risk assessment, the main models used in this thesis, namely, FCMM and PSO–AHP, are classified into function models and introduced in more detail later. In summary, this chapter provides a picture about what has been done in the literature and introduces the definition of risk used in this chapter to provide the base for this thesis to address the research questions posed in **Chapter 1**. Then in the later chapters of this thesis, it will provide the detail methods and examples to show how to do the risk assessment in terms of large scale logistics projects, and address the research questions introduced in **Chapter 1**.

2.1 Risk Overview

2.1.1 Definitions of Risk

The main task of the American Society of Risk Analysis is to identify risks (Jap and Ganesan, 2000; Min et al., 2005; Sun, 2007). However, after four years of hard work, the committee finally decided to abandon this task because the difficulty of demonstrating a completely unified risk definition cannot be overcome (Zhang and Huo, 2013). In the financial industry, the concept of risk refers to the variability of asset returns (Bernard et al., 2018; Ceryno et al., 2015; Chang et al., 2015; Copeland, 1993). In the insurance industry, risk is defined as the probability of loss (Bowersox and Daugherty, 1987; Chen et al., 2016; Cheng et al., 2018; Michael et al., 2018). On this basis, risk has been defined in many different fields, where it can refer to the uncertainty of loss and the uncertainty of profit. Sun (2007) argues that the following are roughly the typical view about the definition of risk:

a）The first view is that risk is the possibility of loss occurrence. The concept of risk is initially incorporated into theory of economics by Haynes. In his article 'Risk as an

Economic Factor' published in 1895, the term risk is used in economics and other academic fields. No technical content is established, and risk only represents the possibility of loss. Haynes (1895) believed that in the implementation of certain economic behaviours, the economic behaviour will bear the risk if uncertainty exists about the occurrence of unfavourable results, and the result of taking the risk is the reduction of the profit of economic behaviour. French scholar Reimann's 'General Business Economics' published in 1928 also defined 'risk' as the possibility of loss. Since then, other scholars, such as Maier, Kemek and Rosenbull (1986) have clearly defined risk as the possibility of loss. Boehm (1991) also defined risk as 'the probability of loss or damage'.

b） The second view is that risk is uncertain. Chapman (2003) defined risk as an uncertain event or condition that positively or negatively affects the content of the project. Modern asset portfolio theory also believes that risk is an uncertainty, and risk and uncertainty are not essentially different.[12]

c） The last view is that risk can be considered the deviation of the results from expectations. Chen et al. (2014) argued that risks are manifested as a fluctuation of variable in the future. Firstly, this volatility comes from the uncertainty of future outcomes, which cannot be accurately predicted in advance. Secondly, the fluctuations of market variables are frequent or even continuously changing with some statistical characteristics. Mathematical statistical methods for measuring volatility mainly include the expected value and variance (or standard deviation) of the variable. The expected value represents the concentrated trend and average level of the fluctuation of the variable, whereas the variance represents the discrete trend of the variable change, that is, the risk level. Using the variance or standard deviation to assess the level of risk has become a basic risk measurement method.

On the basis of the definitions of risk, most scholars believe that risk is related to loss

[12]Major differences still exist between risk and uncertainty. Commonly, risk can be appraised with probability. People do not know what is going to happen but know what distribution looks like. By contrast, uncertainty cannot be measured entirely. Hence, people neither know what is going to happen nor what possible distribution looks like.

and uncertainty and that risk is a multidimensional concept. However, when it comes to risk in logistics projects, the definition of risk must be clarified and made precise for the intended propose to be understood by everyone in this industry. Such actions can guide the analysis of this thesis. On the basis of the different interpretations and definitions of risk, the definition of risk in this thesis is as follows[13]:

Large Scale Logistics Projects Risk is a negative activity or event and a potential consequence that people do not want, including (1) the probability of loss or gain and its measurable size;(2) it is an event that can cause the occurrence of another event that is unrelated to the other, multiple simultaneous events or an ongoing event.

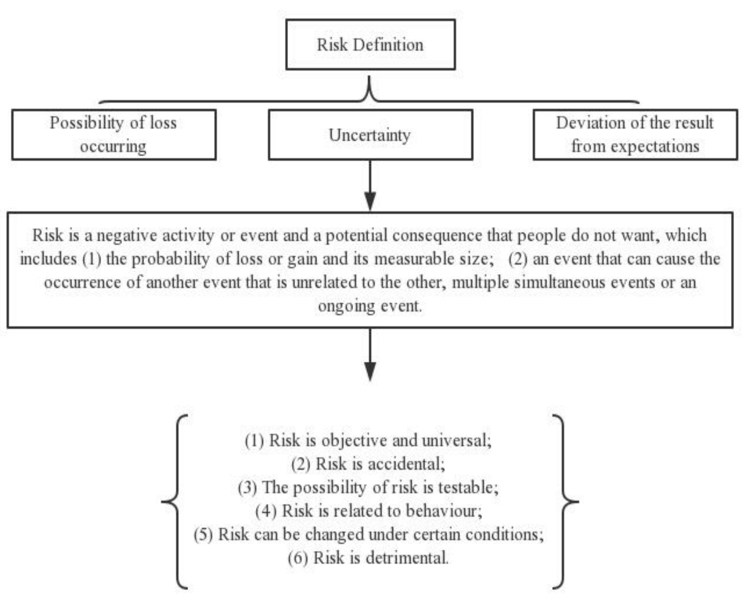
As argued by Sun (2007), as a common phenomenon in social and economic life, risk has the following characteristics (Barry et al., 2001; Ko et al., 2010; Ljungqvist and Ricjardson, 2003): **(1)** Risk is objective and universal; it does not depend on human will. Although humans always want to identify and control risks and try to change the conditions in which risk may occur within a limited time and space, people can typically only reduce the frequency of occurrence of the risk and the losses caused by the corresponding risk and they cannot eliminate the risk entirely (Bernard et al., 2018; Chen et al., 2016; Cheng and Xiao, 2009; Cheng et al., 2008; Daugherty et al., 2006). **(2)** Risk is accidental. Contingency is also the uncertainty in the usual sense, which is the essence of risk characteristics.[14] This assumption is due to the randomness of objective conditions and people's lack of understanding of the future environment, which prevents them from fully determining the outcome of an event (Chen et al., 2010; Day, 2000). **(3)** The possibility of risk is testable. Uncertainty determines that risk can only be a possibility, and this possibility becomes a reality depending on other relevant conditions.

[13]Defining risk in logistics projects in this way is reasonable. In terms of logistics projects, what people care about is the profit and loss, which are the main reasons why this thesis includes the probability of loss or gain in the definition of risk. Moreover, logistics projects cannot be implemented alone. The process of logistics projects almost includes each part of the society, which is the direct reason why this thesis considers the second part of risk definition.

[14]In this thesis, contingency does not differentiate accident and contingency; however, knowing that these contingency and accident are different is important. Briefly speaking, **contingency** is (uncountable) the quality of being contingent, of happening by chance, whereas **accident** is an unexpected event with negative consequences occurring without the intention of the one suffering the consequences (Lalonde and Boiral, 2012).

However, this potential uncertainty can be predicted and measured by analysis, statistics, subjective judgement or evaluation of a series of similar events in the past (Fawcett et al., 2008; Nyaga et al., 2010; Tsanos et al., 2014). **(4)** Risk is related to behaviour. Behavioural associations indicate that the risks faced by decision-makers are closely related to their decision-making behaviours. The behavioural relevance of risk indicates that any type of risk is basically formed by the combination of decision behaviour and risk status, that is, the unity of risk status and decision behaviour. Although risk status is objective, results will vary due to different risk attitudes and decision-making behaviours (Hartmann and de Grahl, 2011). **(5)** Risk can be changed under certain conditions. Objective conditions change; thus, the nature and the number of risks may also change or be eliminated with the control of certain risk within a specific time period, and new risk may also arise (Grudinschi et al., 2014). **(6)** Risk is detrimental. The occurrence of risk will have a certain influence on specific targets. Generally, the influence of risk in this thesis refers to the effect that a particular subject does not want to see. This effect can cause damage to the subject and affect effective decision making. In other words, non-destructive risk is also a risk (Fawcett et al. 2012). The discussion of risks and definitions is summarised in **Figure 2-1**.

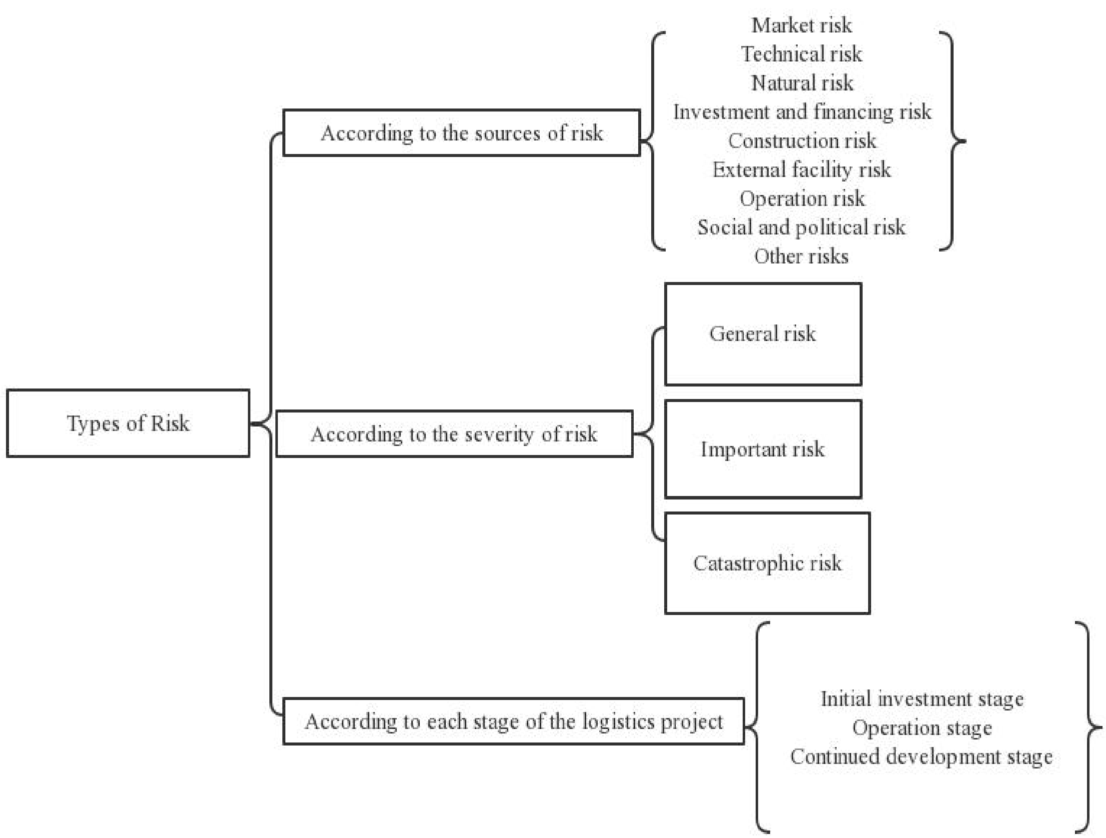
Figure 2- 1 Definition and Characteristics of Risk in This Thesis



2.1.2 Types of Risk

After defining risk, this thesis discusses the types of risk. Logistics projects generally have large investment and professionalism. During project construction and operation, logistics projects are often affected and interfered by many factors. Most of these factors are relatively uncertain, which leads to their specific classification being difficult. In view of the objective of this thesis, which is to assess and manage risk, risk is categorized briefly following different aspects, namely, the source of risk and severity of the risk, the process of construction of logistics projects and other aspects such as each stage of logistics projects (Hofer et al, 2014; Keers and van Fenema, 2018; Song, 2003). The risk types are also summarised in **Figure 2-2**.

Figure 2- 2 Risk Types



2.1.2.1 According to Risk Sources

On the basis of risk sources, this thesis divides risk into nine types, which are similar to Hofer et al (2014), Keers and van Fenema (2018) and Song (2003). The **first** type is market risk, which is a risk that is often encountered in construction projects, especially in competitive projects. The loss is mainly due to the insufficient market demand for products or services, which results in lower than expected product yields and operating income. Market risk mainly comes from three aspects, namely, the actual situation of the total supply and demand in the market is inconsistent with the forecast; the market environment is deteriorating; the actual price deviates from the expected price (Chen et al., 2016; Germain and Iyer, 2006; Hofer et al, 2014; Keers and van Fenema, 2018; Rodrigues et al, 2004; Sanders and Premus, 2005). The **second** type is technical risk. Usually, many feasibility studies are performed during project decision. However, risk factors must also be considered in the technical aspects of feasibility study, such as, whether the applicability and reliability of the technology used in the project are insufficient for making a decision and whether the actual capacity or high consumption index may be controlled after a project construction starts. The current analysis shows that the necessary reliability and applicability test in investment projects using advanced technology will give investors additional opportunities to obtain accurate results. However, the actual project implementation process may still experience unpredictable problems due to various subjective and objective reasons, which cause a certain degree of loss to projects (Chen et al., 2013; Chopra and Sodhi, 2004; Dufour et al., 2017; Stock et al., 2000). The **third** type is natural risk. Although feasibility studies (Chen et al., 2013; Cohen and Kunreuther, 2007; Dufour et al., 2017) have performed some investigations on the geological structure and meteorology of project areas, geological conditions and meteorological laws may not fully predict the actual changes due to the limitations of technical capabilities and working depth. Accidents caused by natural factors still exist, especially in areas with complex natural conditions or lack of surveys and statistical information, thereby leading to economic losses in project operations (Cassivi, 2006; Christopher et al., 2011; Cooper, 2014; Ellram and Sanders, 2008; Sanders and Premus, 2002). The **fourth** type is investment and financial risk. The project investment scale and proportion of funds and the timely availability of various funds are closely related to the future economic benefits of projects. Therefore, investment risk is critical to projects, where the main risk in this regard is expected insufficient investment, extended construction period, rising loan interest rates, disappearing financing channels or delays in payment (Auramo et al., 2005; Bernard et al., 2018; Colicchia and Strozzi, 2012; Craighead et al., 2007; Whipple and Russell, 2007). The **fifth** type is construction risk. During the project construction, problems with the capacity of the construction unit and the on-time supply of construction materials will affect the construction period, which will delay the completion time. This risk also has a considerable effect on projects (Cruz and Liu, 2011; Horvath, 2001; Kärkkäinen and Holmström, 2002; Michael et al., 2018). The **sixth** type is external facility risk. Although all feasibility studies have considered the external facilities required for the normal operation of projects, problems may actually exist when external facilities are not being implemented. As a result, projects cannot perform their intended function, which affects operational efficiency and results in risk (Pala et al., 2014). The **seventh** type is operational risk, which refers to the fact that after projects are placed in production, the expected revenue of projects is difficult to achieve due to poor management of the internal organisation of the enterprise and equipment failure. A series of problems related to the unsatisfied product or service quality, insufficient labour supply, rising operating costs and weak coordination units exist (Cruz and Liu, 2011; Michael et al., 2018; Richey et al., 2012; Zarbakhshnia et al., 2018). The **eighth** type is social and political risk, which is due to the political changes, wars, strikes, emergencies and other risks that cause losses to projects (Lai et al., 2008).[15] **Finally**, other risks should also be considered for some projects. For example, Chinese–foreign cooperation projects should consider the legal status and credit issues of partners (Bowersox and Daugherty, 1987; Cooper and Ellram, 1993; Ellram and Cooper, 1990).

[15]This type may be the main risk to consider in the logistics projects in South Africa.

2.1.2.2 According to Risk Severity

On the basis of risk severity, risks can be divided into three levels (Hofer et al, 2014; Keers and van Fenema, 2018; Song, 2003), namely, general, important and catastrophic risks. **(1)** General risk implies that the risk is unlikely to occur, and the loss after the occurrence is small and generally does not affect the project feasibility (Allred et al., 2011; Corsten and Kumar, 2005; Koufteros et al. 2007; Mishra and Shah, 2009; Rosenzweig, 2009). **(2)** Important risk pertains to risk that is likely to occur and poses considerable loss; however, the extent of the loss can be within the scope of the project (Cruz and Liu, 2011; Daugherty et al., 2006; Keers and van Fenema, 2018; Zarbakhshnia et al., 2018). Important risks include the following situations: firstly, the risk is highly likely to occur whilst the projects remain feasible even if the risk causes a certain loss; second, although the risk causes significant damage, it is unlikely to occur. Adequate precautions can be taken to avoid such risks (Narayanan et al., 2015). **(3)** Catastrophic risks refer to those that have a high possibility. At the same time, the damage caused not only seriously affects the project feasibility but may also lead to a series of chain reactions that result in irreversible consequences (Cao and Zhang, 2011; Hofer et al, 2014; Keers and van Fenema, 2018; Song, 2003).

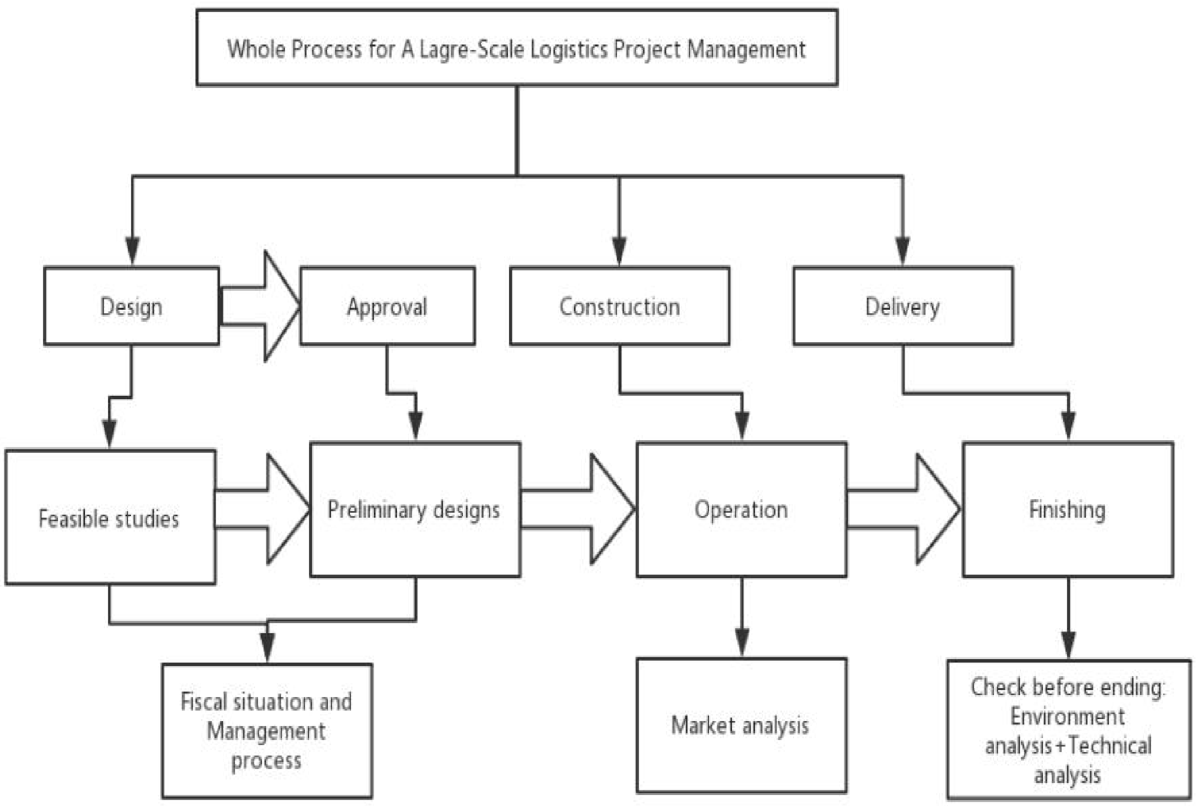
2.1.2.3 According to Each Stage of Logistics Projects

In addition to the preceding classifications, the risk identification of the logistics projects should consider the stage of the overall project given the risk characteristics of such projects (Hofer et al, 2014; Keers and van Fenema, 2018; Song, 2003; Sun, 2007). By using the work structure decomposition method,[16] this thesis mainly divides projects into

[16]Work structure decomposition method can be considered a type of WBS, which is a key project deliverable that organises the team's work into manageable sections. On the basis of this principle, this thesis introduces work structure decomposition method to consider the risk in each stage of logistics projects.

three stages according to Sun (2007), namely, investment construction stage, operation stage and continuous development stage (**Figure 2-3**). This thesis also identifies the risk existing in each stage using the same breakdown method. The work content or task of each stage is decomposed into risk, causes of risk and risk that may be caused and identified layer by layer on the basis of each logistics item.

Figure 2-3 Whole Process Risk Management of Logistics Project



(1) Initial Investment Stage of Logistics Project

The risk of initial investment stage of logistics projects is mainly due to the large amount of capital invested in infrastructure construction and hardware equipment (Carter et al., 2015; Keers and van Fenema, 2018; Song, 2003; Zarbakhshnia et al., 2018). Logistics service is comprehensive. Companies that provide logistics services must deliver a full range of services, including warehousing and transportation. This high standard of service puts high demands on the hardware resources of logistics enterprises. Different customers have various individual requirements for the storage and transportation of goods. Before providing logistics services for specific large-scale manufacturing enterprises, logistics enterprises must build a personalised warehouse on the basis of the specific attributes and requirements of goods, purchase special transportation equipment or advance or modify warehouses and transportation tools. At the same time, the timeliness of logistic information system requires increased stability and accuracy due to the requirements of logistics service efficiency. However, given the various information systems used by different enterprises, the logistic information system must be connected to the system interface of enterprises when performing logistics. Enterprises should be equipped with an information system that matches the logistics information system used or has obtained an information system suitable for the enterprise information system in the logistics projects (Hofer et al, 2014; Keers and van Fenema, 2018; Song, 2003). The state of the equipment in the entire hardware will directly affect the quality of future logistics services. Meanwhile, the main risk faced by logistics projects in the early stage is the key to decision making. A large part of the funds is used for infrastructure investment and information system construction.

The construction of such huge capital investment is targeted. Hence, if an accident leads to the emergence of risk after the capital investment, then the ability of enterprise transformation or asset realisation will be poor. For example, a logistics company signed a tire sales logistics service contract with a large tire manufacturer (Chen et al., 2013). The company refurbishes remodels and equips the company’s existing warehouses on the basis of customer requirements. The company is also equipped with a dedicated fleet to achieve short-distance transportation from the factory to the warehouse and rectify the vehicle to meet the requirements of cargo handling. Given the large daily output of customers, the size of the warehouse and fleet must be equal to the capacity of the factory. The initial investment in this logistics project is tens of millions of Yuan. In addition to ensuring high-quality logistics services to customers, they must also have the ability to invest large amounts of money and repay debts. In addition, they must be willing to bear the possible losses caused by such risk.

(2) Operation Stage of Logistics Project

The risk in the operation stage is divided into controllable and uncontrollable risks; controllable risk is due to the problems caused by business management and logistics services, whereas uncontrollable risk is caused by accidents or force majeure and other unforeseen risks (Chen et al., 2014; Hofer et al, 2014; Keers and van Fenema, 2018). In terms of controllable risks, the service during the operation stage can begin with the logistics project and terminate the entire stage of the logistics service contract. This stage is crucial in the success of logistics investment. Companies providing logistics services to customers are involved in many aspects of the process, and any part of the error will directly affect the smooth operation of the entire logistics system. The risk at this stage is mainly reflected in the following aspects (Chen et al., 2014; Cooper and Ellram, 1993; Hofer et al, 2014; Keers and van Fenema, 2018). **(1)** Customer risks. In the operation of logistics projects, the acquisition of logistics service fees is the only source of revenue for logistics operations. Therefore, the process of logistics projects, customers' credit and business conditions directly affect the economic risk of projects. If a customer cancels the contract midway or the client company goes bankrupt, then the pre-investment of the customer's professional logistics service cannot be recovered in time, thereby bringing considerable economic losses to the enterprise. **(2)** Risks of hardware equipment. During the process of logistics service, hardware equipment is the prerequisite for logistics enterprises to provide efficient and low-cost logistics services (Hofer et al., 2014; Song, 2003). In addition to the risk associated with some of the most common equipment failures during business operations, some unexpected outcomes can be considered important risks in business operations; **(3)** Operational risks (Hofer et al., 2014; Song, 2003). During the operation of the entire logistics system, all aspects of the relationship among logistics companies rely on the coordination of managers. If managers cannot complete their work, then they will result in reduced services and may even lead to accidents, such as major casualties and property damage. This operational risk in the implementation of logistics projects deserves a great attention. Therefore, this risk control is a guarantee for the smooth operation of the entire logistics system.

(3) Continued Development Stage of Logistics Projects

After entering this stage, project risks are mainly due to the financial risks brought by the existing business (Ding et al., 2013; Ellinger, 2000). The development of this stage does not require considerable capital investment, and only a guarantee of the continuous operation of the original business can ensure a stable return. From a financial perspective, this stage is important in project profitability. As a project enters a stable phase, operation and management risk is considerably reduced from the initial development stage. However, financial risk has increased remarkably due to the increase in customers. Each customer's personalised service is accompanied by a new capital investment, and this customer's own risk is directly related to the risk of logistics projects. In addition, if the customer stops the contract at this stage, then the company will face very large economic losses.

2.1.2.4 According to Other Characteristics Related to the Nature of Risk

In addition to the aforementioned two classification methods (Hofer et al., 2014; Song, 2003; Xu et al., 2018), risks can also be classified into pure and speculative, economic and noneconomic risks according to the nature of risk. On the basis of the ability of investors to take risks, risks can be divided into affordable and unaffordable risks. In terms of the degree of controllable risk, risks can be divided into controllable and uncontrollable risks (Daugherty et al., 2006; Cruz and Liu, 2011; Keers and van Fenema, 2018; Zacharia et al., 2009; Zarbakhshnia et al., 2018).

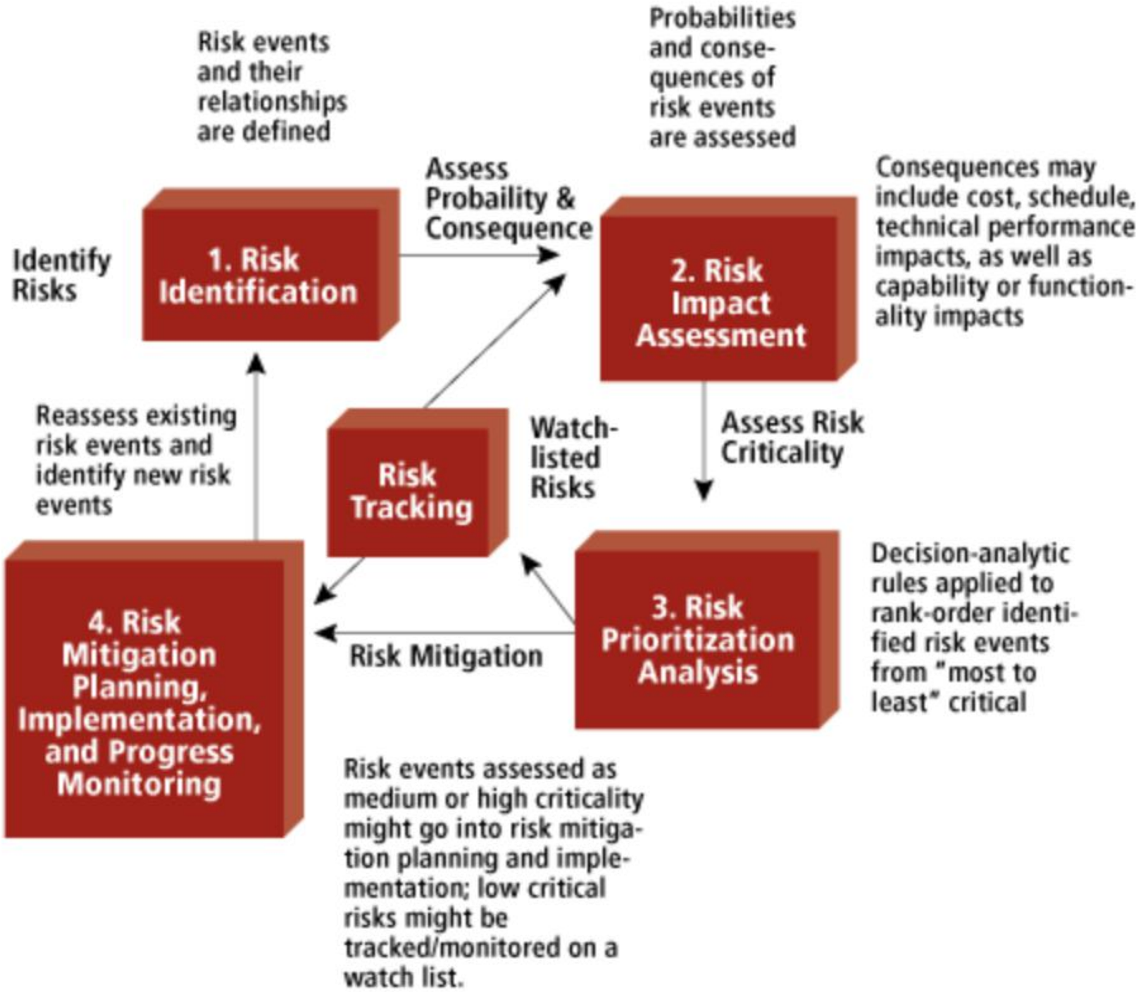
Not all of the risks mentioned above exist in every project. A particular project may only have two or three risks (Xu et al., 2018). The specific risk differs in accordance to the actual situation and needs to be carefully confirmed.

2.2 Risk Management in Logistics Projects

Risk management, as an indispensable technology in the modern project management process, originated in Germany. It began to emerge in the United States in the 1930s and became a separate discipline in the 1950s. It developed rapidly in China in the mid-1980s and was applied to project management. Every project has some uncertain risks. With the introduction of project management technology into the logistics industry, the importance of logistics project risk prevention and control is becoming more prominent. Because of the particularity of the logistics industry, the effective prevention and control of the risk of logistics projects to achieve the goal of logistics projects has become a hot issue in modern society. In a project decision-making process, a good control mechanism for risk control is developed and monitored to ensure a successful project; this mechanism is called risk management (Daugherty et al., 2006; Keers and van Fenema, 2018; Narayanan et al., 2015; Zarbakhshnia et al., 2018). Specific risk management refers to risk management by identifying, assessing and analysing the risk that may be encountered and managing the risk to achieve maximum security at the lowest cost (**Figure 2-3**; Mejias-Sacaluga and Prado-Prado, 2002). In other words, people can systematically apply risk analysis techniques, modern science and technology through risk management techniques, such as planning, organisation, command and control, to identify, analyse, assess, manage and monitor risks according to logical procedures (Richey et al., 2010). On the basis of scientific decision making, people can rationally allocate limited management resources, improve management efficiency, and establish management tasks to achieve the purpose of healthy organisation and minimise damage (Moberg and Speh, 2003). The logistics project is a complex system (Xu et al., 2018) due to the characteristics of logistics services. Many factors, which affect the smooth progress of projects, are direct, indirect, predictable, unpredictable, avoidable or inevitable. When analysing project risks, the risks must be classified on the basis of the original assessment, and the complex occurrences that lead to the risk into relatively simple and easily identifiable basic units must be broken down to find the essential relationship between factors from the intricacies of the occurrences. Among several effects, the main factors must be grasped (Michael et al., 2018; Richey et al., 2010; Song, 2003), and the relationship and main features must be analysed to predict, control and save various risks in the logistics project before a project is launched during the project operation and after the project is implemented.

On the basis of the definition of risk management, the content of risk management can be divided into risk identification, assessment and prevention (**Figure 2-4**), which is the same argument as Sun's (2007). On the basis of the content of this thesis, risk management of logistics projects also has the following corresponding contents (Daugherty et al., 2006; Keers and van Fenema, 2018; Song, 2003; Sun, 2007; Zarbakhshnia et al., 2018). **(1)** The risk identification of logistics projects is the most basic and important part of risk management of logistics projects. The specific objectives of risk identification are to understand the objective existence of the risk of logistics projects; determine the causes and current status of the risk after the occurrence of risk events, as well as the consequences and effects; and identify the existence of major risk, as well as qualitative analysis of their specific reasons (Kampstra et al., 2006; Richey et al., 2012). **(2)** The risk assessment of logistics projects is based on risk identification. People can comprehensively analyse risk, estimate risk probability and its possible loss scale and identify key risks by establishing a risk assessment model in determining the manner in which the overall risk level can be addressed to ensure the scientific basis of the smooth progress of the project (Ellram et al., 2008). **(3)** The risk prevention of logistics projects refers to actively taking measures to eliminate risk or reduce losses caused by risk after risk identification and assessment in the process of establishing logistics projects, that is, the frequency of risk is reduced before it occurs, and the loss should be minimized after risk occurs to achieve the risk management of logistics construction projects (Hofer et al, 2014; Keers and van Fenema, 2018; Levina and Vaast, 2008; Song, 2003; Zarbakhshnia et al., 2018).

Figure 2- 3 Fundamental Steps of Risk Management



Note: This figure is obtained from Garvey (2008). This thesis borrows the steps from the fundamental steps of risk management to form risk identification steps of logistics projects. As seen from Figure 2-3, these fundamental steps of risk management are consistent with ISO 31000.

2.2.1 Risk Identification of Logistics Projects

Risk identification is the identification of events that may affect logistics projects and is a prerequisite for risk analysis. Only by fully revealing the possible risk in logistics projects can people further evaluate the probability and severity of the judgement risk to identify the key risk and propose corresponding countermeasures (Hofer et al, 2014; Keers and van Fenema, 2018; Keers and van Fenema, 2018; Song, 2003; Zacharia et al., 2011; Zarbakhshnia et al., 2018). The main principles of large-scale logistics risk identification introduced in Sun (2007) are as follows. **(1)** The certainty and possibility of loss caused by risk is used as the basis for discriminating risk. A certain risk event must determine the time and scope according to certain criteria. On the basis of this certain risk, the goal of measuring the uncertainty classification of risk is to convert the uncertainty into relative certainty, which requires that the certainty in the risk assessment is the inevitable goal. Uncertainty can be measured in many ways, such as modern econometric theory and variance theory; especially, the VaR index can be used to reflect uncertainty. **(2)** The various risks in different stages of the implementation of logistics projects should be fully considered. **(3)** The risk of different projects should be identified in a targeted manner, and the specific analysis of specific problems should be emphasised. **(4)** The projects must be analysed as clearly as possible to identify the risk source. **(5)** On the basis of the experience of historical assessment, 'reverse thinking' may find some factors that make projects infeasible.

The content of risk identification can be divided into four aspects as follows (Daugherty et al., 2006; Song, 2003; Sun, 2007; Xu et al., 2018; Zarbakhshnia et al., 2018;). **(1)** Identify the risk source. Accurately identifying the risk faced by logistics help to avoid the loss or failure caused by the incomplete understanding and prevention of risk on the implementation process of logistics. **(2)** Confirm the time of occurrence of risk. The project at which risk may occur must be clarified. Under normal circumstances, risk control will be arranged on the basis of the timing of risk occurrence. The earlier the risk occurs, the more priority should be given to control. The later risk can be gradually resolved and controlled by monitoring and observing their various signs. **(3)** Confirm the nature of the risk. The nature of the risk must be confirmed for targeted control and prevention because risks of different natures have various effects on large-scale logistics projects. **(4)** Identify the causes and controllability of risk. The causes of risk must be understood to predict and formulate countermeasures and clarify responsibilities. The controllability of risk control can determine the possibility of controlling risk (Keers and van Fenema, 2018; Song, 2003; Zacharia et al., 2011; Zarbakhshnia et al., 2018).

2.2.2 Risk Assessment and Prevention of Logistics Projects

Risk assessment is the analysis and evaluation of the overall risk of the project development stage (Xu et al., 2018), this includes the interaction and effect of each risk and the overall influence on the project and the project's ability to withstand the overall risk. Generally, risk assessment is a systematic process for describing and quantifying the probability of adverse outcomes or events. It is a comprehensive analysis of the probability and scope of risk and an important part of investment decisions. Risk assessment can be divided into four aspects as follows (Dufour et al., 2017; Song, 2003; Zhou, 2009). **(1)** Project risks must be compared and evaluated, and their order must be determined. The scope of project risks, that is, what risk exists, must be determined, and the scope of risk in the project must be analysed one by one. Risk analysis is based on people's basic understanding of the project risk system. Often, risk factors must be listed down from multiple perspectives and aspects, and how each factor affects the project must be considered from a holistic perspective to specific details and from a macro to a micro perspective at different levels (Mishra and Shah, 2009). **(2)** Many seemingly unrelated multi-risk events are often caused by a common risk source. For example, an unexpected technical problem will result in cost overruns, delays in progress, unqualified product quality requirements and other consequences. Therefore, risk assessment must start from the entire project, clarify the causal relationship among risk events and evaluate the entire project system (Zacharia et al., 2011). **(3)** The conditions for the mutual conversion among different risks must be fully considered, and how the risk is realised should be studied (Barratt, 2004; Hofer et al, 2014; Keers and van Fenema, 2018). **(4)** The probability and consequences of identified risks must be further quantified to determine the frequency of occurrence of risks and determine the acceptability of the consequences of the project pairs derived from each risk (Bernard et al., 2018; Lambert et al., 1998; Michael et al., 2018).

Risk assessment can be divided into three steps as follows (Sun, 2007; Zhou, 2009). **(1)** The risk assessment benchmark, which is the acceptable level for the project entity, should be determined to find the consequences of each risk. A single risk and an overall risk must determine the basis of the assessment, which can be referred to as single and overall assessment baselines. An acceptable risk level can be absolute or relative. **(2)** The overall project risk level should be determined by combining all individual risks. Analysing the various factors that influence the project, determining the project risk and clarifying the relationship among different risks as well as the extent and consequences of their influences on the project are important to determine the overall project risk. In other words, from the perspective of risk predictability, the probability of occurrence and consequence prediction, a comprehensive multilevel analysis of the factors that affect project risk must be conducted. Depending on the requirements and characteristics of the project, people can select the appropriate assessment method to ensure the accuracy of the assessment results (Fawcett et al., 2012). **(3)** Important single risks must be analysed. After a comprehensive assessment of the overall project risk, if the overall project risk is less than or equal to the overall assessment criteria, then the risk level is within the acceptable range and the project can proceed as planned. To further understand the project risk, the risk of a single factor involved in the core objectives of the project must be analysed (Daugherty, 2011). People should compare the overall project risk level with the overall assessment criteria with the level of individual risk and individual assessment criteria to determine whether the project risk is within acceptable limits and then determine if the project should stop or continue.

Since the 1970s, project management has realized the development of globalization and diversification, and has carried out rich research with regard to project management risk prevention and control aspects. Some scholars seemed to study project risk management from both qualitative and quantitative perspectives. Tyebjee and Bruno (1984) were the first researchers to use factor analysis and the questionnaire approach to study investment projects in the USA, and to establish a risk assessment model. Tah et al. (1993) explored the source-to-consequences of the entire risk and classified the risks by combining the principles of the risk-decomposition structure. Kaming et al. (1997) conducted research on cost risk from the starting point of high-rise construction projects in Indonesia, and then pointed out that the impact of project costs was the most important factor in material price volatility. Jaafari (2001) pointed out that risk analysis and management should not be separated from the project. Throughout the project process, the risk assessment goal should not only be scheduled delivery and a reasonable budget, but also meeting or exceeding the business objectives of the parties. Wideman (1992) studied the environmental risks of the project and the nature of project risk, and proposed a risk mitigation method. Meanwhile, the application of project management to logistics projects has been found to take place relatively early in the process. Some research studies have been conducted on the prevention and control of logistics project management risk. Scholars have analyzed the risk of third-party logistics projects from different perspectives. Cavinato (1992) and other scholars conducted research on the risk of supply chain logistics. Caron et al. (1998) argued that project logistics risk is mainly due to the lack of coherence between the material procurement and construction processes, and introduced a parametric model to solve this problem. Hobbs et al. (2002) explored the issue of risk management from the view of a food supply chain logistics project. Wang and Regan explored the outsourcing risk of logistics projects, and divided the risks of outsourcing projects into four categories: finance, market, management and conflict. Regan and Wang (2003) conducted research into automotive logistics project management.

2.2.3 Models of Risk Assessment

According to the argument of Bernard et al. (2018), Michael et al. (2018) and Song

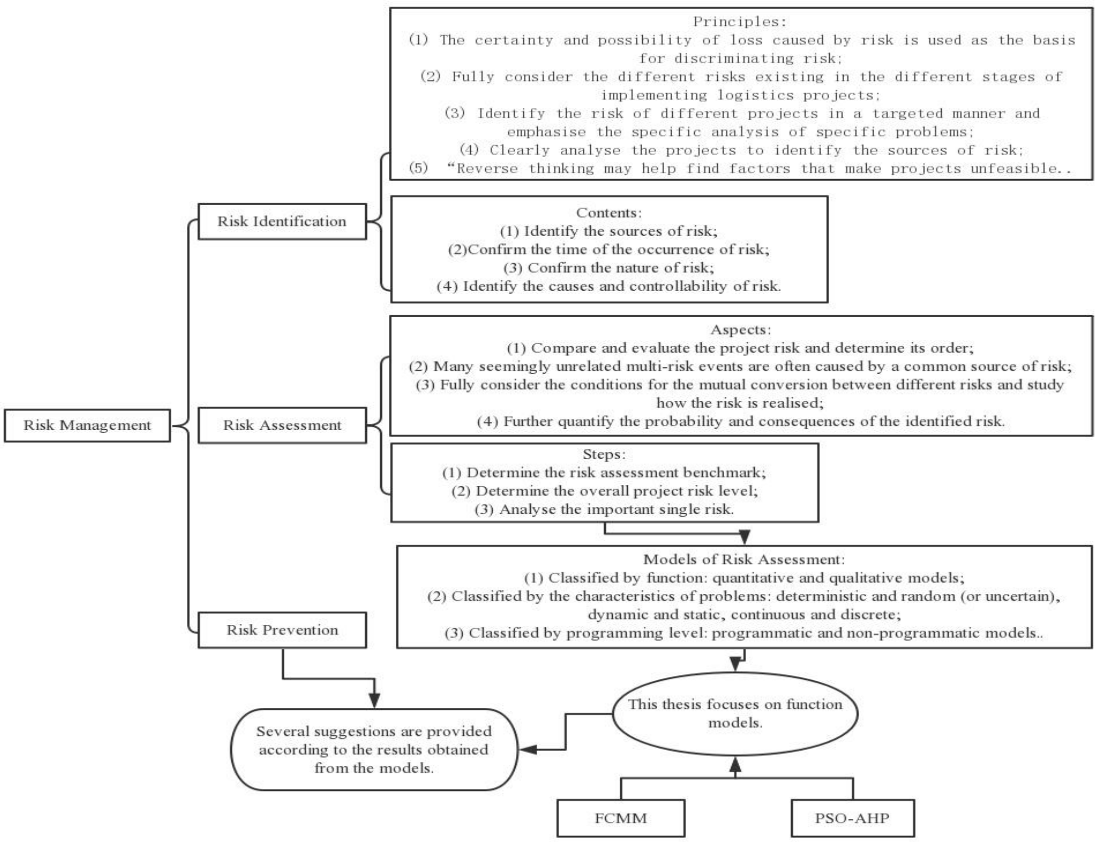
(2003), a mathematical model is a structure that abstracts and simplifies the actual prototype for a certain purpose. It is an essential description of the simplification of the actual prototype using for example mathematical symbols, mathematical expressions and quantitative relationships. It uses a formal language to express the basic characteristics of processes. The idea of a mathematical model is to describe and solve the problem through mathematical language and tools. It uses the concept of mathematics and applies it in the real world. Mathematical models are widely used in risk assessment and they can be classified from different perspectives for use in risk assessment as follows (Bernard et al., 2018; Chen et al., 2013; Dufour et al., 2017; Richey et al., 2010; Song, 2003). **(1)** Classified by function. A risk assessment model is a mathematical expression that represents the relationship among the numbers of variables in an event. According to function, mathematical models can be divided into quantitative and qualitative models. Quantitative assessment methods include risk mapping, network models, fuzzy comprehensive evaluation and some economic evaluation models in risk assessment. A qualitative risk assessment model is a graph, symbol or language that represents the relationship among objects, including subjective scoring methods, analytical hierarchical processes and decision trees, diagnostic charts, and other methods (Carter et al., 2015; Chen et al., 2013; Dufour et al., 2017). In this thesis, two types of methods are used together to assess the risk of large-scale logistics projects. **(2)** Classified by the characteristics of problems. Depending on the nature of the problem being studied, a risk assessment model can be divided into different types of deterministic and random (or uncertain), dynamic and static, continuous and discrete (Mena et al., 2013; Xu et al., 2018). For project economic risk analysis involving many uncertain factors, the Monte Carlo method and fuzzy evaluation model can be used, which can solve the risk assessment brought by uncertainty. In addition, dynamic models often study the transition from one state to another. The static model only describes the relationship between two stable states, does not care about the transition from one state to another and can usually be described by algebraic equations. Although dynamic models are more complex and difficult than static models, they often reveal the nature and influence of static models. A continuous model refers to the temporal or spatial distribution without interrupting processes. However, for continuous calculations or actual needs, continuous variables can be discretised, such as using economic risk analysis to calculate intervals, where continuous and discrete variables can usually be converted. **(3)** Classified by programming level. Models that are processed by computer programs can be divided into programmatic and nonprogrammatic models (Narayanan et al., 2015). A programmatic model is used based on their certain program, such as a Monte Carlo model, neural network model, and so on. Meanwhile, a nonprogrammatic model does not indicate that no program can be followed but only depends on general programs (Hartmann and de Grahl, 2011; Zacharia et al., 2009). On the basis of the actual needs of man-machine dialogue, not only databases and libraries exist but also knowledge bases (Chen et al., 2013; Dufour et al., 2017; Xu et al., 2018). Nonprogramming models are primarily used for high-level policy decisions that are often combined with intuitive judgment and exploratory problem-solving techniques. Numerous nonprogramming models are required in artificial intelligence systems and expert decision systems (Xu et al., 2018).

We then briefly introduce neural network model here, which could be considered as the future study for this thesis. Note that there are many successful neural network models and algorithms, but the most commonly used ones are the former artificial neural network model and the BP network model. The former artificial neural network model has good function approximation ability, which can well reflect the complex non-linear relationship between the input and output of the object by learning the training samples. The former artificial neural network is divided into input layer, hidden layer and output layer. All layers are connected by layers, and there is no interconnection between units on the same layer. The learning process of BP network model consists of forward transmission and error reverse transmission, which embodies the essence of artificial neural network. Due to its good self-learning and self-associative functions, BP network model has become the most widely used artificial neural network. BP network can approximate any continuous function with arbitrary precision, so it is widely used in nonlinear modeling, function approximation and pattern classification (Zhou, 2009).

Besides the above discussions, there are a large number of models that can be used to assess the risk in the logistics projects, such as the Fuzzy Comprehensive Measurement

Method (FCMM), AHP and PSO-AHP methods. For example, Giaglis (2004) discussed the operational risk of a logistics park construction project by using the AHP, and divided it into five categories of risk: market competition, economic change, technological development, nature and management. Barkuizen et al. (2011) used the fuzzy method in their systems approach to risk management. **Chapter 3** will summarise the commonly used risk assessment models from quantitative methods and demonstrates the advantages of each selected model in more detail. Note that risk evaluation is a critical decision for logistics projects in today's competitive environment. Regardless how the project plan is properly decided, risk is still one of the the main issues people need to consider. Risk assessment often presents a complex structure composed of tangible and intangible factors. Hence, FCMM is a convenient way to solve the problem of risk analysis. In this thesis, the risk evaluation of the logistics projects will also be addressed according to FCMM. PSO is the new method used in a novel and integrated manner in this thesis. To overcome some limitations of the existing research methods, such as FCMM, this thesis proposes and tests to some extent a logistic alliance risk identification and analysis method based on PSO algorithm and penalty function method. The two methods are compared in appropriate detail to analyse and calculate the optimisation problem in **Chapter 5**, which assist in a novel manner to make the result of logistics project risk assessment more accurate and realistic.

Figure 2- 4 Risk Management in Logistics Projects

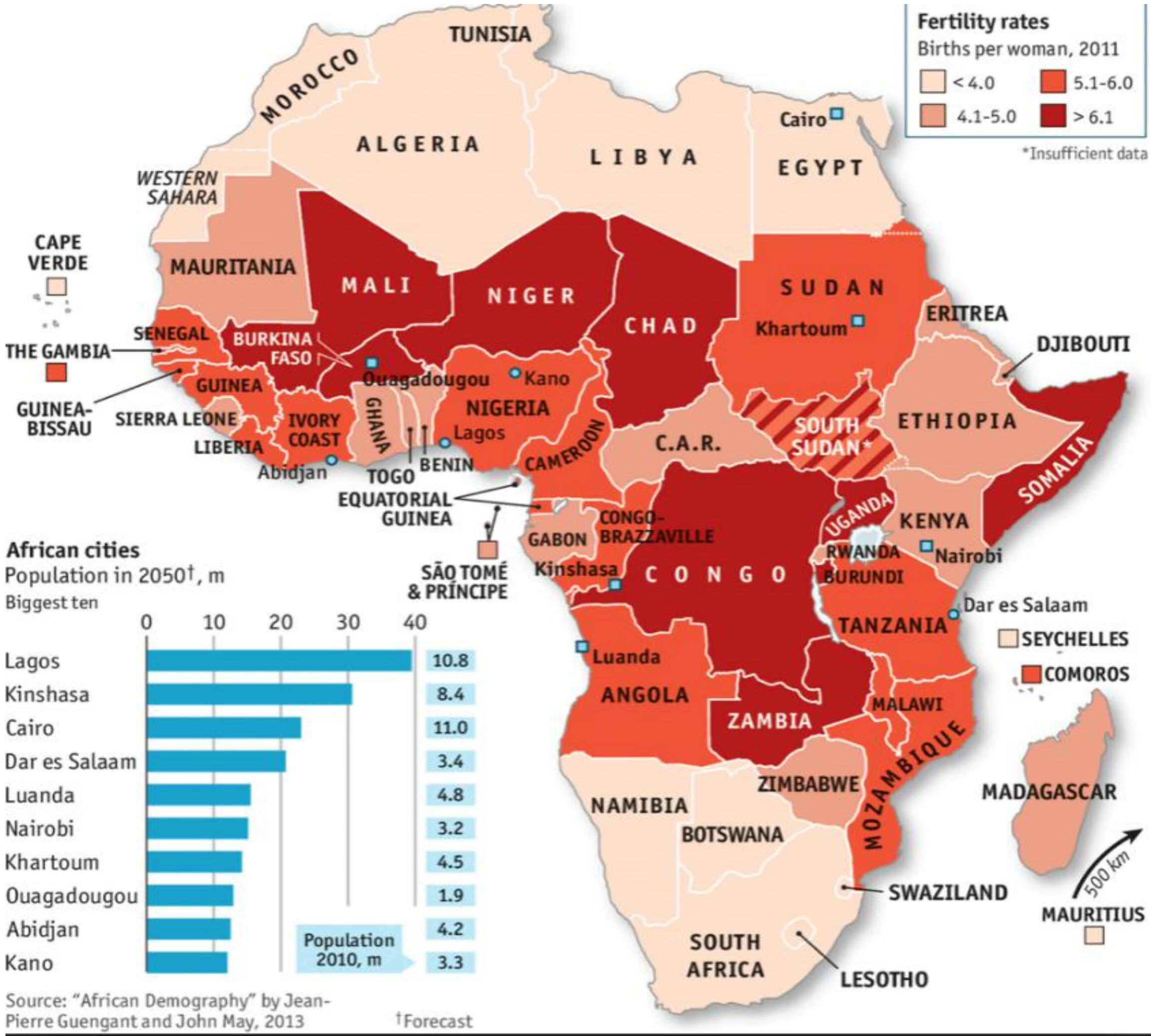


2.3 Summary

When people invest in logistics projects, they need to be careful about the risk, especially also in Africa, which has poor construction basis due to the high cost of logistics (**Figure 2-5**). In this chapter, the main concepts and types of risk are introduced. This thesis defines risk as a negative activity or event, which is a potential consequence that people do not want. This risk includes two parts, that is, the probability of loss or gain and its measurable size; and the event can cause another unrelated event to occur or even multiple events to occur simultaneously or an ongoing event. This definition of large scale logistics projects risk is important for this thesis;[17] it guides the basic analysis of models and suggestions. This chapter has introduced different risk types according to various principles. Introducing risk types can help this thesis identify all potential risks when performing modelling analysis. Subsequently, this thesis briefly introduces risk management and extends its concept to logistics projects, including risk identification, assessment and prevention. On the basis of the content in risk management, this chapter has indicated the main models used in this thesis to identify the risk of logistics projects belonging to function models, while in **Chapter 3**, this thesis will focus on the introduction of a methodology framework for risk assessment based on the literature and concepts introduced in this chapter. Then later, by combining the results obtained from models and real situations in China and South Africa, this thesis examines risk prevention and considers it from six dimensions according to the new and novel risk index system designed, namely, management, technical, operational, market, fiscal and environmental risk, which could be consider as a part of contribution of this thesis.

[17]In this thesis, we focus on large-scale logistics projects, such as the Hanjing case used in this thesis, which has a large international customer base and manages the flow of raw material through the finishing process and responsible for customer satisfaction. One of the main characteristics of large-scale logistics project is that they are built across different countries. With the development of technology, large-scale logistics projects will become more and more common.

Figure 2- 5 Distribution of Cities in Africa



Note: Data are from BCG, World Bank, and the actual figure is from http://billbaroni.com/africa-population-map/contemporary-design-africa-population-map-africa-population-density-2000-data-basin/. The figure shows the long distance of each city in Africa, which results in increased cost for logistics projects. Thus, the risk of logistics projects must be given attention.

2.4 References

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Chapter 3:

Methodology Framework for Risk Assessment

Research and development of risk management gradually develops as the level of industrialization increases (Michael et al., 2018; Petticrew and Roberts, 2006; Zarbakhshnia et al., 2018). The rapid development of society requires modern science and technology to actively promote the application of risk management. Research in this direction has become an important branch of management disciplines (Sun, 2007). The application of risk management theory is becoming increasingly popular (Denyer and Tranfield, 2009; Michael et al., 2018; Xu et al., 2018). Identifying and assessing risk is important in risk management. For large-scale logistics projects, risk identification and assessment should be performed from the feasibility study of a project to prevent damages caused by risks (Davies and Crombie, 1998; Tranfield et al., 2003; Xu et al., 2018). This chapter mainly focuses on the methodologies used in risk assessment in this thesis and introduces details of FCMM and PSO–AHP to give a methodology framework for risk assessment. It also clearly shows the advantages of the models and provides fundamental reasons for the selection of the models. According to the content in this chapter, this thesis could answer the research questions introduced in Chapter 1. In detail, the aim is to measure the risks of large-scale logistics projects in Hanjin Shipping[18] by employing the FCMM (Xu et al., 2018) and PSO–AHP separately and comparing the effects of the two methods, This thesis generates PSO method to PSO–AHP method and applies it in the risk assessment of large-scale logistics projects, in which Hanjin Shipping is taken as an example in a novel way. Many studies primarily use FCMM to perform the risk assessment. However, limited research focuses on the use of PSO–AHP methods on the risk assessment of large-scale logistics projects (See summary in Xu et al., 2018). This thesis not only uses FCMM to handle risk assessment

[18]The thesis verifies the appropriateness of the theoretical research direction by analysing the logistics control system of Korea Hanjin Marine Logistics Co., Ltd. as a case study. This study also takes the New Jiahong Logistics Company as a partner case study and experimental target and conducts an experimental operation to confirm the feasibility of the logistics risk control mechanism.

but also uses the PSO–AHP method and then selects the better method on the basis of certain criteria. By doing so, this thesis provides an excellent example for researchers to select between the two models for risk assessment.

3.1 Methodology Background

The logistics risk relationship is defined as the 'participants usually building or adjusting their business relationships through cooperation, sharing, and practice to achieve a long-term relationship of cooperation and win–win situation' (Whipple et al., 2010). Sun (2007) reports that the early research on risk dates back to the mid-14th century, when marine insurance at ports along the Mediterranean opened a prelude to human exploration (Daugherty et al., 2006). In the 19th century, Henri Fayol, the founder of French management theory, initially listed risk management as one of the important functions of business management (Hazen and Byrd, 2012). In 1931, the American Insurance Association's insurance department advocated risk management and began to study risk management and insurance issues (Richey et al., 2010). The establishment of the New York City Brokers Association in 1932 marked the rise of risk management at that time. On August 13, 1953, General Motors's transmission failure caused a fire, which resulted in the company to lose as much as $50 million (Barratt, 2004; Ireland and Bruce, 2000). The fire shocked the American business community and academia, making it an opportunity for the development of risk management science (Richey et al., 2010). By the 1960s, a new set of management science–risk management was formally established in the United States. Since then, risk management has grown rapidly (Daugherty, 2011; Ellinger and Richey, 2013; Stank et al., 2011).

On the basis of the argument of Cao and Zhang (2011) and Sun (2007), the theoretical study of risk management in terms of logistics projects has been developed with the formation of the international engineering construction market (Cao and Zhang, 2011; Chen et al., 2013; Michael et al., 2018; Xu et al., 2018). As early as the Second World

War, risk analysis techniques have been applied in the field of systems engineering and operations research. With the reconstruction of the Western society, especially the economic recovery in Western Europe, numerous large aerospace, hydropower, energy and transportation projects were established in Europe (Cooper et al., 1997; Ellram and Cooper, 1990; Min et al., 2005). The large investment makes project managers pay increasing attention to the issue of risk management. However, several project uncertainties still exist due to the complex project environment. How to quantitatively predict the effect of uncertainty on project risk is a great concern for managers (Michael et al., 2018; Whipple et al., 2010; Zarbakhshnia et al., 2018). Thus far, numerous project risk assessment techniques have been developed and studied by scholars, such as early project planning review techniques, subsequent sensitivity analysis and simulation techniques (Daugherty, 2011; Daugherty et al., 2006; Michael et al., 2018; Xu et al., 2018).

In an initial study (Braunscheidel and Suresh, 2009; Flynn et al., 2010; Ralston et al., 2015; Swink et al., 2007), only one effect is described and evaluated using mathematical statistics and probabilities, such as factors that influence project objectives, which are changes in time or cost (Chen et al., 2009). With the emergence of new evaluation methods, risk analysis has also developed in a comprehensive and multidimensional way. One of the earliest and most successful practical applications were the ‘Beihai Oilfield Development Project’ in Europe in the 1960s and 1970s (Creswell, 2013; Denzin and Lincoln, 1994; Glaser and Strauss, 2012; Pagell and Wu, 2009; Sabath and Fontanella, 2002). The project lasted for more than 10 years and was invested in billions of dollars completed by numerous international contracting companies. For this project, experts attempted several and different risk management methods and gained some experiences and achievements (Barratt, 2004; Cao and Zhang, 2011; Devaraj et al., 2007; Kahn and Mentzer, 1996). After decades of theoretical research and exploration and preliminary application in practice, the international academic community has reached an agreement on project risk management theory as follows (Ellinger, 2000; Esper et al., 2010):

Project risk management is a systematic project involving all aspects of project *management, including risk identification, analysis, assessment, control and decision making. Its objective is designed to reduce losses and control costs by studying and controlling the environmental uncertainty of the project (Creswell, 2013; Glaser and Strauss, 2012; Pagell and Wu, 2009; Sabath and Fontanella, 2002; Denzin and Lincoln, 1994).*

All of the existing methods are based on the assumptions that have no restrictions on resources (Michael et al., 2018; Strauss and Corbin, 1998; Zarbakhshnia et al., 2018). The focus is on mathematical analysis and analytical calculations, which simplify the correlation between the risk problem and the complexity, thereby limiting the practical application of these methods to a certain extent (Glaser and Strauss, 2012). The scientific methods of project management mainly include decision tree, probability distribution, mathematical, simulation and random network methods (Charmaz, 2001). These methods focus on the use of advanced computational techniques to analyse the effects of various risk factors on investment decision parameters and management objectives under limited resource conditions (Rousseau et al., 2008), thereby avoiding complex mathematical analyses and helping investors make scientific and effective investment risk decisions (Denyer and Tranfield, 2009).

As discussed in **Chapter 2**, the risk of logistics projects depends on many issues, including environmental ones. Thus, people can provide scores on each risk and then perform the analysis. Moreover, collecting data for logistics projects is difficult. To overcome this shortcoming, Fuzzy Comprehensive Measurement Method (FCMM) is selected in this thesis.[19] The logistics project risk measurement treats in this application $\{a(j)|j = 1,2,\ldots,p\}$ as an optimization variable, making it a complex nonlinear optimization problem, where $a(j)$ can be profit or risk. Many studies (Denyer and Tranfield, 2009; Xu et al., 2018) solve it via the conventional optimization method; however, this method may

[19]In terms of risk assessment on the logistics projects, using absolute value to accurately describe the objective reality is difficult due to the complexity of evaluation factors, the hierarchy of evaluation objects and the ambiguity of evaluation criteria. A vague phenomenon often exists, and its description is often expressed in natural language, where the most important feature of natural language is its ambiguity, and using a classical mathematical model to measure the ambiguity uniformly is difficult (See https://baike.baidu.com/item/FCMM/2162444?fr=aladdin). Therefore, in this thesis, FCMM based on fuzzy sets is used to comprehensively judge the subordinate status of the risk from multiple indicators.

be difficult due to nonlinear issues. Thus, this thesis proposes a risk identification and analysis method for the logistics projects based on PSO and AHP,[20] where this thesis not only combines AHP and PSO, but also uses WBS together to build the risk indicator system, which is the base of PSO-AHP method, while Huang et al. (2011) only focus on the combination of AHP and PSO, and use it to maximize the value of product updating so as to extend the product life cycle. The remaining parts of this chapter focus on the introduction and detailed discussion of the two methods.

3.2 Methodologies of Risk Identification

As argued in **Chapter 1**, this thesis aims to perform risk assessment of logistics projects based on modelling methods. Cheng et al. (2008) presented a fuzzy logic-based method, which synthesizes the fuzzy AHP method on the basis of a three-point scale, fuzzy set theory and fuzzy logic which are integrated into a single approach to measure the risk of bridges during construction. However, studies focusing on the use of PSO-AHP method for the risk assessment of large-scale logistics projects are limited (See the summary in Xu et al., (2018)). Huang et al. (2011) focus on the combination of AHP and PSO and use it to maximize the value of product updating so as to extend the product life cycle, while this thesis combines AHP and PSO and uses WBS together to build the risk indicator system, which is the base of PSO-AHP method. Therefore, the present study not only uses the FCMM to deal with risk assessment but also employs the PSO-AHP method and then selects the best one according to some criteria. By doing so, this thesis provides an excellent example for researchers to choose between the two models for conducting risk assessment.

Hence, risk identification is performed initially. Risk must be identified before implementing a project. A logistics project will be full of considerable risks due to

[20] AHP method is widely used in evaluation, although its objective is slightly poor. However, similar to the previous argument, the weight defined by objective methods sometimes cannot match its importance in practice completely. Especially in the risk assessment of logistics projects, using objective methods is difficult because of excessive data. Thus, in this thesis, the AHP method is combined with PSO to perform the analysis.

uncertainty. Thus, identifying risks can help people reduce unnecessary costs. This section mainly introduces the method used in this thesis to identify and evaluate risks.

Many methods can be used to perform risk identification, such as WBS, scenario analysis,[21] Delphi method,[22] Brainstorming,[23] Check-list and Flow-procedure (**Table 3-1**).[24] However, there is almost no study using WBS method to do the risk identification in the logistics issue. This thesis mainly uses WBS method (**Figure 3-1**) which refers to the grouping of the elements in a project based on the purpose of deliverables. This approach summarizes and defines the scope of work for the entire project, with each drop representing a detailed definition of the project's work. The use of the WBS method can help clarify the nature of the various components of the project and their relationship with one another, as well as the relationship between the project and the environment, thereby reducing the uncertainty in the process of identifying the project structure. Therefore, in the risk identification of large-scale logistics, this thesis can use the WBS method to transform large into small systems, decompose complex into simple and easily recognised situations and clearly show the hierarchical relationship of risk. By doing this, this thesis can construct more clearly and concise a risk index system. Several studies on risk assessment prefer obtaining the risk factors by using the Delphi method (Dalkey and Helmer, 1963; Dufour et al., 2017; Fan, 2019). This method usually

[21]Scenario analysis is based on the diversity of development trends—through the systematic analysis of relevant issues inside and outside of project—to design various future development possibilities. Then, a method similar to writing a screen script is used to make a situation and picture of the system development situation from beginning to end. Large-scale logistics projects often last for a long time; thus, people often need to consider various technical, economic and social factors. For risk identification of such projects, scenario analysis can also be used to identify key risk factors and their effects (Sun, 2007).

[22]Delphi method is a structured expert survey method. It aims to obtain relatively objective information and opinions through independent and subjective judgements of multiple experts in the process of information collection, that is, the investigation team will pass anonymous ways to conduct multiple rounds of consultation on selected expert groups (Sun, 2007). It differs from other methods in that the experts who are consulted express their opinions anonymously, and experts cannot discuss with one another. Therefore, this method overcomes the fear of authority and the unwillingness to hear different opinions. Hence, experts can fully express their opinions and finally obtain objective and practical findings.

[23]Brainstorming uses expert creative thinking to request a way to visually predict and identify future information. The method can generally be performed by a person or a group of people. Through the exchange of information and mutual inspiration among the participants, participants are encouraged to raise their own opinions.

[24]The two methods are not commonly used in risk assessment and are thus not introduced in detail here.

has a disadvantage in that the personal judgement method of an expert is limited by the individual's knowledge, ability and experience. The recognised result is also influenced by the subjective factors of the expert. According to the argument of Su (2012), WBS has four important purposes: First, WBS is a planning and design tool. WBS can help project managers and project teams effectively identify and manage the possible risks. Secondly, WBS is a structural design tool, which clearly shows the relationship between project units and allows managers to make reasonable project planning. Thirdly, WBS is also a planning tool, which can display the complete project progress, that in turn allows managers to make a reasonable project schedule. Finally, WBS is a project status reporting tool. Project managers can report project status to clients or senior managers based on the status displayed by WBS. Thus, this thesis utilizes and applies in a novel and integrated manner the WBS method together with the identified risk models, to provide and eventually analyse reasonable risk factors. The specific steps are as follows. The entire large-scale logistics project[25] is decomposed into subprojects by category and hierarchy, and each potential risk factor is then searched separately. Subsequently, the subproject is further decomposed, and finally, layer analysis is performed until all relevant risk factors are determined.

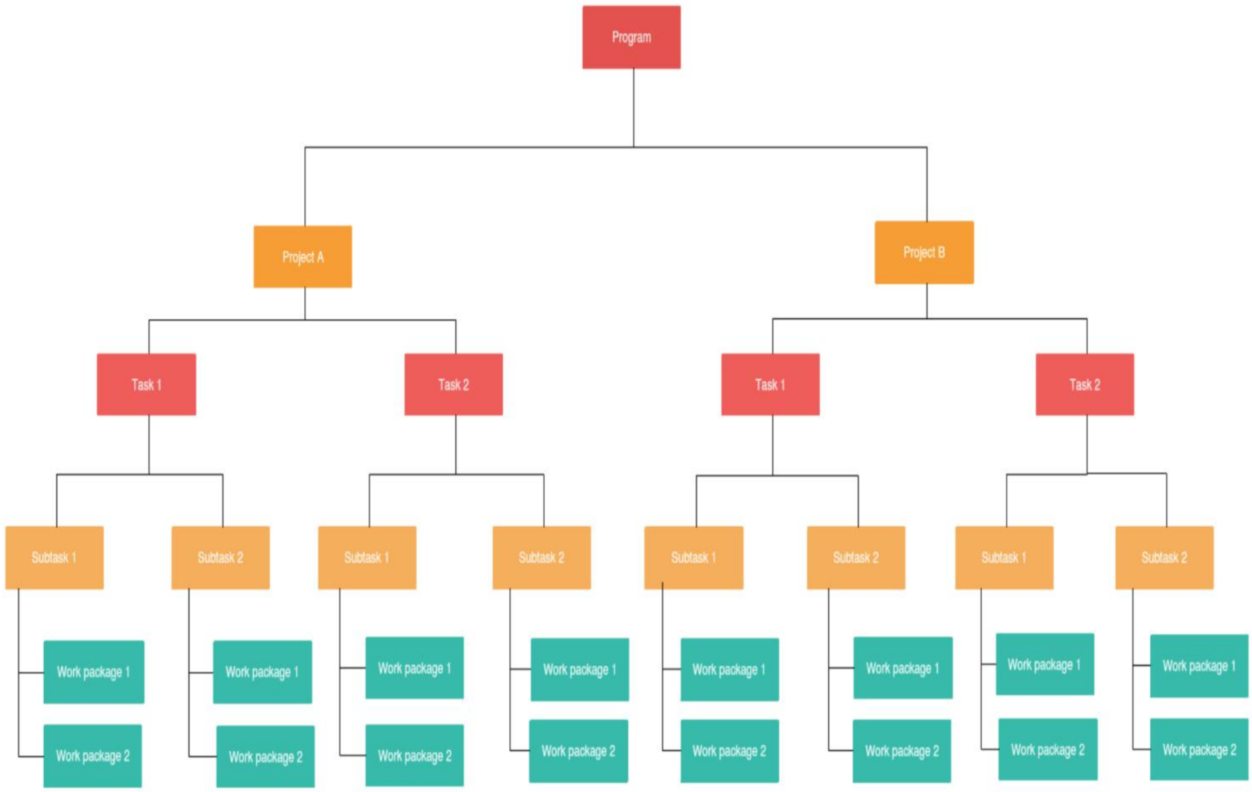
Table 3- 1 Comparison Among Different Identification Methods

Method	**Advantage**	**Disadvantage**
WBS	Change complex to simple situations	Expensive
Scenario Analysis	Show future situations	Inaccurate predictions
Delphi method	Easy to implement	Affected by subjective consideration
Brainstorming	Collect Group Ideas	Cannot get uniform idea
Check-list	Easy to implement	Not comprehensive
Flow-procedure	Full of detail	Need to understand each part of flow

[25]This thesis focuses on large-scale logistics projects, such as the Hanjing case used in this thesis. One of the main characteristics of large-scale logistics project is that they are built across different countries. With the development of technology, large-scale logistics projects will become more and more common.

Note: This table is borrowed from Sun (2007). From the table, the only disadvantage of WBS is its cost. However, this cost is reasonable considering the risk damage.

Figure 3- 1 Example of WBS



Note: Figure 3-1 presents the WBS for multiple projects obtained from the *Creately Blog(2018)*. A key advantage of this diagram is that people can easily see the main risk that needs attention.

3.3 Methodologies of Risk Assessment

Modelling tools have an important role in solving risk issues. These tools can document and analyse current risk conditions and further suggest improvements and analyse the expected effects of the proposed changes. Through the study of a large number of current literature (See **Chapter 2**), this section summarises the commonly used risk assessment models from qualitative and quantitative methods (**Table 3-2**) and demonstrates the advantages of each selected model in more detail. Specifically, following the idea of Sun (2007), this thesis combines qualitative with quantitative analysis, where this thesis applies risk assessment to logistics projects and divides the risk assessment of logistics projects into two levels. In the first level, various risk factors in the process of investment, construction and operation of the logistics projects are fully considered, and a set of risks and a comprehensive evaluation index system for the logistics projects are established. In the second level, combined with the results of the overall risk assessment of the logistics projects, this thesis provides several suggestions on risk prevention for these kind of logistics projects. This thesis not only measures the risk of large-scale logistics projects but also provides several strategies to improve the management of logistics projects and reduce the probability of risk in the Chinese context. Moreover, this thesis generates suggestions to the development of Chinese large-scale logistics projects in South Africa.

Moreover, FCMM divides the change intervals of assessed objects and considers its hierarchical nature; thus, it can achieve the combination of qualitative and quantitative factors, expand the amount of information and improve the evaluation number. The evaluation conclusion will also be more credible. Thus, this thesis will focus on FCMM model. Meanwhile, as previously mentioned, this thesis also considers PSO–AHP method and combines them with WBS together to build the risk indicator system, which is the base of PSO-AHP method, while Huang et al. (2011) only focus on the combination of AHP and PSO, and use it to maximize the value of product updating so as to extend the product life cycle.

Table 3- 2 Differences between Qualitative and Quantitative

Qualitative	Quantitative
Broad, open-ended questions	Specific, closed questions
Data collected through observations and interviews; text and images; interviews and conversations	Directly collects data from participants and measurement
Focus on experience, opinions, feelings	Focus on measurement, comparison and

and knowledge	generalisation
Analysis through themes emerging from fieldnotes and/or interviews	Analysis through statistics to test hypothesis
Findings presented as quotes, narratives, and explanations	Findings presented in graphs and tables
Produce results that give meaning, experience and views	Produce results that generalise, compare and summarise

Note: The table is obtained from https://www.zhihu.com/question/19603466.

3.3.1 Qualitative Models

The qualitative research method originated in anthropology, sociology, psychology, folklore and other disciplines at the beginning of the 20th century (Sun, 2007; Zhou, 2009). In the early stage of its development, it mainly relied on the subjective experience and theoretical speculation of an individual. Since the 1970s, social scientists have increased their awareness of the limitations of quantitative methods and have begun to re-examine and enrich qualitative methods. In terms of risk assessment, the main qualitative models used for this thesis are subjective evaluation and AHP methods (Huang et al., 2011; Xu et al., 2018; Sun, 2007; Zhou, 2009).

3.3.1.1 Subjective Evaluation Method

Zhou (2009) argued that the subjective evaluation method mainly uses the knowledge of the expert's experience in intuitively assessing each project risk and assigning corresponding weights, such as a number between 0 and 10. This method is the most common and simple. During project risk assessment, people must initially identify risk factors, risk events or risk related to the evaluation object and list the risk evaluation forms. Then, they let experienced experts evaluate the risk factors or events that may arise and assign weights between 0 and 10, where 0 and 10 indicate no risk and highest risk, respectively. Finally, the weights of each risk are added analysed and compared with the risk assessment benchmark (Zhou, 2009) to obtain the comprehensive risk level.

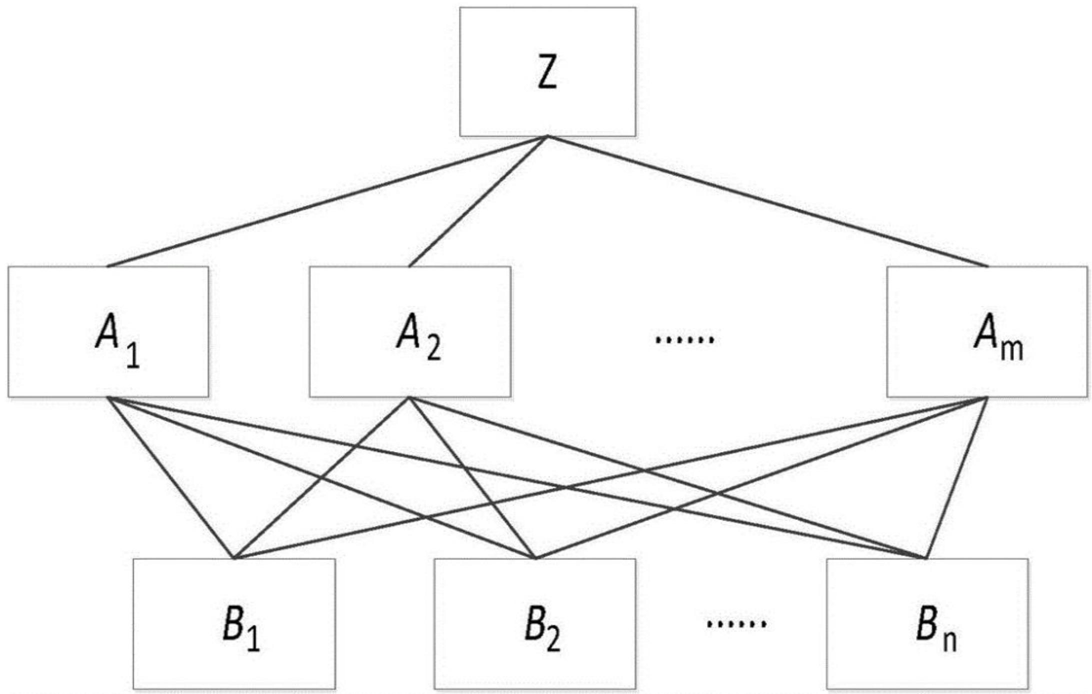
3.3.1.2 AHP Method[26]

AHP was introduced by Aaaty, an American operations researcher who applied the theory of network systems in the early 1970s in studying the issue of ‘power distribution according to the contribution of various industrial sectors to national welfare. AHP (Huang et al., 2011; Sun, 2007; Zhou, 2009) is a comprehensive evaluation method for objectives and a hierarchical weighted decision analysis method. It combines qualitative and quantitative solutions to solve complex problems of multiple objectives and uses the experience of the decision maker to assess the relative importance among the standards that can be achieved from the measurement targets. It also reasonably gives the weight of each standard for each decision plan. The weights are used to find the order of the advantages and disadvantages of each scheme and they are effectively applied to problems that are difficult to solve via fully quantitative methods.

The basic idea of the AHP is to level the problems to be analysed (See **Figure 3-2**, we have three levels). On the basis of the nature of the problem and the overall goal to be achieved, the problem is decomposed into different components. Moreover, the factors at different levels are condensed form a multilevel analytical structure model on the basis of the related influences of these factors and their affiliation. Finally, the problems are compared and ranked (**Figure 3-2**).

[26]AHP is commonly used in research and is thus not introduced in detail here. This thesis just briefly introduce how AHP works.

Figure 3- 2 Basic structure of AHP



The argument of Zhou (2009) indicates that for risk analysis, AHP provides a mathematical approach for people's thinking process and objective judgement, simplifies the amount of calculation and helps decision makers maintain the consistency of their thinking process and decision-making principles. This also shows the relationship between risk management and decision analysis. Note that When using the AHP method to solve multi-attribute decision-making problems, researchers must first determine the expert judgment matrix. Then the ranking weight vector is calculated according to the judgment matrix. The consistency problem of the judgment matrix is the core problem of the AHP method. Whether the consistency is reasonable or not directly affects whether the final ranking weight vector can truly and objectively reflect the objective ranking among various schemes or attributes. Therefore, the method to modify the inconsistent expert judgment matrix and the consistency test of the judgment matrix have become a core content of the analytic hierarchy process. This thesis will apply the PSO method to solve this question, see more discussions in Section 3.3.2.3.

3.3.2 Quantitative Models

Through the study of a large number of current literature (See **Chapter 2**), this section summarises the commonly used risk assessment models from quantitative methods and demonstrates the advantages of each selected model in more detail. Specifically, this section introduces Fuzzy Comprehensive Measurement Method (FCMM), PSO and PSO-AHP methods, which will be used in this thesis to do the risk evaluation.

3.3.2.1 Fuzzy Comprehensive Measurement Method (FCMM) Model

Song (2003) argued that the basis of fuzzy theory is the fuzzy set founded by Professor Zadeh at the University of California Los Angeles. Fuzzy theory has a strong vitality and penetration as a new mathematical system because considerable fuzzy information exists in real life. A large amount of fuzzy information exists, especially in various risk assessment activities (Huang et al., 2011; Xu et al., 2018; Zhou, 2009). Fuzzy theory can solve this problem and improve the scientificity and reliability of risk assessment results. The most widely used application of fuzzy theory is the comprehensive evaluation method of fuzzy evaluation, which is based on the assessment of evaluation factors, evaluation criteria and weights of factors. The fuzzy set transformation principle is used to describe the fuzziness of various factors and factors by membership degree. The boundary is constructed to construct a fuzzy evaluation matrix, and the level of the evaluation object is finally determined by the multilevel coincidence operation. Details of FCMM are as follows (Xu et al., 2018): [27]

Assume U= {U1, U2, U3, ⋯ , Un} are n factors, V={V1,V2, ⋯ ,V_m } are m judgments of

[27] Details of FCMM and PSO–AHP have been introduced in 'Predict the Logistic Risk: Fuzzy Comprehensive Measurement Method or Particle Swarm Optimization Algorithm?' EURASIP Journal on Wireless Communications and Networking in 2018

factors. Their number of elements and names can be subjectively defined by people according to practical problems. Given the different status of various factors, the role and the weight are different; thus, the judgement is different. People are not absolutely positive or negative about m types of judgments. Hence, the comprehensive judgment should be a fuzzy subset of V, and B = $\{B_1, B_2, \cdots, B_m\} \in \phi$(V), where b_j (j = 1, 2, ⋯, m) reflects j's position (V_m) in the comprehensive judgement (that is V_m degree of membership of fuzzy sets: B(V_j) = B_j). Comprehensive judgement B depends on the weight of each factor, and each weight is a fuzzy subset A = $\{A_1, A_2, \cdots, A_n\} \in \phi$(U) on U, and $\sum_{i=1}^{n} A_i = 1$, where A_i denotes the weight of the i factor. Therefore, once a weight is given, a comprehensive judgement B can be obtained accordingly. On the basis of specific problems, people need to establish a fuzzy transformation T from U to V. If people make a separate judgement f(u_i) for each factor u_i, it can be regarded as the fuzzy projection f from U to V, that is, $f{:}U \mapsto \phi(V)$ and $U_i \mapsto f(U_i) \in \phi(U)$. From f, people can derive a fuzzy transformation T_f from U to V, and T_f can be regarded as the mathematical model of comprehensive evaluation B obtained from weight A.

From the above discussion and description, it is evident to see that the mathematical model of fuzzy comprehensive evaluation consists of three elements, and the steps are divided into four steps:[28] (1) Obtain factor set $U = \{U_1, U_2, U_3, \cdots, U_n\}$; (2) Obtain judgment set $V = \{V_1, V_2, V_3, \cdots, V_m\}$; (3) Perform the single factor evaluation $f{:}U \to \phi(V)$ and $u_i \mapsto f(U_i) \in \phi(U)$. Fuzzy mapping f can induce a fuzzy relationship $R_f \in \phi(U \times V)$,[29] which is $R_f(U_i,V_j) = f(U_i)(V_j) = r_{ij}$. Thus R_f can be represented by $R \in u_{n\times m}$, where

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{3.1}$$

[28]Details of each step are provided in Chapter 5, and FCMM is used to assess risk for a logistics project.
[29]U × V means the combination of set U and set V.

is a single factor evaluation matrix, and the fuzzy transformation T_f from U to V can be induced by the fuzzy relation R. U (U1, U2, ⋯, Un) forms a fuzzy comprehensive decision-making model, where U1, U2,⋯, Un are the n elements of the model; (4) Perform the comprehensive evaluation. Weight A= (A1, A2, ⋯, An) can be calculated according to fuzzy mathematical evaluation model formula A*R=B, where B= (B1, B2, ⋯, Bm) is the total assessment results. In accordance with the principle of maximum membership, V_j is the result of comprehensive evaluation, that is when applied to risk assessment, the risk level of the evaluated object, where j is the highest value of B_{jmax} in B_j.[30]

3.3.2.2 PSO Model

Given the restriction of many types of influencing factors, the risk identification of the logistics projects is complex, fuzzy and difficult to quantify completely. At the same time, the logistics projects' risk is transitive and accumulative, which is sometimes different from the general risk. Establishing the analytical relationship among the indirect natural logistics project risk indexes is difficult, as it is difficult for researchers to build a comprehensive risk index system (Xu et al., 2018). Meanwhile, the logistics project risk measurement is a generally a complex nonlinear optimisation problem with $\{a(j)|j = 1,2,\cdots,p\}$ as an optimisation variable where $a(j)$ could be risk or profit (Xu et al., 2018), where the conventional optimisation method is difficult to handle due to the optimization issue. To overcome these difficulties, this thesis also proposes a logistic alliance risk identification and analysis method based on the PSO and penalty function method, which are combined to analyse and calculate the optimisation problem to make the result of logistics project risk identification more accurate and realistic (**Figure 3-3**).

Huang et al. (2011) reports that PSO was proposed by Kennedy and Eberhart (1995). Following Xu et al. (2018), this thesis assumes the population size of the particle is N (In terms of the logistics project, it represents the number of risk factors). S_l represents the

[30] For the detail of FCMM method, this thesis refers readers to Xu et al. (2018).

position of the particle of $l(l = 1, 2, \cdots, N)$, v_l represents the speed and f_l represents the adapted value. In each iteration of a simulation in PSO, the extremum of the particle tracking individual $p_{best_l}(t)$ (the best position of the particle in the flight process) and the global extremum $g_{best_l}(t)$ (the best position of the particle swarm in the flight process) are updated after the initial position and velocity are randomly generated (**Figure 3-3**). When the two optimal values are found at t + 1, the position and velocity of the particles are updated according to the equations as follows:

$$v_l(t+1) = wv_l(t) + c_1 b_1(t)(p_{best_l}(t) - s_l(t)) + c_2 b_2(t)(g_{best}(t) - s_l(t)$$

$$s_l(t+1) = s_l(t) + v_l(t+1), \qquad (3.2)$$

where w is the weight; c1 and c2 are the individual particle and learning factors, respectively; b1(t) and b2(t) are the random numbers uniformly distributed between 0 and 1 respectively, describing the randomness of particle individuals and groups in the speed update process.

Assuming $f_l(t+1)$ denotes the adaptation of particle l at time t+1; $f(p_{best_l}(t))$ represents the best fit for individual history of particle l; and $s_{max}(t+1)$ represents the particle position corresponding to the largest $f(p_{best_l}(t))$ in all particles at time t+1. Then, the individual and global extremum of all particles for each random case of particle individuals and groups in the speed update process simulation can be updated as

$$p_{best_l}(t+1) = \begin{cases} s_l(t+1) & f_l(t+1) \geqslant f(p_{best_l}(t)) \\ p_{best_l}(t) & f_l(t+1) < f(p_{best_l}(t)) \end{cases}$$

$$g_{best}(t+1) = s_{max}(t+1), \qquad (3.3)$$

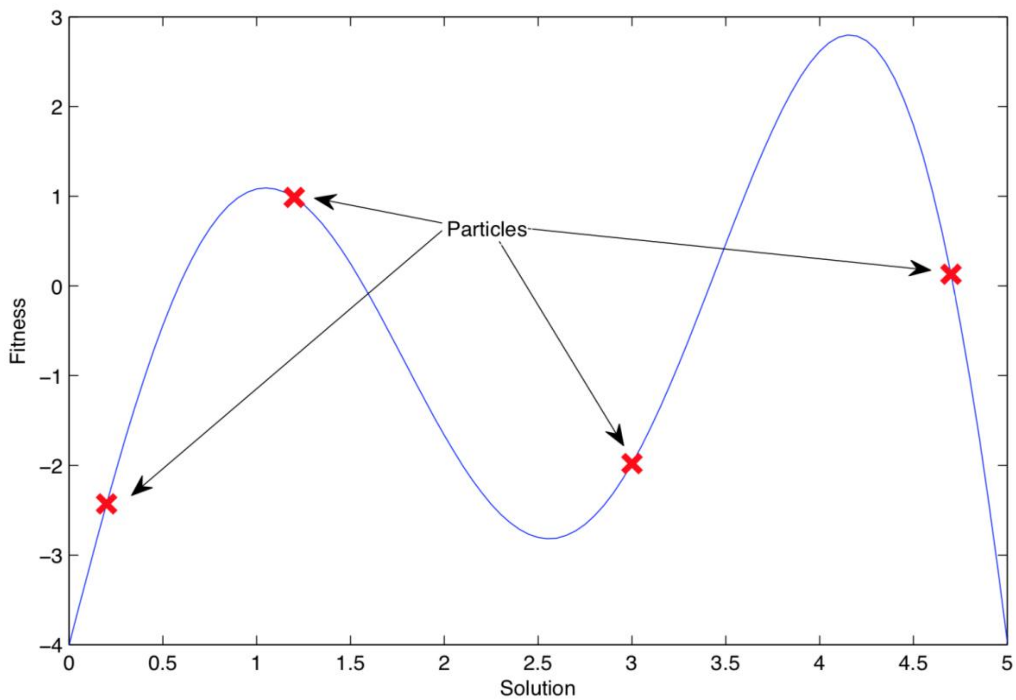
However, given that the optimisation of the problem contains some constraints, the penalty function method (sequence unconstrained optimisation method (Xu et al., 2018)) is used in this thesis to solve the constraint – constrained optimisation problem by changing the constraint optimisation problem to the unconstrained optimisation problem, where for the constraint optimisation problem,

$$\min \quad f(x)$$

$$s.t.\begin{cases} g_i(x) \le 0 \\ h_j(x) = 0 \end{cases} \tag{3.4}$$

i=1,2,···, m; j=1,2,···, n,

Figure 3- 3 Implementation of PSO



Note: This figure is obtained from http://www.cs.armstrong.edu/saad/csci8100/pso_slides.pdf. It shows that PSO algorithm can maintain multiple potential solutions at one time. The particles 'fly' or 'swarm' through the search space to find the maximum value returned by the objective function.

On the basis of the penalty function method, the constrained optimisation problem is transformed into the minimisation of an augmented objective function, which can be expressed as follows:

$$\min_{x \in R^n} F(x,r) = \min\{f(x) + r * p(x)\}$$

$$p(x) = \sum_{i=1}^{n}[\max g_i(x), 0]^2 + \sum_{i=1}^{m}[h_j(x)]^2 , \quad (3.5)$$

where r is the penalty factor, f(x) is the objective function without penalty and r*p(x) is the penalty. In p(x), for the point x that does not satisfy the constraint condition, the penalty term r*p(x) > 0 is a penalty when the constraint condition is unsatisfied, and r*p(x) = 0 when the constraint condition is satisfied.

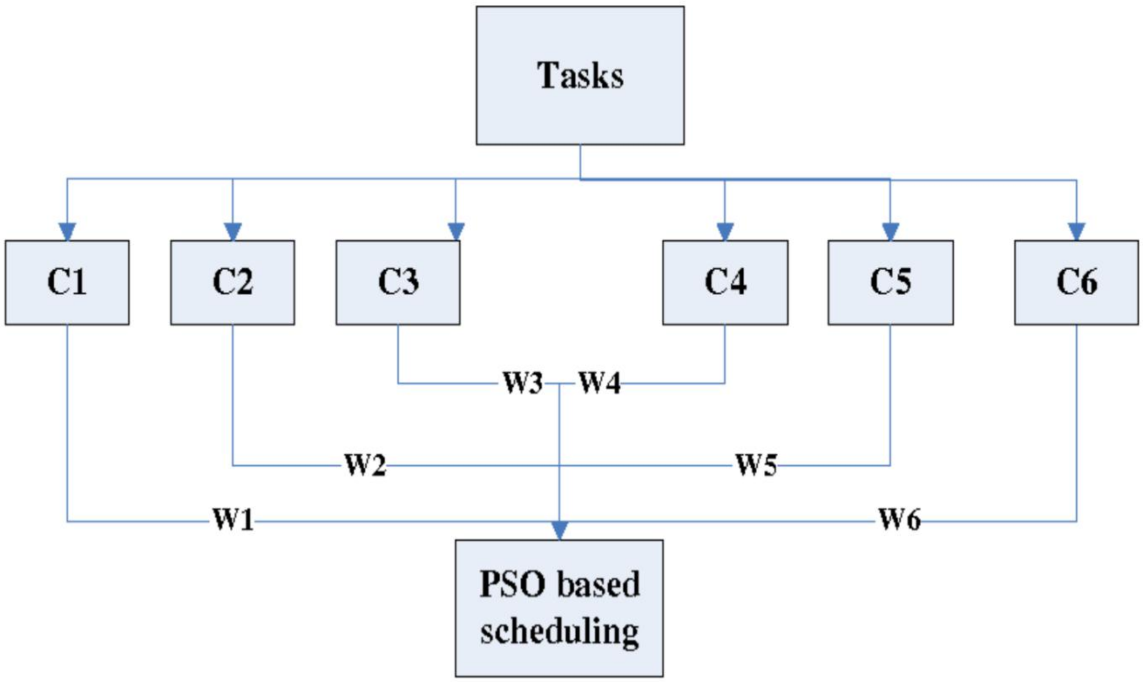
3.3.2.3 PSO–AHP Model

Note that When determining the weights in the AHP method, once the judgment matrix is determined, the consistency and weight of the judgment matrix are also determined, neither of which can be improved. In order to maintain the original information of the decision maker to the greatest extent and to ensure the judgment matrix has better consistency when the judgment matrix is determined, this thesis proposes to use a PSO–AHP method in performing risk assessment to combine the strengths of AHP and PSO (**Figure 3-4**) in accordance to Huang et al. (2011),[31] where the study can be separated into two parts. The first part uses AHP to confirm that some components in a logistics project must be changed to meet the minimum risk requirements for a project. In other words, the logistics project needs to maintain the basic operations and functions. Therefore, one can analyse the project risk and determine which risk has caused most frequent failures. The second part follows the PSO, which is to establish the parameters for developing a risk assessment model and develop an optimisation algorithm based on

[31]For details of the PSO–AHP method introduction, this thesis refers to e.g. Huang et al. (2011). The difference between the risk method in this thesis and Huang et al. (2011) is that this thesis not only combines AHP and PSO, but also uses WBS together in an integrated manner to build the novel risk indicator system, which is the base of PSO-AHP method, while Huang et al. (2011) focus on the combination of AHP and PSO, and use it to maximize the value of product updating so as to extend the product life cycle. Comparing with Huang et al. (2012), this thesis therfore provides a more novel and reasonable model system to evaluate the logistics risks with the improved and reliable risk indicator system built from and integrated with the WBS

PSO as discussed in the previous subsection. This part aims to utilise the improved performance of PSO to help assess risk, which as discussed in the previous subsection will be given to project owners for their reference use in decision making.

Figure 3- 4 PSO–AHP Task Scheduling Process



Note: This figure is adopted from Wang et al. (2014). It shows when a batch of tasks arrives, they initially classify these tasks into six different classes and then do the standard PSO scheduling process.

(1) First Step: AHP Model

As previously introduced (Section 3.3.2.1), AHP is a multicriteria decision-making method developed by Saaty in 1976 (Saaty, 1976). This method has been successfully applied in various fields due to its advantages such as easy to implement (Xu et al., 2018). Moreover, this method considers tangible and intangible factors, and this attribute is consistent with the some of the subjective characteristics of real-world problems. In addition, a hierarchical structure containing multiple time periods, decision makers and standards can be called another advantage. Even if differences exist in each study, the core of AHP is four general steps. Firstly, alternatives, major standard and secondary standard must be identified. Secondly, the decision problem is hierarchically modeled by considering the previously selected criteria. Decision makers' judgements are collected through pair-wise comparisons in the third step. Thirdly, the importance of substitutes and criteria are determined by analysing and comparing these data obtained. Therefore, a comparison must be made between these standards and alternatives. During this process, Saaty's relative importance scale is used, which ranges from 1 to 9 (**Table 3-3**). In this thesis, after building the risk index system, the comprehensive evaluation system will be recorded sequentially and the relative importance of each element and the judgment matrix of each layer according to the scale of 1~9 of **Table 3-3** will be made. The detail will be discussed in **Chapter 5**.

Table 3- 3 Fundamental Scale used in AHP (Huang et al., 2011; Xu et al., 2018)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak	--
3	Moderate Importance	Experience and judgment slightly favor one activity over another
4	Moderate Plus	--
5	Strong Importance	Experience and judgment strongly favor one activity over another
6	Strong Plus	--
7	Very Plus	An activity is favored very strongly over another
8	Very strong	--
9	Extreme Importance	The evidence favoring one activity over another is of highest possible order of affirmation

As shown in **Table 3-3**, the ranking must be as follows: 1 is equally important, 3 is medium, 5 is strong and 7 is very important. If one element of comparison is more important than the other, then people must give nine points. If the decision maker is hesitant between two values, then other options can be used. From these comparisons, a pairwise comparison matrix is obtained.

Fourthly, the ratio of inconsistencies for each matrix is calculated. These ratios can determine the possible error assessments in the comparison. Generally, 0.10 is the upper limit of this ratio. However, some scholars (Dufour et al., 2017; Huang et al., 2011) indicate that this ratio can be accepted to 0.20. If consistency is guaranteed in all matrices, then this process will continue. Otherwise, pairwise comparisons must be repeated for inconsistent pairwise comparisons until a ratio within limits is provided. The determination of the relative importance level according to the judgement can be defined as the following step. The synthesis of this result and the best choice provide the solution for the final step.

(2) Second Step: PSO Model

Huang et al. (2011) reported that PSO was proposed by Kennedy and Eberhart (1995) (The detail of the PSO method can be seen in Section 3.3.2.2). The fundamental concept stems from the behaviour of predatory birds and it is gradually developed into an intelligence-based optimisation algorithm for the assessment of biological systems. This method is an evolutionary search method. The main characteristics of the PSO algorithm lie in minimal parameter adjustments, easy implementation and simple instructions. Therefore, it is extensively used by many scholars (Huang et al., 2011; Xu et al., 2018; Zhou, 2009) and has wide applications. Some present applications are found in the neural network, engineering optimisation and fuzzy system control areas, all yielding excellent results. PSO has been previously introduced (Section 3.3.2.2) and is thus not introduced again in this section.

3.4 Summary

Risk evaluation is a critical decision for logistics projects in today's competitive environment. Regardless how the project plan is properly decided, risk is still the main issue people need to consider. Risk assessment often presents a complex structure composed of tangible and intangible factors. Hence, FCMM is a convenient way to solve the problem of risk analysis. In this thesis, the risk evaluation of the logistics projects will also be addressed according to FCMM. PSO is the new method used in this thesis. To overcome some limitations of the existing research methods, such as FCMM, this thesis proposes a logistic alliance risk identification and analysis method based on PSO algorithm and penalty function method. The two methods are compared to analyse and calculate the optimisation problem in **Chapter 5**, which makes the result of logistics project risk assessment accurate and realistic. This thesis also introduces an improved model, namely, PSO-AHP, to combine the strength of AHP and PSO specifically in logistics projects. According to the introduction in this chapter, in **Chapter 4**, this thesis mainly discusses how to use WBS method to construct the risk index system, which is the basis for this thesis to do the risk assessment analysis. In **Chapter 5**, the nature of the various components of the project and their relationship with one another are clarified, as well as the relationship between the project and the environment, thereby reducing the uncertainty in the process of identifying the project structure. By doing this, this thesis can construct more clearly and concise a risk index system, which is the basis to answer the research questions in **Chapter 1**.

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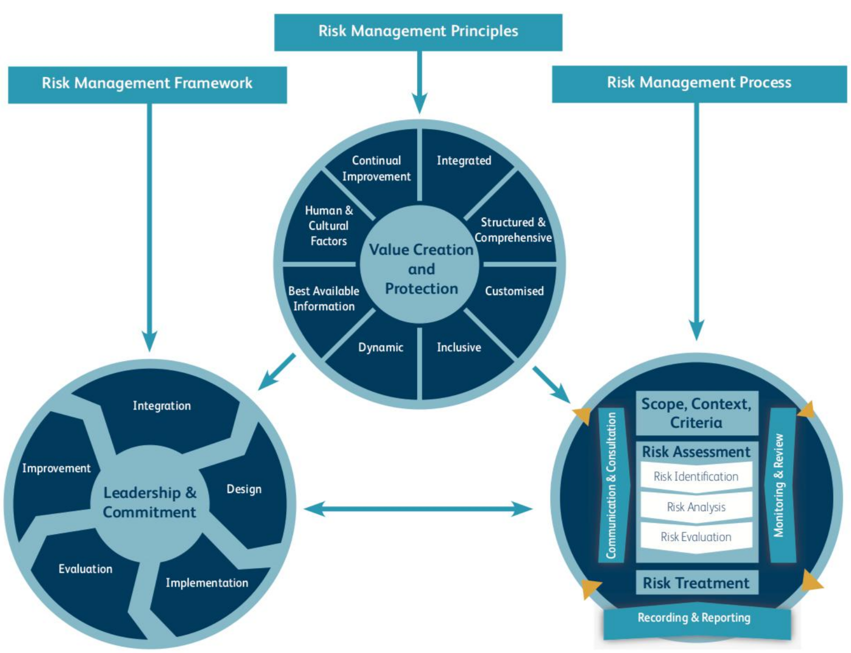
Chapter 4：
Risk Assessment Index System of A Logistics Project

The process of investment, construction and operation of logistics projects requires considerable capital investment. Enterprises may encounter various risks after and during the completion of the project construction. As rational agents who want to achieve profit, investors must understand investment projects to form proper investment decisions and investments, control investment decision-making risk effectively, analyse project risk levels objectively and reduce investment failure risk. According to the principles and methods of risk identification mentioned in **Chapter 2** and the characteristics of logistics projects (Section 2.2), this thesis divides the risks of large-scale logistics project into two categories, that is, logistics enterprise risk and logistics environment risk. These categories are divided further into six classifications: management, operational, technical, fiscal, market and environmental (Daugherty et al., 2006; Song, 2003; Zhu, 2015). Meanwhile, there is not much research using the WBS method to do the risk identification in the logistics issue (Xu et al., 2018; Zhang, 2014). A large number of researchers prefer to using AHP to do the risk identification (Liu et al., 2019; Lyu et al., 2019; Wang and Shi, 2016; Zhu, 2015). This thesis uses the framework of work breakdown structure (WBS) (The detail of method can be seen in **Chapter 3**) to build a risk assessment index system used in Chapter 5 to perform the empirical analysis. This can help clarify the nature of the various components of the project and their relationship with one another, as well as the relationship between the project and the environment, thereby reducing the uncertainty in the process of identifying the project structure for logistics projects. By doing this, this thesis can construct more clearly and concise a risk index system, which is the basis to answer the research questions in **Chapter 1**.

4.1 Setting Principles of the Risk Assessment Index System

Risk assessment is part of a key decision process for logistics enterprises in the current competitive environment (Liu et al., 2019; Lyu et al., 2019; Zhang, 2018). Regardless of how the business line is determined, risk assessment can bring numerous advantages to enterprises and because of the different criteria, the results of each method may differ and the results may be in conflict with each other (Defour et al., 2017; Swink et al., 2007; Tranfield et al., 2003; Xu et al., 2018). Therefore, the design of an investment risk index system has considerable significance in the formulation of decision-making in logistics projects. Numerous indicators for project evaluation exist (**Figure 4-1**). Different projects can focus on different indicators for investigation based on their actual situation. According to the argument of Song (2003), when the present thesis considers the setting of a risk assessment index system, the thesis uses mainly the following principles (Lyu et al., 2019; Rousseau et al., 2008; Wang and Shi, 2016) as shown in **Figure 4-1** and **Figure 4-2**.

Figure 4- 1 Principles of Risk Management from ISO 31000 (Lalonde and Boiral, 2012)



Note: This figure is from 'A Risk Practitioners Guide to ISO 31000: 2018', which states that principles may already exist in full or in part within an organisation. However, these principles need to be adapted or improved so that risk management is efficient, effective and consistent. Motivated by this statement, the current thesis introduces basic principles that require attention when choosing risk factors to form a risk index system.

(1) Comprehensive principle (Cruz and Liu, 2011; Song, 2003)**:** Acquiring profit is the goal of logistics projects. At the corresponding risk evaluation level, comprehensive consideration of numerous factors affecting the project, economic and social systems plays a main role in the project process. In the construction of the evaluation index system, it is first necessary to fully reflect the various elements of the process of risks identification in the context of the logistics projects, to measure the actual situation of the research object, and to adapt to the real conditions. Secondly, the evaluation system needs to be able to reflect the overall situation, and it is necessary to form a rigorous systematic evaluation index system for the evaluation target requirements and content.

(2) System completeness principle (Lyu et al., 2019; Rousseau et al., 2008; Wang and Shi, 2016**):** A certain logical relationship must exist between the indicators. The indicators should reflect the main characteristics, status and internal relationship of the projects, economic and social subsystems from different aspects (Liu et al., 2019). The system completeness principle requires individual risk factors to be understood in their entirety, and the overall situation of evaluated objects should be reflected comprehensively. All risk factors of the project must be covered. Meanwhile, the research object is a dynamic process. The selection of indicators should not only reflect the development status of the assessment object statically, but also be dynamic. It can measure the change of the consent index at different time periods and require the selected indicators to be longer. At the same time, it is necessary to take into account various possible realities, try to reduce the number of indicators, and be able to adapt to the evaluator's judgment on the indicators to carry out the actual operation.

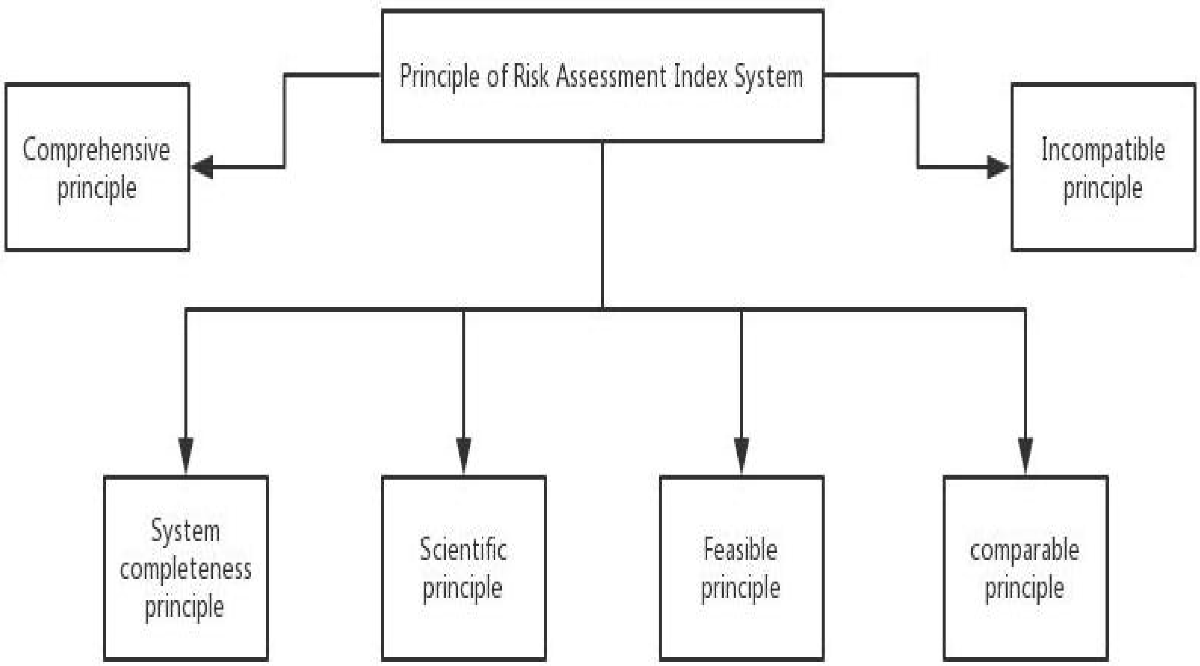
(3) Scientific principle (Cruz and Liu, 2011; Song, 2003)**:** The design of each index system and the selection of evaluation indicators must be based on scientific principles, which is similar with the Design Science Research approach (Lyu et al., 2019; Wang and Shi, 2016). This principle can reflect objectively the characteristics and conditions of environmental, economic and social development and can reflect objectively and comprehensively the true relationship between indicators. Project risk evaluation is a decisive task before project construction. Mistakes may cause extremely large losses to the enterprise and the country (Liu et al., 2019; Hazen and Byrd, 2012). Therefore, the evaluator must hold a high degree of responsibility to avoid the blind and repeated construction phenomenon and ensure the project can create benefits after completion. In the assessment work, attention should be given to the combination of comprehensive investigation and key verification, quantitative and qualitative analysis, experience summarization and scientific prediction to ensure objectivity of the relevant project data and the science of using methods, like PSO-AHP and FCMM introduced in this thesis.

(4) Feasible principle (Chen et al., 2013; Song, 2003)**:** The principle of feasibility is used to measure whether a decision on the project is doable, that is, logistics project decision-making can be implemented from the aspects of manpower, material resources, financial resources and scientific and technological capabilities. If the decision made is impossible to achieve from the external environment or internal conditions of the enterprise, then such a decision is not feasible. If decisions cannot be implemented, then such decisions have no practical significance. Furthermore, the authenticity and reliability of the data are prerequisites and important guarantees for the evaluation. A large amount of statistical data is needed to support the construction of the evaluation index system. When setting evaluation indicators, it is necessary to accurately reflect the dominance relationship between each level and each must have a clear connotation.

(5) Comparable principle (Song, 2013)**:** The principle of comparability means the indicators that people choose for risk assessment should be comparable. Only when indicators are comparable can they provide accurate useful information and play a role in the index system. The indicators at the same level in the index system should meet the principles of comparability to ensure that indicators can reflect the actual situation of logistics projects.

(6) Incompatible principle (Song, 2013)**:** In general, indicators with relative independence should be chosen to establish the evaluation index system. That is, the indicators of the index system should satisfy the relative independence as much as possible under the premise of the principle of integrity (Gu and Yang, 2017). The principle of relative independence requires that selected indicators must be independent. No inclusion and similarities should remain, overlap or be irreplaceable, thereby avoiding duplication of information.

Figure 4- 2 Principle of Risk Assessment Index System



4.2 Risk Assessment Index System

Based on the above arguments, it shows that the index system needs to be closely organized around the purpose of evaluation, objectively describing the essential structure and components of the evaluation target object, thereby achieving the purpose of serving the evaluation and providing a basis for the judgment of the evaluation results. Therefore, when constructing the indicator system, it is necessary to understand and grasp whether the indicators are the key factors affecting the logistics projects from the purpose of reflecting the real situtaion in the context of logistics projects. Several studies on risk assessment prefer obtaining the risk factors by using the Delphi method (Dalkey and Helmer, 1963; Dufour et al., 2017; Fan, 2019). This method usually has a disadvantage in that the personal judgement method of an expert is limited by the individual's knowledge, ability and experience. The recognition result is also influenced by the subjective factors of the expert. Thus, this thesis applies the WBS method, which can provide reasonable risk factors and clarify the nature of the various components of the risk and their relationship with one another (Xu et al., 2018), as well as the relationship between the risk and the environment, thereby reducing the uncertainty in the process of identifying the project risk. This thesis begins from the introduction of different risks in the large-scale logistics project.

4.2.1 Risk in the Large-Scale Logistics Project

In this chapter, the risk occurring in large-scale logistics projects (Chen et al., 2013; Xu et al., 2018) is considered mainly. According to the principles and methods of risk identification mentioned in **Chapter 2**, this thesis divides the risk of large-scale logistics projects into two categories, logistics enterprise risk and logistics environment risks. The logistics enterprises risks involve risks pertaining to a company's operations and risks at the macro level, such as business risk, production safety, environmental protection, tax management, company standard operations, laws and regulations. The logistics risk is inherent in logistical activities, such as accidents, drivers carrying goods to escape and so on. Based on these, this thesis further divides risk in the large-scale logistics projects into six categories: management risk, operational risk, technical risk, fiscal risk, market risk, and environmental risk (Daugherty et al., 2006; Devaraj et al., 2007; Song, 2003).

4.2.1.1 Logistics Enterprise Risk

Logistics enterprise risk mainly includes management risk, technical risk and operational risk (Daugherty et al., 2006; Devaraj et al., 2007; Song, 2003). The detail is also summarised in **Table 4-1**.

(1) Management Risk

Management risk refers to the level of management that has an effect because of information asymmetry, poor management and misconception in the management process. Song (2003) argued that management risk is an extremely large risk that logistics projects can face when in operation. This risk is intangible and not as obvious as market performance risk. However, the entire project may fail if management risk occurs. Management risk can be divided into five sections: quality of the manager, organisational structure, corporate culture, shareholder protection and management process (Chen et al., 2013; Michael et al., 2018; Provan et al., 2007; Xu et al., 2018). **1)** The survival and development of logistics enterprises depend to a large extent on the decision-making of managers, especially the strategic decisions of top managers and whether senior managers can review the situation, seize opportunities, grasp changes and have the courage to conduct risk decisions. Strengthening the manager's own moral cultivation and enhancing corporate cohesion and motivation are necessary. **2)** Whether the logistics enterprise's organisational structure is reasonable plays a vital role in the enterprise's development and survival. Logistics projects can include many aspects in a society, and thus, the appropriate organisational structure in an enterprise can smoothen the project activities, reduce conflicts and frictions, avoid unnecessary endless coordination and improve project efficiency. Management risk can occur if a logistics enterprise has a bad organisation structure. **3)** Corporate culture can bring employees together and form a strong centripetal force; therefore, employees are united, consistent and strive to achieve their goals. If employees cannot cooperate with each other, especially for the logistics enterprise, then difficulty arises for a logistics project to proceed smoothly. **4)** Shareholders of a logistics enterprise can influence the project activities of the enterprise, and thus, protection of shareholder rights is meaningful. If shareholder rights cannot be guaranteed, then shareholders' actions may negatively affect a logistics project, thereby resulting in management risk. **5)** Management process refers to the purpose of controlling risk, reducing cost and improving service quality, working efficiency and response to the market and ultimately improving customer satisfaction and market competitiveness to achieve maximum profits and improve operating efficiency. A well-managed process can provide a positive environment for the project, whereas a negative management process can make logistics projects fail, thereby resulting in management risk.

(2) Technical Risk

Technical risk refers to the risk brought through advanced, applicable and economical technologies in the logistics project investment. A large-scale logistics projects requires the introduction of numerous new technologies (Chen et al., 2013; Min et al., 2005; Xu et al., 2018). The technical status and applicability of the infrastructure and equipment invested in logistics projects is the basis for the smooth operation of logistics services. The key to the transformation from traditional to modern logistics, especially as to Chinese economic development, lies in the development and application of modern technology in logistics activities. Advanced logistics technology can be applied widely to all aspects of logistical operations to improve the operational efficiency and efficiency level of the enterprise or the entire logistics industry and realise the optimal allocation of logistics resources to achieve overall benefits. In terms of logistics projects, the present thesis considers technical risk from the following aspects: **1)** Technical deficiencies risk. Within the environment of economic development, numerous logistics enterprises cannot receive sufficient financial support to update their technical operations immediately, which can result in technical deficiencies risk. With the development of machine learning, any technical operation older than three years is superseded. However, the profit process for logistics projects is so long that no guarantee that a logistics enterprise can update technical operations every three years exists; **2)** Technical protection risk. China's government has focused on protecting technologies, especially for Chinese logistics enterprises, however the risk remains that technologies may be acquired by other enterprises; **3)** Technical development risk. Numerous large-scale logistics enterprises spend money developing their own technical systems. However, investing money for the accrual of benefits is not guaranteed. During the process of logistics projects, if one technology cannot be achieved in time, then the technology may affect the entire logistics project; and **4)** Technical use risk. Numerous logistics enterprises use another enterprise's technology given the low development of their own technology. During this process, if a logistics enterprise cannot deal well with other enterprises with regard to the copyright or technology, then the problem may cause risk for the entire logistics project.

(3) Operation Risk

The provision of smooth and efficient logistics services to customers is an important goal of logistics operations. Given that logistics services are comprehensive services that involve multiple aspects, they face various risks in the operation of logistics services. The main risks can be summarised as follows: **1)** Risk due to shippers. During the process of shipping, if shippers do not have a basic sense of responsibility, they may not pay sufficient attention to the goods they are shipping, which results in damaged goods that further bring operation risk for logistics enterprises; **2)** Equipment risk. A variety of logistics equipment provides support for the entire logistical system. Logistics equipment is the main part of the material basis of the logistics system. The rationality of the layout, level, selection and configuration has a direct effect on the realisation of logistical functions and on the efficiency of the logistics system. During the operation process of logistics projects, if the equipment has certain problems, then such problems would affect the entire logistics project; and **3)** Customer risk. During the process of operation of a logistics project, if customers suddenly change their sentiments or are not willing to continue the contract, the failure of logistics projects occurs. Given that logistics services are the main method for a logistics enterprise to receive money, if customers cancel their contracts and the upfront investment in the professional logistics service for this customer cannot be recovered in time, then extremely large economic losses to logistics enterprises will occur.

Table 4- 1 Details of the Logistics Enterprises Risk

Types	**Risk Elements**	**Element Meaning**
Management Risk	Manager quality	Whether senior managers can review the situation, grasp the changes in the environment, seize the opportunities and have the courage to conduct risk decisions.
	Organisational structure	The logistics project can include most things in the society, thus an enterprise's organisational structure can make the project activities smooth, reduce conflicts and friction, avoid unnecessary coordination and improve the efficiency of the project.
	Corporate culture	Corporate culture can bring employees together and form a strong centripetal force to ensure that employees are united and consistent and strive to achieve their goals.
	Shareholder protection	The shareholders of the logistics enterprise can influence the project activities, thus protecting their rights is meaningful.
	Management process	Management process refers to the purpose of controlling risk, reducing cost, improving service quality, working efficiency and response to the market and ultimately upgrading customer satisfaction and market competitiveness to achieve maximum profit and improve operating efficiency.
Technical Risk	Technical deficiencies	Within the environment of economic development, numerous logistics enterprises cannot receive sufficient financial support to update their technical operations immediately, thereby resulting in technical deficiencies risk.
	Technical protection	Although China's government has made efforts to protect techniques, the risk that techniques may be acquired by other enterprises remains.
	Technical development	During the process of logistics projects, if one technique cannot be achieved in time, then such a delay may affect the entire logistics project.
	Technical use	If logistics enterprises cannot deal with other enterprises regarding copyright or technique, this inability may cause risk

		for the entire logistics project.
Operational Risk	Risk due to shippers	During the process of shipping, if shippers do not have a basic sense of responsibility, then they may not pay sufficient attention to the goods they are shipping, which can result in damaged goods.
	Risk due to equipment	During the operation process of logistics projects, if the equipment has certain problems, then these problems affect the entire logistics project.
	Risk due to customers	During the process of operation, if customers suddenly change their minds or are not willing to continue the contract, then the failure of logistics projects will occur.

4.2.1.2 Logistics Environment Risk

For logistics environment risk, it includes market, fiscal and environment risk. The detail is also summarised in **Table 4-2**.

(1) Market Risk

The market risk of a logistics project refers to the possibility that the benefit of the logistics enterprise can reduce because of the uncertainty of the business and the related external environment, thereby failing to achieve the expected market effect and affecting the survival and development of the logistics enterprise. For enterprises, market risk can lead to a series of problems, such as the failure of corporate investment activities and investment risk. Logistics service demand is the main components of the logistics market. Logistics services can be divided into two categories according to the product: industrial product logistics market and agriculture product logistics market (Chen et al., 2013; Craighead et al., 2007; Defour et al., 2017; Strauss and Corbin, 1998; Xu et al., 2018), where the industrial logistics market is the mainstay of the logistics market. These categories are reflected mainly in the following aspects of market risk in large-scale logistics projects:

1) Changes in consumer demand. Consumers' purchasing decisions are a choice behaviour affected directly by their consumption preferences and other factors, such as difference in logistics service, variant price of logistics enterprises, quality of service and relationship between different services. Consumers' demand preferences for logistics services from a certain company may change, which can lead to market risk; **2)** The behavior of competitor. The degree of market competition continues to increase as the market economy continues to develop and improve. Logistics enterprises encounter competitive pressure from their original competitors and face the threat of potential competitors. At present, market competition shows a trend from simple price competition to complex price competition and non-price competition. Compared with the non-price competition, price competition of logistics enterprises can be fully expressed in the market, which can be detected by other enterprises. Non-price competition is more concealed than price competition, such as improving quality and developing new products. Non-price competition poses more risks to logistics enterprises than price competition; **3)** uncertain and asymmetrical information. Information is an important resource in logistics management and can generate value similar to other resources. Logistics include most things in society; thus, the accumulation and transmission of information can allow the full and rational use of other production factors by acting upon the production and operation process to realise and expand the value of other production factors. Furthermore, fully accurate information can assist logistics enterprises in reducing market risk. However, the lack, asymmetry and inaccuracy of information can lead to decision-making mistakes and market failures; **4)** exchange rate risk refers to the risk of currency loss because adverse changes in exchange rates. China's numerous large-scale logistics enterprises have foreign business activities. If the exchange rate changes suddenly and dramatically, market risk may occur.

(2) Fiscal Risk

An extremely large investment in time and opportunity cost can bring unexpected changes in the financial market after capital investment can lead to a backlog of logistics projects and a large amount of capital loss, which can pose great risk to enterprises. Based on current research, this thesis divides fiscal risk into the following sections: **1)** Investment risk. Investment risk is due mainly to the uncertainty via investing activities in the financial results of logistics enterprises. The investment activities of a logistics enterprise include the main business of the enterprise and other project operations. The investment risk of the logistics enterprise is determined according to the rate of return of the project. If the profit rate of a project is greater than the interest rate of debt, then the risk is smaller; otherwise, the investment risk is relatively larger; **2)** liquidity risk refers to the possibility that the assets of a logistics enterprise cannot transfer cash through a normal and certain method or the debt and payment obligation cannot be performed normally. The liquidity risk of a logistics enterprise can affect the entire process of a logistics project; **3)** financing risk refers to the uncertainty caused by the financing of enterprises from the financial institutions because of the changes in the supply and demand market of funds and the macroeconomic environment. Numerous logistics enterprises, especially in China, need to acquire funds through financing to maintain their logistics projects. Once such enterprises cannot receive enough funding, the logistics project may fail; and **4)** risk of changes in interest rates. The same as the exchange rate, during the debt period, owing to the influence of inflation, the change in the loan interest rate and the increase of the interest rate may inevitably increase the logistics enterprise’s capital cost, thereby offsetting the expected return, which can result in fiscal risk.

(3) Environment Risk

The development of the logistics service market and tourism sources are influenced directly by the changes in the country’s macroeconomic and political environment, which can have an indirect effect on the success of logistics project construction. Based on the argument of Song (2003) and Xu et al. (2018), the current thesis divides environment risk into the following three sections: **1)** Macroeconomics development. Logistics projects include most things in society. If the macroeconomics of a country proceeds well, then such macroeconomics may bring sizeable opportunities for logistics enterprises to develop their projects, otherwise, the development of logistics projects can be affected because of the effects of numerous other activities, such as political environment; **2)** policy and law risk refer to major changes in the governments' policies of the relevant logistics enterprises or the introduction of important measures and regulations, which cause fluctuations in the price of the logistics market, thereby bringing losses to the logistics enterprises; and **3)** political risk refers to the uncertainty caused by the political environment of the host country or the political relationship between the host country and other countries. Events that bring economic losses to foreign-invested companies include nationalisation, political interference and regime change in the host country or war.

Table 4- 2 Details of Risk of Logistics Environment Risk

Types	Risk Elements	Element Meaning
Market Risk	Changes in consumer demand	As consumers' demand preferences for logistics services from a certain company may change, which can lead to market risk.
	Behaviour of competitor	With the development and improvement of the economy, the degree of market competition is increasing. Logistics enterprises face the competitive pressure of their original competitors and encounter the threat of potential competitors.
	Uncertain and asymmetric information	Lack, asymmetry and inaccuracy of information can lead to mistakes and market failures in logistics enterprises decision-making.
	Exchange rate	During the debt period, due to the influence of inflation, a change of loan interest rate and the increase of interest rate can inevitably increase the logistics enterprise's capital cost, thus offsetting the expected return, which can result in fiscal risk.

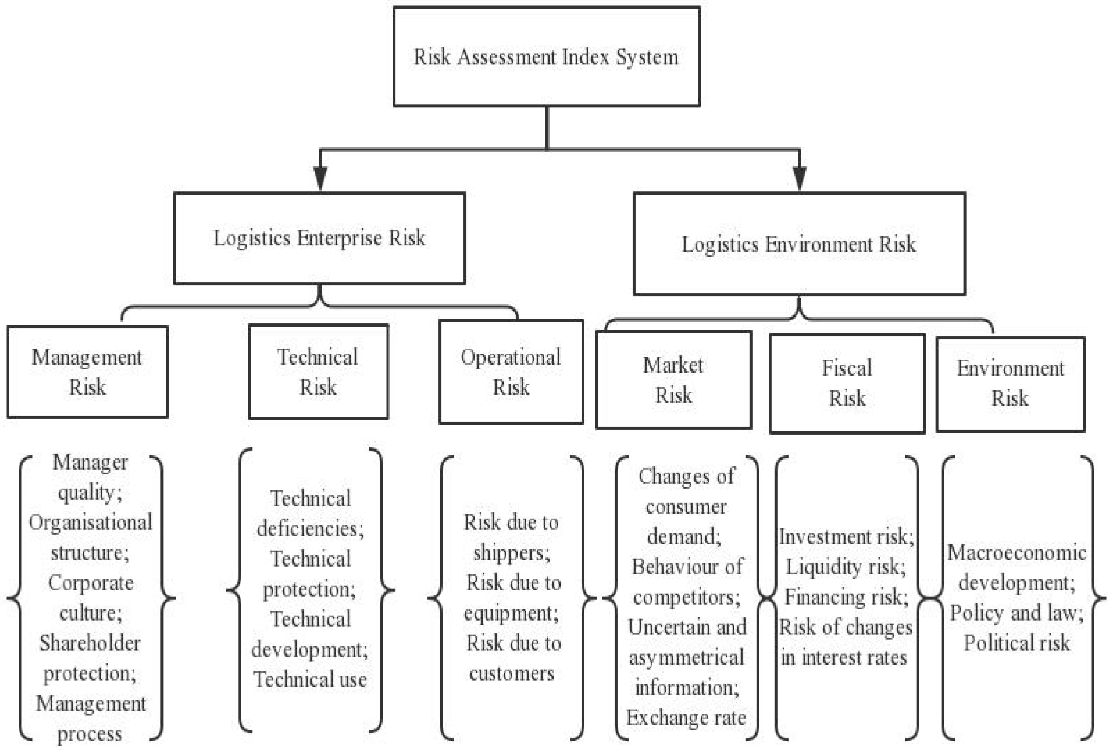
Fiscal Risk	Investment risk	Investment risk is due mainly to the uncertainty caused by the business activities from the financial results of the logistics enterprises.
	Liquidity risk	Liquidity risk refers to the possibility that the assets of the logistics enterprise cannot transfer cash through a normal and certain method, or the debt and the payment obligation cannot be performed normally.
	Financing risk	Financing risk refers to the uncertainty caused by the fiscal of enterprises from the financial results due to changes in the supply and demand markets of funds and the macroeconomic environment.
	Risk of changes in interest rates	The same or similar as the exchange rate.
Environment Risk	Macroeconomic development	Logistics projects include most things in society. If the macroeconomics of a country proceeds well, sizeable opportunities for logistics enterprises to develop their projects will occur, otherwise, the development of logistics projects may be affected because of the effect of numerous other activities.
	Policy and law	Policy and law risks refer to the government's major changes in the policies of the relevant logistics enterprises or the introduction of important measures and regulations, which cause fluctuations in the price of the logistics market.
	Political risk	Political risk is the uncertainty caused by the political environment of the host country or the political relationship between the host country and other countries.

4.2.2 Risk Assessment Index System

In this section, this thesis uses the WBS method to construct the risk assessment index system based on Sun (2003) (for the detail of WBS method, please see **Chapter 3**), which refers to the grouping of the elements in a project based on the purpose of deliverables. WBS summarises and defines the scope of work for the entire project, with each part of WBS representing a detailed definition of the project's work. By using WBS method, this thesis can clarify the nature of the various components of the risk and their relationship with one another (Xu et al., 2018; Zhang, 2014), as well as the relationship between the risk and the environment, thereby reducing the uncertainty in the process of identifying the project risk. Therefore, this thesis uses WBS method to transform large into small systems, decompose complex into simple and easily recognised situations and clearly show the hierarchical relationship of risk. By doing this, this thesis can construct more clearly and concise a risk index system. The specific steps taken in this process are as follows. The entire large-scale logistics project is decomposed into subprojects by category and hierarchy, and each potential risk factor is then decided separately. Subsequently, the subproject is further decomposed, and finally, layer analysis is performed until all relevant risk factors are determined.

Specifically, the basic idea of WBS is to ask people to consider each part of project to make the work plan more concise. Following the same steps and idea, this thesis at firstly considers from the whole process to divide risk into two parts: logistics enterprise risk and logistics environment risk as discussed previously in this chapter, which is the first step of WBS. Then considering each part separately, for logistics enterprise risk, this thesis divides it further into **3 parts**, which are management risk, technical risk and operation risk also shown separately earlier in this chapter. Then for each part, this thesis divides into different types of risks. As seeing from here, following the idea of WBS method, this thesis considers risk from top to bottom and considers each type of risk that large-scale logistics projects may face. Following the same steps, this thesis sets 23 indicators for the six types of risk to evaluate the risk of the logistics project based on the actual situation. (**Figure 4-3**). The logistics enterprise risk includes mainly management, technical and operational risk, whereas the logistics environment risk includes mainly market, fiscal and environment risk. This is presented as follows:

Figure 4- 3 Risk Assessment Index System



(1) Logistics enterprise risk

a) Management Risk (U_1): Manager quality (U_{11}), Organizational structure (U_{12}), Corporate culture (U_{13}), Shareholder protection (U_{14}) and Management process (U_{15});

b) Technical Risk (U_2): Technical deficiencies (U_{21}), Technical protection (U_{22}), Technical development (U_{23}) and Technical use (U_{24});

c) Operational Risk (U_3) : Risk due to shippers (U_{31}) , Risk due to equipment (U_{32}) and Risk due to customers (U_{33});

(2) Logistics environment risk

a) Market Risk (U_4): Changes of consumer demand (U_{41}), Behavior of competitors

(U_{42}), Uncertain and asymmetrical information (U_{43}) and Exchange rate (U_{44});

b) Fiscal Risk (U_5): Investment risk (U_{51}), Liquidity risk (U_{52}), Financing risk (U_{53}) and Risk of changes in interest rates (U_{54});

c) Environment Risk (U_6): Macroeconomic development (U_{61}), Policy and Law (U_{62}) and Political risk (U_{63}).

The notation for each risk, such U_1, will be used in **Chapter 5** in the detailed discussion and presentation of a logistics application. Sun (2003) argued that the index system cannot be the same at all times and must be changed with different situations. The index systems of certain projects have not changed for several years. These index systems often fail to keep up with changes, and index evaluation has just become a kind of form. An index system must be adjusted in a timely manner to respond to the variant changes in the real situation. What the market demands and what customers require must be reflected in the performance index in a timely manner. When the reality changes, the index should be adjusted in time using the method introduced in this thesis and the evaluation criteria and weights should be adjusted at any time to reflect the risk focus of the logistics enterprises.

4.3 Summary

Risk identification is the prerequisite of risk analysis. In this chapter, the study introduced different types of risk and cause for risks. Only by first revealing the risk factors of all projects can the seriousness of the risk be determined and the probability of the occurrence. Then through further evaluation can the crucial risk factors be determined and certain corresponding risk measures be proposed. (Zacharia et al., 2011). More specifically, based on the aforementioned principles and WBS method, where the main idea is to consider each part of logistics project, this chapter divided risk in the large-scale logistics projects into two types, namely, logistics enterprise risk and logistics environment risk. Logistics enterprise risk includes mainly management, technical and operational risk, whereas logistics environment risk includes market, fiscal and environment risk. Based on this division, this chapter further designed the risk assessment index system via WBS method, which is used for the remaining analysis.

By using WBS method, this chapter clarifies the nature of the various components of the risk and their relationship with one another, as well as the relationship between the risk and the environment, thereby reducing the uncertainty in the process of identifying the project risk. This chapter uses the WBS method to transform large into small systems, decompose complex into simple and easily recognised situations and clearly show the hierarchical relationship of risk. By doing this, this chapter constructs a clearer and more concise risk index system. In **Chapter 5**, based on the risk index system built here, this thesis addresses each factor fundamentally and in more detail, judges the degree of risk of each factor in logistics projects and evaluates the risk degree of the logistics projects via the fuzzy comprehensive measurement method (FCMM). and PSO–analytic hierarchy process (PSO–AHP) method. On the basis of the index system and methods introduced, this thesis uses Hanjin Shipping and Shandong New Jiahong Company as novel cases to show how risk evaluation is performed in the context of logistics projects in **Chapter 6** as well.

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Chapter 5：
Risk Evaluation Based on the Risk Index System

Chapter 3 introduced the basic models that this thesis uses when performing the risk evaluation and **Chapter 4** introduced the principles that need to be followed when building a risk index system. Based on these models and principles, this chapter focuses on the risk evaluation and introduces the details of each model (Fuzzy Comprehensive Measurement Method (FCMM) and Particle Swarm Optimization-Analytic Hierarchy Process (PSO–AHP)). It also presents how these models can be used to perform the risk evaluation. The FCMM is a comprehensive evaluation method based on fuzzy mathematics. The FCMM transforms qualitative evaluation into quantitative evaluation according to the membership degree theory of fuzzy mathematics, that is, using mathematics equations or models to conduct an overall evaluation of objects subject to various factors that researchers or managers may need to consider. As also inferred in the previous chapter, the FCMM has the characteristics of clear results and a strong system, which can solve fuzzy and difficult quantification problems and is suitable for solving various non-deterministic problems. Li et al. (2016) argues that when the weight of each factor is determined through the AHP method, once the judgment matrix is

determined, the judgment matrix consistency and weight are also determined, and no way exists to improve both. The present thesis considers combining the advantages of AHP and PSO together to obtain the PSO–AHP method,[32] maximise the original information of the decision-makers, improve the consistency of the judgment matrix and enhance the weight value when determining the judgment matrix. This chapter presents results for both of these models, compares them to show the advantage of each model in detail and provides a clear indication to researchers when a model to perform the risk evaluation is chosen. Details of the codes used in this thesis are given in the appendix at the end of this thesis (**Appendix 1**). A detailed case study using these methods in a

[32]PSO-AHP has been applied in some research (Huang et al., 2011), but this thesis firstly applies it in the content of logistics risk evaluation in a novel way, see 'Xu et al. (2018). Predict the Logistic Risk: Fuzzy Comprehensive Measurement Method or Particle Swarm Optimization Algorithm?' *EURASIP Journal on Wireless Communications and Networking in 2018*.

logistics context is presented in **Chapter 6**.

5.1 Details of FCMM Model Steps

The fuzzy comprehensive evaluation rule refers to the use of fuzzy mathematical theory to quantify all kinds of uncertainties to obtain more objective and factual evaluation, and to judge by object, and has unique evaluation value for the object to be evaluated and not evaluated. The influence of the set of objects on which the object is located, thereby further solving other related ambiguity problems. Numerous studies have focused on the use of the FCMM model (Chen et al., 2015; Deng et al., 2017; Huang et al., 2011; Xu et al., 2018). Evaluation of the level of risk through an exact quantitative method is difficult, especially in the risk evaluation area because of the uncertainty of risk factors (Wang et al., 2012). Bai et al. (2018) stated that in 1965, Zadeh proposed the use of the concept of fuzzy sets to address this issue, which is the foundation of the FCMM method. The main advantage of the FCMM method is that it can change a qualitative question to a quantitative one (Chen, 1984; Cheng and Tao, 2010; Xie et al., 2017). Thus, the FCMM method has become a very popular model in terms of risk evaluation (Yazdani et al., 2014) and has been used in numerous real-world problems (Afful-Dadzie et al., 2014; Chen et al., 2015; Deng et al., 2017; He, 1983; Li et al., 2015; Xie et al., 2010). Based on the aforementioned research, the current study focuses on the use of the FCMM model to observe how it evaluate the risk level of logistics projects.[33] The fuzzy comprehensive analysis method is used to calculate the risk level according to the risk assessment index system presented as a design construct in the previous chapter. From Chapter 3, this thesis introduces the following four steps:[34] **(1)** Obtain factor set $\mathrm{U} = \{\mathrm{U}_1, \mathrm{U}_2, \mathrm{U}_3, \cdots, \mathrm{U}_n\}$; **(2)** Obtain judgment set $\mathrm{V} = \{\mathrm{V}_1, \mathrm{V}_2, \mathrm{V}_3, \cdots, \mathrm{V}_m\}$; **(3)** Perform the single factor evaluation $\mathrm{f}: \mathrm{U} \rightarrow \phi(\mathrm{V})$ and $\mathrm{u}_i \mapsto \mathrm{f}(\mathrm{U}_i) \in \phi(\mathrm{U})$. Fuzzy mapping f can induce a fuzzy relationship $\mathrm{R}_f \in$

[33]The main objective to use FCMM method is to compare FCMM with PSO-AHP to show the advantage of each model in detail and provides a clear indication to researchers when a model to perform the risk evaluation is chosen.

[34]Details of each step are provided in Chapter 5, and FCMM is used to assess risk for a logistics project.

$\phi(U \times V)$,[35] which is $R_f(U_i, V_j) = f(U_i)(V_j) = r_{ij}$. Thus R_f can be represented by $R \in u_{n\times m}$, where

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{5.1}$$

is a single factor evaluation matrix, and the fuzzy transformation T_f from U to V can be induced by the fuzzy relation R. U (U_1, U_2, ⋯, U_n) forms a fuzzy comprehensive decision-making model, where U_1, U_2,⋯, U_n are the n elements of the model; **(4)** Perform the comprehensive evaluation. Weight A= (A_1, A_2, ⋯, A_n) can be calculated according to fuzzy mathematical evaluation model formula A*R=B, where B= (B_1, B_2, ⋯, B_m) is the total assessment results. In accordance with the principle of maximum membership, V_j is the result of comprehensive evaluation, that is when applied to risk assessment, the risk level of the evaluated object, where j is the highest value of B_{jmax} in B_j.[36] Here, this thesis shows the detail of the method (**Figure 5-1**), which is extended and summarised from **chapter 3** as needed.

(1) Determine the hierarchy of evaluation indicators

The assessment of the risk is arranged according to the degree of risk from weak to strong, where $V = \{V_1, V_2, \cdots, V_m\}$ can be used as an evaluation set. V_1 indicates the lowest risk, whereas V_m indicates the highest risk. m is the comment number. In this thesis, according to the characteristic of comprehensive evaluation for logistics risk, m=5 is assumed. Then the comment set V=(low risk (V_1), medium–low risk (V_2), general risk (V_3), medium–high risk (V_4) and high risk (V_5)) is defined.

(2) Determine the pairwise comparison matrix of evaluation indicators

The weight of the risk can be determined using the AHP evaluation method discussed in **Chapter 3**. The advantage is that the order of each indicator can be determined

[35] $U \times V$ means the combination of set U and set V.
[36] For the detail of FCMM method, this thesis refers readers to Xu et al. (2018).

reasonably based on problems researchers or managers are facing. Assume there is a set $U = \{U_1, U_2, \cdots, U_n\}$ needing to be assessed, where U can be the risk factor, n is the total of factors. Then, the respondents can assign a weight to each of the indicators according to their knowledge or experience (**Table 5-1**), where $\overline{X}_j = \frac{1}{s}\sum_{i=1}^{s} a_{ij}$, $S_j = \frac{1}{s}\sum_{i=1}^{r=s}(a_{ij} - \overline{X}_j)^2$ and A_i is the weight for risk factor i.

Table 5- 1 Weight of Each risk Indicator

People	A_1	A_2	...	A_n	$\sum$
1	a_{11}	a_{12}	...	a_{1n}	1
2	a_{21}	a_{22}	...	a_{2n}	1
...	...	...	...	...	...
s	a_{s1}	a_{s2}	...	a_{sn}	1
Mean	$\overline{X}_1$	$\overline{X}_2$	...	$\bar{X}_n$	
Variance	S_1	S_2	...	S_n	

Note: $\sum$ represents the sum of each row in this table and s is the total number of respondents.

The process for gathering empirical evidence on the risks is as follows: send all data consistently to each respondent, along with other supporting information and ask each person to give a new estimate after reading and thinking. Repeat several times until the variance is less than or equal to a predetermined criterion, and the average value at this time is used as the index weight, expressed as $A = (\overline{X_1}, \overline{X_2}, \ldots, \overline{X_n}) = (A_1, A_2, \ldots, A_n)$ .The scale each person or respondent can use is shown in **Table 5-2**.

Table 5- 2 Scale of 1-9

Value of a_{ij}	Importance of indicator i relative to that of indicator j
1	A_i and A_j have equal influence
3	A_i has slightly stronger influence than A_j
5	A_i has stronger influence than A_j
7	A_i has much stronger influence than A_j
9	A_i has absolutely stronger influence than A_j
2,4,6,8	The influence ratio of A_i to A_j lies between that of two adjacent layers
$\frac{1}{2},\cdots,\frac{1}{9}$	The influence ratio of A_i to A_j is the reciprocal of a_{ij}

Note: The source of the table is Wang (2015).

(3) Determine the relative weight vector of each competency indicator

The same as in (2), the evaluation matrix of logistics project risks is determined through the AHP method. The customized logistics project risk assessment grade classification standard and logistics project indicator system are submitted to each respondent. If having *s* respondents, the risk index U_j has *k* factors, and for each indicator U_{ik}, which is the kth factor in index U_i , has a total of $s_i k_j$ reviewers drawing “1” using **Table 5-2** on risk level V_j, then the evaluation of the U_{ik} evaluation index is the probability of selecting “1” :

$$r_{ikj} = s_i k_j / \mathrm{n} \quad (i = 1,\ldots,n; j = 1,2,\ldots,m),^{37} \qquad (5.2)$$

where s is the total number of respondents and j represents the risk level.

Then the index vector is

[37] The detail of method can be seen in Xu et al. (2018). For easy explanation, this thesis uses j=1,2,3,4,5, which means we have 5 risk levels.

$$R_{ik} = (r_{ik1}\ r_{ik2} \dots\ r_{ikm}) = \left(\frac{s_ik_1}{\mathrm{n}}\frac{s_ik_2}{\mathrm{n}} \dots \frac{s_ik_m}{\mathrm{n}}\right), \tag{5.3}$$

The index matrix $\mathrm{R_i}$ is

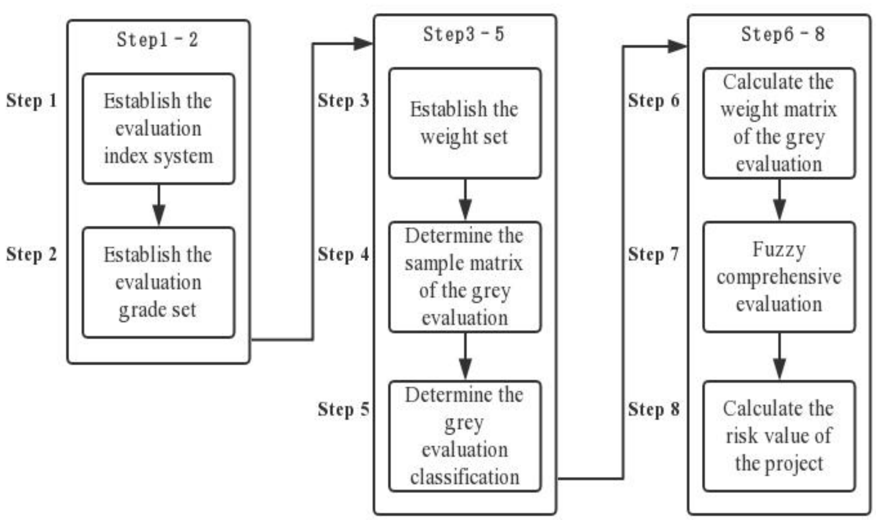
$$R_i = \begin{bmatrix} R_{i1} \\ R_{i2} \\ \cdots \\ R_{ik} \end{bmatrix} == \begin{bmatrix} \mathrm{r_{i11}} & \mathrm{r_{i12}} & \cdots & \mathrm{r_{i1m}} \\ \mathrm{r_{i21}} & \mathrm{r_{i22}} & \cdots & \mathrm{r_{i2m}} \\ \cdots & \cdots & \cdots & \cdots \\ \mathrm{r_{ik1}} & \mathrm{r_{ik2}} & \cdots & \mathrm{r_{ikm}} \end{bmatrix} \tag{5.4}$$

where R_i is the fuzzy evaluation matrix which signifies a mapping from the index hierarchy to comment set.

(4) Fuzzy Comprehensive Analysis

Lastly, researcher can compute the risk factor comprehensive evaluation vector and its comprehensive evaluation value which can represent risk level. If one defines the weight researchers obtain from **Table 5-1** and **Table 5-2** are $\mathrm{A_1, A_2,\ldots,A_n}$ *and* the index matrix from equation (3) is $\mathrm{R_1, R_2,\ldots,R_n}$ as the number of risk factor is n, then the final assessment value for risk level is $\mathrm{V} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{A_iR_i}$, where V represents the risk level.

Figure 5- 1 Risk Assessment using FCMM

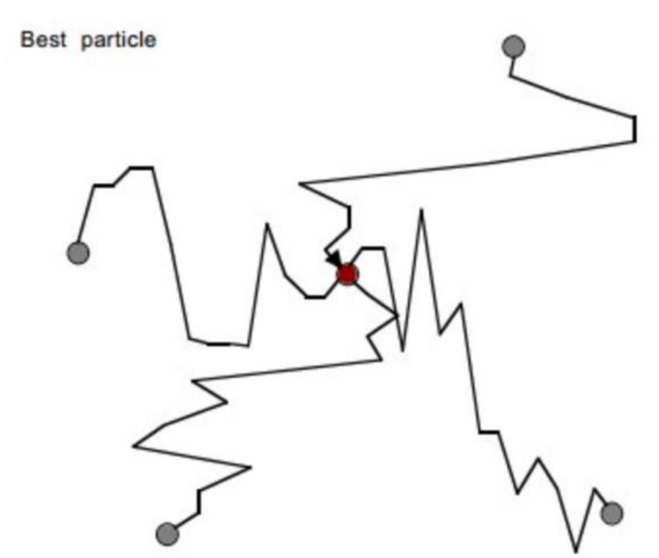


Note: This figure is obtained from Li et al. (2017) and clearly indicates how the FCMM method may be used to conduct risk evaluation.

5.2 Details of PSO Model Steps

In a previous chapter the present thesis introduces the PSO–AHP method. A further introduction to the PSO method is necessary to make clear some details for implementation in the next case studies. Researchers typically like to combine the use of PSO with another method (Kennedy and Eberhart, 1995). PSO essentially simulates a bird in a flock by using a massless particle. The particle has two properties: velocity and position, where velocity represents the speed of movement and position represents the direction of movement (**Figure 5-2**). Each particle searches for the optimal solution separately in the search space, renders a record as the current individual extremum and shares the individual extremum with other particles in the entire particle swarm to find the optimal individual extremum. All particles in the particle group adjust their speed and position according to the current individual extremum found by themselves.

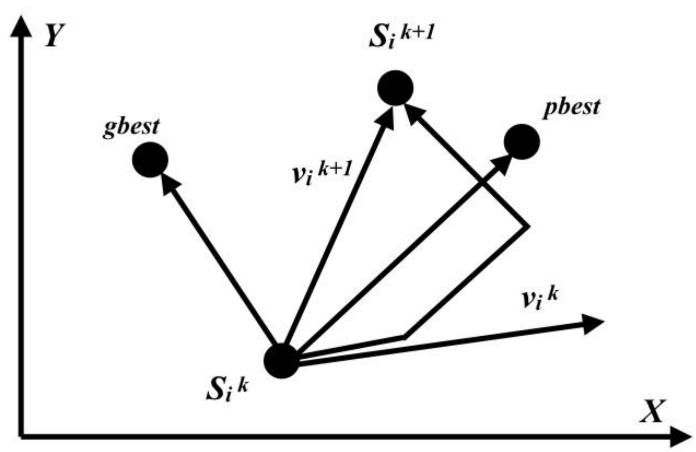
Figure 5- 2 Particles Moving Towards the Best Position



Note: This figure is obtained from DOI: 10.13140/RG.2.2.34256.76805 by Sarvepalli (2015).

The idea of PSO is relatively simple and is divided mainly into five steps: **(1)** initialise the particle swarm; **(2)** evaluate the particle, that is, calculate the fitness value; **(3)** find the individual extremum; **(4)** find the global optimal solution and **(5)** modify the particle speed and location (**Figure 5-3**).

Figure 5- 3 The Figure of Equation (5.5)



(1) Initialize particles

The maximum speed interval needs to be set to prevent the maximum range from being exceeded. The location information is the entire search space and the speed and position are initialised randomly in the speed interval and search space. The group size also needs to be set.

(2) Individual extremum and global optimal solution

The individual extremum is the historical optimal position information found by each particle. A globally optimal solution is found from these individual historical optimal solutions and compared with the historical optimal solution. The best solution is selected as the current history optimal solution.

(3) Update velocity and location

Following Xu et al. (2018), this thesis assumes the population size of the particle is N (In terms of the logistics project, it represents the number of risk factors). S_l represents the position of the particle of l(l = 1, 2, …, N), v_l represents the speed and f_l represents the adapted value. In each iteration of a simulation in PSO, the extremum of the particle tracking individual $p_{best_l}(t)$ (the best position of the particle in the flight process) and the global extremum $g_{best_l}(t)$ (the best position of the particle swarm in the flight process) are updated after the initial position and velocity are randomly generated. When the two optimal values are found at t + 1, the position and velocity of the particles are updated according to the equations as follows (**Figure 5-3**):

$$v_l(t+1) = wv_l(t) + c_1b_1(t)(p_{best_l}(t) - s_l(t)) + c_2b_2(t)(g_{best}(t) - s_l(t)$$

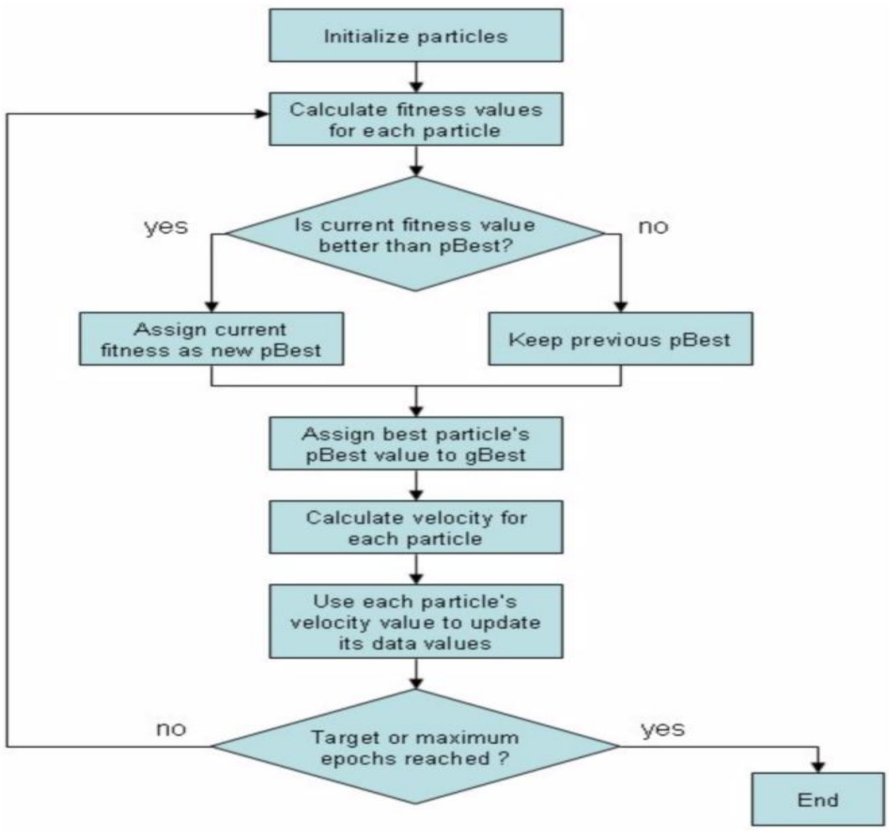
$$s_l(t+1) = s_l(t) + v_l(t+1), \quad (5.5)$$

where w is the weight; c1 and c2 are the individual particle and learning factors, respectively; b1(t) and b2(t) are the random numbers uniformly distributed between 0 and 1 respectively, describing the randomness of particle individuals and groups in the speed update process.

(4) Stop condition

Researchers who use the PSO method can specify a condition to stop the algorithm as shown in **Figure 5-4**.

Figure 5- 4 Framework of A PSO Algorithm



Note: This figure is obtained from DOI: 10.13140/RG.2.2.34256.76805 by Sarvepalli (2015).

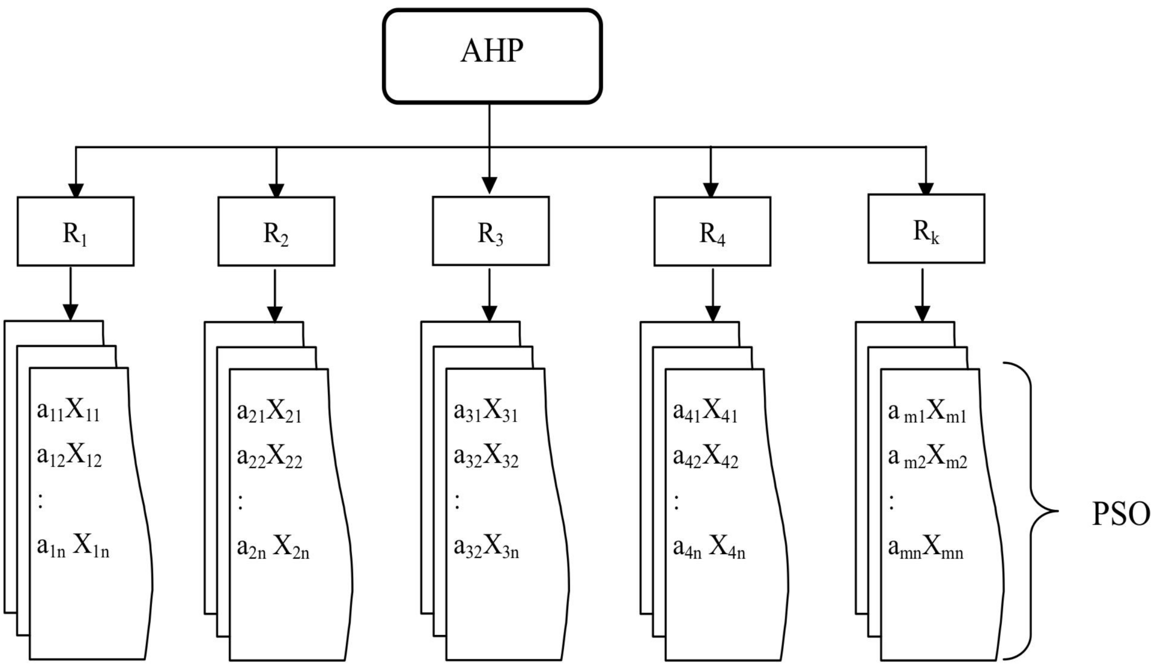
5.3 Details of PSO–AHP Model Steps

Numerous studies have used AHP and PSO to perform the analysis.[38] Huang et al. (2011) presented a two-phase algorithm approach to address the issue of a product part change, and the issue of supplier selection derived from the former. In the first step, AHP is used on people interview records to select the module in a product that needs to be changed with top priority, whereas in the second step, PSO is used to select the best suppliers. AHP is a structured technique used in organizing and analyzing complex

[38]According to the argument of Awad et al. (2011), PSO–AHP has the following advantages: **(1)** Enabling to develop risk information management; **(2)** Supporting effective decision-making for risk management; **(3)** Establishing practical risk organizing for organizations; **(4)** Providing valuable analysis data for future estimation.

decisions (Derbali et al., 2016; Ishizaka and Labib, 2014; Saaty, 2001); occasionally however, the results obtained from AHP alone are not appropriate enough. The current thesis combines the use of AHP and PSO to overcome this drawback, which has been used frequently by other studies (Huang et al., 2011).[39] PSO–AHP can be used to determine the weights in risk assessment (Di et al., 2018). The establishment process of the AHP model based on PSO is then as follows (**Figure 5-5 and Figure 5-6**):

Figure 5- 5 System Plan of AHP



Note: This figure is from Awad et al. (2011).

(1) Establish a hierarchical structure of the comprehensive evaluation system

[39]PSO-AHP has been applied in some research (Huang et al., 2011), but this thesis firstly applies it in the content of logistics risk evaluation, see ‘Predict the Logistic Risk: Fuzzy Comprehensive Measurement Method or Particle Swarm Optimization Algorithm?’ *EURASIP Journal on Wireless Communications and Networking (Xu et al., 2018)*.

Assume that the comprehensive evaluation system for a risk in project has four layers from top to bottom, which are recorded sequentially as A, B, C and D layers. The A layer is the overall goal of the system evaluation, which has only one element. The number of elements in the B, C and D layers is recorded as n_b, n_c and n_d.

(2) Construct a judgment matrix

In terms of the elements at B, C and D, people can compare them with each other using the method introduced in Section 5.1 with the 1–9 scale matrix. Thereafter, the judgement matrix for B is $A_K = (a_{ij})_{n_b \times n_b}$, where a_{ij} is the relative importance of B_i to B_j considering A. The judgement matrix for C is $B_K = \{b_{ij}^k | i,j = 1,\ldots,n_c; k = 1,\ldots,n_b\}_{n_c \times n_c}$ and the judgement matrix for D is $C_K = \{c_{ij}^k | i,j = 1 \sim n_d; k = 1 \sim n_c\}_{n_d \times n_d}$. Given that the general comprehensive evaluation uses numerous indicators, using the 1–9 scale method directly to determine the importance of the two elements is difficult, as sometimes it is not easy to do the calculation with 9 evaluation levels (Xu et al., 2018). For this reason, the indirect judgment matrix of the three judgment scales of 0, 1 and 2 can be used first, and then the indirect judgment matrix can be converted into a judgment matrix of the 1–9 level judgment scale to avoid logical errors; for the detail, please refer Xu et al. (2018).

(3) Establish a weight optimization model

Take the judgement matrix $A_K = (a_{ij})_{n_b \times n_b}$ as an example. Define the weight at B level as $w_K, k = 1,\ldots,n_b$. If A_K satisfies $a_{ij} = w_i / w_j (i,j = 1,\ldots,n_b)$, where w is the weight of each factor obtained from AHP, then A_K is completely consistent.[40] Thus, one can obtain the following equation

$$\sum_{i=1}^{n_b} \left| \sum_{k=1}^{n_b} (a_{ik} w_k) - n_b\, w_i \right| = 0, \qquad (5.6)$$

[40]The consistency of judgment matrix is important and requires that ratings should be transitive, meaning if A is better than B, and B is better than C, then A must be better than C (Wang et al., 2014).

where (5.6) indicates if the left value is small, then the consistence of A_K is high. When (5.6) is satisfied, then A_K is completely consistent. Thus the problem can be converted to the following optimal representation:

$$\mathrm{MinCIF}(n_b) = \sum_{i=1}^{n_b} \left| \sum_{k=1}^{n_b} (a_{ik} w_k) - n_b\, w_i \right| / n_b \qquad (5.7)$$

$$\begin{cases} \sum_{k=1}^{n_b} w_k = 1 \\ w_k > 0 (k = 1 \sim n_b) \end{cases},$$

where $\mathrm{CIF}(n_b)$ is the consistency indicator. If the matrix A is consistent and assumes λ is the largest eigenvalue of A, then the normalization vector of λ requires weights (Wang et al., 2014). Let *n* be the factor number and define consistency index

$$\mathrm{CI} = \frac{\lambda - n}{n - 1}, \qquad (5.8)$$

if CI=0, then Matrix A has complete consistency; if CI is close to 0, then Matrix A has acceptable consistency, which means the larger the matrix, the more inconsistency. Now define

$$\mathrm{CR} = \frac{CI}{RI}, \qquad (5.9)$$

if CR<0.1, then the consistency can be in an acceptable range, where the values of the random consistency index (RI) is as shown below (Saaty, 2001).[41]

Table 5- 3 Random Consistency Index (RI)

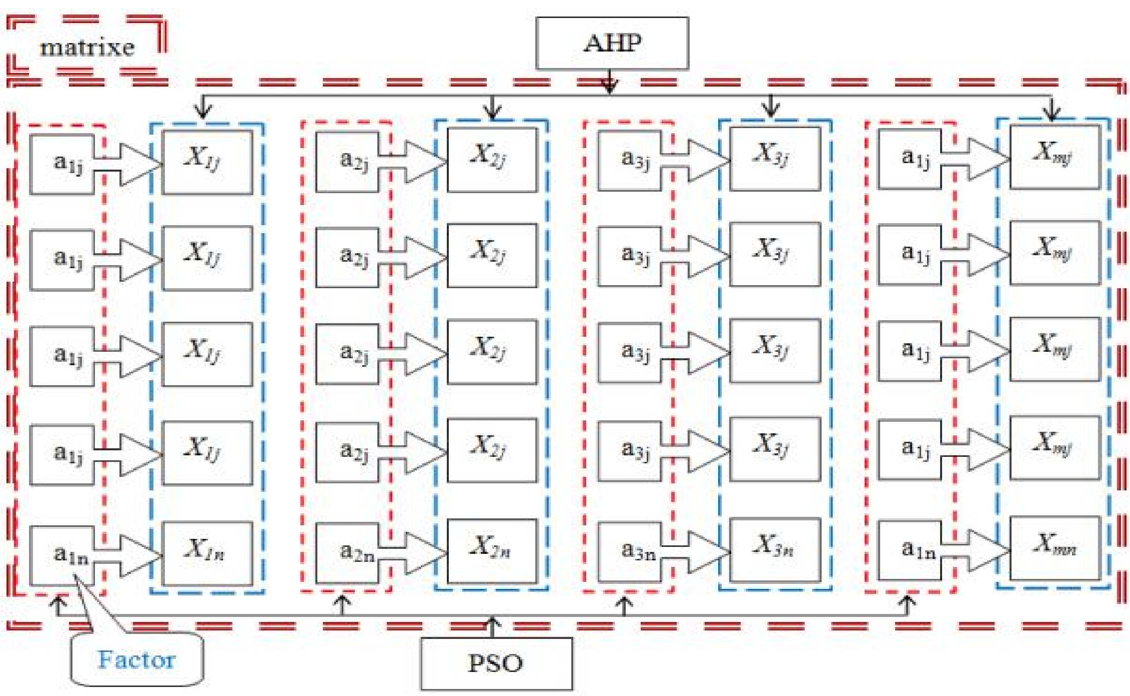
n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1,24	1.32	1.41	1.45

[41]Saaty (2001) proves that for consistent reciprocal matrix, the largest eigen value is equal to the size of comparison matrix. Then he gives a measure of consistency, called Consistency Index as deviation or degree of consistency. Saaty (2001) proposes that we use this index by comparing it with the approximate one. The approximate consistency index is called Random Consistency Index.

(4) Solve weight optimization via PSO and perform a consistency check

The PSO algorithm can be used to solve the optimal weight and to perform the consistency check, where level B has $\mathrm{w_K}(\mathrm{K}=1,\dots,\mathrm{n_b})$ and CIF($\mathrm{n_b}$), level C has $\mathrm{wc_i^A}=\sum_{\mathrm{k}=1}^{\mathrm{n_b}}\mathrm{w_k wc_i^k}(\mathrm{i}=1,\dots,\mathrm{n_c})$ and $\mathrm{CIF^A}(\mathrm{n_c})=\sum_{\mathrm{k}=1}^{\mathrm{n_b}}\mathrm{w_k CIF^K}(\mathrm{n_c})$ and level D has $\mathrm{wd_i^A}=\sum_{\mathrm{k}=1}^{\mathrm{n_c}}\mathrm{wc_k^A wd_i^k}(\mathrm{i}=1,\dots,\mathrm{n_d})$ and $\mathrm{CIF^A}(\mathrm{n_d})=\sum_{\mathrm{k}=1}^{\mathrm{n_c}}\mathrm{wc_k^A CIF^K}(\mathrm{n_d})$. When the value of $\mathrm{CIF^K}(\mathrm{n_d})$ is less than a certain standard (using the value in **Table 5-3**), the total sorting result of each element of the D layer can be considered to have satisfactory consistency and the total sorting weight $\mathrm{wd_i^A}$ of each element calculated according to this is acceptable. Otherwise, the maximum direction improvement method and the interval number improvement method is required to adjust the judgment matrix until the appropriate standard is met.

Figure 5-6 Maternal AHP & PSO



Note: This figure is from Awad et al. (2011).

5.4 Numerical Examples[42]

Now, this thesis applies the above two methods on the risk system building in **Chapter 4**. In Section 5.4, this thesis shows clearly how to use above two methods to do the risk evaluation in terms of logistics risk as a case example. Most of the calculation shown here is based on computer simulation, where the code is shown in the Appendix 1 at the end of the thesis. As shown in **Chapter 4**, this thesis sets 23 indicators shown in **Figure 5-7** for the existence of six types of risk to evaluate the risk of the logistics project, where:

(1) Logistics enterprise risk

a) Management Risk (U_1): Manager quality (U_{11}), Organizational structure (U_{12}), Corporate culture (U_{13}), Shareholder protection (U_{14}) and Management process (U_{15});

b) Technical Risk (U_2): Technical deficiencies (U_{21}), Technical protection (U_{22}), Technical development (U_{23}) and Technical use (U_{24});

c) Operational Risk (U_3) : Risk due to shippers (U_{31}) , Risk due to equipment (U_{32}) and Risk due to customers (U_{33});

(2) Logistics environment risk

a) Market Risk (U_4): Changes of consumer demand (U_{41}), Behavior of competitors (U_{42}), Uncertain and asymmetrical information (U_{43}) and Exchange rate (U_{44});

b) Fiscal Risk (U_5): Investment risk (U_{51}), Liquidity risk (U_{52}), Financing risk (U_{53}) and Risk of changes in interest rates (U_{54});

c) Environment Risk (U_6): Macroeconomic development (U_{61}), Policy and Law (U_{62}) and Political risk (U_{63}).

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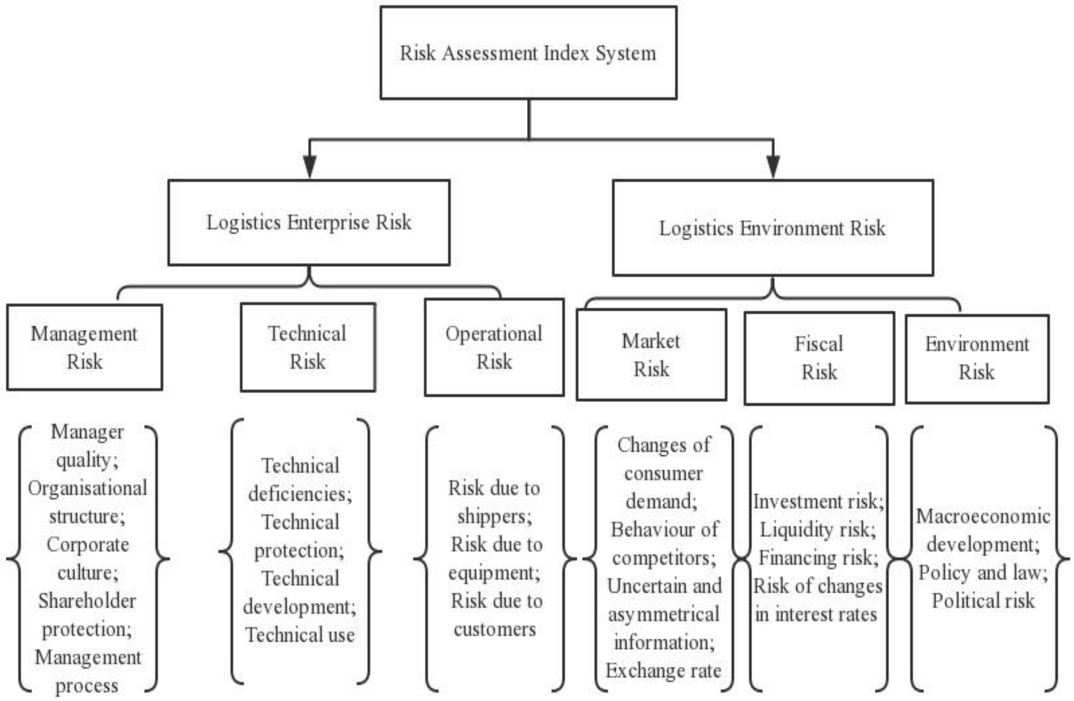
[42]This application is newly developed and carefully discussed in this thesis. Further detail of FCMM and PSO–AHP have been introduced by the author in a paper titled "Predict the Logistic Risk: Fuzzy Comprehensive Measurement Method or Particle Swarm Optimization Algorithm? *EURASIP Journal on Wireless Communications and Networking* (Xu et al., 2018).

Figure 5- 7 Risk Assessment Index System



5.4.1 Results of Fuzzy Comprehensive Measurement Method

Given that each index cannot be evaluated using the simple quantitative analysis method as a realistic case study example would be based on some solid experienced judgement of the author in the field of logistics, the FCMM method is used to make a fuzzy comprehensive evaluation of the risk. The indicator design is divided into two layers that require two fuzzy operations. The specific operation process is as follows.

(1) Grade classification of logistics project risk evaluation

The risk level is divided into 5 levels: low risk (V_1), medium–low risk (V_2), general risk (V_3), medium–high risk (V_4) and high risk (V_5). The above 5 evaluation rank elements constitute the evaluation level set $V=\{V_1, V_2, V_3, V_4, V_5\}$.[43]

(2) Weight allocation of evaluation index

For the six weights of the evaluation indicators, the following weight table can be obtained as shown in **Table 5-4.**[44]

Table 5- 4 Weight of Evaluation Index Subset of Logistics Project

Evaluation index subset	U_1	U_2	U_3	U_4	U_5	U_6
Weight	0.31	0.18	0.25	0.16	0.29	0.10

where the weight vector obtained by solid experienced judgement of the author in the field of logistics for risk index are as follows:

$$A_1 = (A_{11}, A_{12}, A_{13}, A_{14}, A_{15}) = (0.2, 0.1, 0.2, 0.3, 0.1)$$

$$A_2 = (A_{21}, A_{22}, A_{23}, A_{24}) = (0.3, 0.15, 0.1, 0.25)$$

$$A_3 = (A_{31}, A_{32}, A_{33}, A_{34}) = (0.15, 0.25, 0.2, 0.3)$$

$$A_4 = (A_{41}, A_{42}, A_{43}, A_{44}) = (0.1, 0.3, 0.15, 0.25)$$

[43]In this thesis, if the indicator of overall risk is 0-0.1, then the situation is considered as low risk. If the indicator of overall risk is 0.1-0.3, then the situation is considered as medium low risk. If the indicator of overall risk is 0.3-0.5, then the situation is considered as general risk. If the indicator of overall risk is 0.5-0.6, then the situation is considered as medium–high risk. Lastly, if the indicator of overall risk is above 0.6, then the situation is considered as high risk.

[44]The calculation step is shown in Section 5.3. The code this thesis used to do the calculation is attached in the Appendix 1.

$$A_5 = (A_{51}, A_{52}, A_{53}) = (0.4, 0.35, 0.2)$$

$$A_6 = (A_{61}, A_{62}, A_{63}) = (0.5, 0.4, 0.45).$$

Note that A_{ij} represents the importance of risk factor i over risk factor j.

(3) Determination of the evaluation matrix

According to the current situation and development forecast of the logistics project discussed in Chapter 1 in terms of the development of Chinese logistics, the evaluation matries used in this thesis are as follows:

$$R_1 = \begin{bmatrix} R_{11} \\ R_{12} \\ R_{13} \\ R_{14} \\ R_{15} \end{bmatrix} = \begin{bmatrix} 0.2 & 0.1 & 0.2 & 0.5 & 0 \\ 0.2 & 0.5 & 0.4 & 0.7 & 0 \\ 0.3 & 0.4 & 0.5 & 0.1 & 0 \\ 0.3 & 0.6 & 0.7 & 0.2 & 0 \\ 0.2 & 0.3 & 0.2 & 0.1 & 0 \end{bmatrix} \quad R_2 = \begin{bmatrix} R_{21} \\ R_{22} \\ R_{23} \\ R_{24} \end{bmatrix} = \begin{bmatrix} 0.3 & 0.2 & 0.2 & 0.2 & 0 \\ 0.3 & 0.1 & 0.4 & 0.3 & 0 \\ 0.2 & 0.4 & 0.3 & 0.1 & 0 \\ 0.5 & 0.2 & 0.1 & 0.2 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} R_{31} \\ R_{32} \\ R_{33} \\ R_{34} \end{bmatrix} = \begin{bmatrix} 0.4 & 0.3 & 0.3 & 0.1 & 0 \\ 0.2 & 0.5 & 0.5 & 0.4 & 0 \\ 0.3 & 0.6 & 0.6 & 0.1 & 0 \\ 0.2 & 0.1 & 0.2 & 0.3 & 0 \end{bmatrix} \quad R_4 = \begin{bmatrix} R_{41} \\ R_{42} \\ R_{43} \\ R_{44} \end{bmatrix} = \begin{bmatrix} 0.2 & 0.5 & 0.3 & 0.1 & 0.1 \\ 0.1 & 0.6 & 0.2 & 0.3 & 0.2 \\ 0.4 & 0.3 & 0.4 & 0 & 0.1 \\ 0.5 & 0.5 & 0.7 & 0 & 0 \end{bmatrix}$$

$$R_5 = \begin{bmatrix} R_{51} \\ R_{52} \\ R_{53} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.3 & 0.3 & 0.3 & 0.1 \\ 0.4 & 0.7 & 0.2 & 0.2 & 0 \\ 0.5 & 0.4 & 0.6 & 0.1 & 0 \end{bmatrix} \quad R_6 = \begin{bmatrix} R_{61} \\ R_{62} \\ R_{63} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.6 & 0.3 & 0.2 & 0 \\ 0.8 & 0.4 & 0.6 & 0.5 & 0 \\ 0.3 & 0.1 & 0.3 & 0.3 & 0 \end{bmatrix}$$

(4) Fuzzy comprehensive measurement

According to the discussion in Section 5.1, this thesis applies the mathematical model formula $A_i * R_i = B_i$ to obtain the risk level indicator, where $B_i = (b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5})$ $(i = 1,2,3,4,5,\ b_{ij} \in [0,1])$

$$(A_{i1}, A_{i2}, A_{i3}, A_{i4}, A_{i5}) * \begin{bmatrix} r_{i11} & r_{i12} & r_{i13} & r_{i14} & r_{i15} \\ r_{i21} & r_{i22} & r_{i23} & r_{i24} & r_{i25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{ik1} & r_{ik2} & r_{ik3} & r_{ik4} & r_{ik5} \end{bmatrix} = (b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5}) \quad , \qquad (5.10)$$

where the fuzzy subset $B_i = (b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5})$ $(i = 1,2,3,4,5,\ b_{ij} \in [0,1])$ is the first level of comprehensive evaluation results, indicating that each R_i (i=1,2,3,4,5) within the scope of the logistics project to the extent of the percentage is in five levels: "low risk", "medium–low risk", "general risk", "medium–high risk" and "high risk". Note that R is determined from equations (5.1) to (5.10).

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} \end{bmatrix} = \begin{bmatrix} 0.25 & 0.38 & 0.47 & 0.1 & 0.2 \\ 0.37 & 0.48 & 0.21 & 0.2 & 0.1 \\ 0.39 & 0.40 & 0.28 & 0.17 & 0.12 \\ 0.34 & 0.49 & 0.29 & 0.26 & 0.33 \\ 0.03 & 0.29 & 0.117 & 0.01 & 0.35 \\ 0.28 & 0.36 & 0.05 & 0.28 & 0.04 \end{bmatrix}$$

Then the weight vector A=($A_1, A_2, A_3, A_4, A_5, A_6$) should be used. According to the fuzzy mathematical evaluation model formula (Section 5.1), the second level fuzzy comprehensive evaluation operation is carried out: A*R=B, where

$$(A_1, A_2, A_3, A_4, A_5, A_6) * \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} \end{bmatrix} = (b_1, b_2, b_3, b_4, b_5) \qquad (5.11)$$

where B=$(b_1, b_2, b_3, b_4, b_5)$ is the overall evaluation results. Then

$$B = [0.31\ \ 0.18\ \ 0.15\ \ 0.16\ \ 0.1\ \ 0.10] * \begin{bmatrix} 0.25 & 0.38 & 0.47 & 0.1 & 0.2 \\ 0.37 & 0.48 & 0.21 & 0.2 & 0.1 \\ 0.39 & 0.40 & 0.28 & 0.17 & 0.12 \\ 0.34 & 0.49 & 0.29 & 0.26 & 0.33 \\ 0.03 & 0.29 & 0.117 & 0.01 & 0.35 \\ 0.28 & 0.36 & 0.05 & 0.28 & 0.04 \end{bmatrix}$$

The calculated results are

B= （0.3327 0.5027 0.33883 0.182 0.2683）

where the result shows that the maximum membership degree of Matrix B is 0.5027 and the overall risk level of the logistics project is medium-high according to the standard introduced in Footnote 43. Moreover, according to the value in weight vector, the result shows that management risk plays the most important role in risk and is consistent with the fact that with the development of economics, management becomes increasingly important in the development of enterprises (Huang et al., 2011; Xu et al., 2018; Bai et al., 2018).

5.4.2 Results of PSO–AHP Algorithm

This thesis considers combining the advantages of AHP and PSO to obtain the PSO–AHP method to maximise the original information of the decision-makers, to make the judgment matrix have substantial consistency and improve the weight value. Details of the PSO–AHP algorithm results are as follows:

(1) Establish a hierarchical structure of the comprehensive evaluation system

According to the risk stratification classification, the comprehensive evaluation system has six layers from top to bottom (See **Chapter 4**, the discussion of system), which are recorded sequentially as A, B, C, D, E and F layers. The number of elements in each layer is 5, 4, 4, 4, 3 and 3, respectively.

(2) Establish judgment matrix

A is the first layer factor. For the factors of B, C, D, E, and F layers, the elements of the above layer are compared with each other according to the criteria. The relative importance of each element and the judgment matrix of each layer according to the scale of 1~9 of **Table 5-1** decided by the author of this thesis according to empirical analysis in existent research (Huang et al., 2011; Xu et al., 2018), is shown below.

$$A = \begin{bmatrix} 1 & 6/5 & 3/2 & 1 & 7 \\ 5/6 & 1 & 6/5 & 4/5 & 6 \\ 2/3 & 5/6 & 1 & 3/4 & 5 \\ 1 & 5/4 & 4/3 & 1 & 7 \\ 1/7 & 1/6 & 1/5 & 1/7 & 1 \end{bmatrix} \quad B = \begin{bmatrix} 1 & 3/2 & 9/4 & 3 \\ 2/3 & 1 & 1 & 9/4 \\ 4/9 & 1 & 1 & 3/2 \\ 1/3 & 4/9 & 2/3 & 1 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 3/4 & 2 & 2 \\ 4/3 & 1 & 8/3 & 5 \\ 1/2 & 3/8 & 1 & 2 \\ 1/2 & 1/5 & 1/2 & 1 \end{bmatrix} \quad D = \begin{bmatrix} 1 & 3/5 & 4 & 8/5 \\ 5/3 & 1 & 5 & 7/3 \\ 1/4 & 1/5 & 1 & 5/2 \\ 5/8 & 3/7 & 5/2 & 1 \end{bmatrix}$$

$$E = \begin{bmatrix} 1 & 1/4 & 1/8 \\ 4 & 1 & 1/2 \\ 8 & 2 & 1 \end{bmatrix} \quad F = \begin{bmatrix} 1 & 3/8 & 1/6 \\ 8/3 & 1 & 2 \\ 6 & 1/2 & 1 \end{bmatrix}$$

(3) Solve via PSO Algorithm

Referring to the solution process of the PSO–AHP model in Section 5.3, the weight value and the consistency index function value of the given judgment matrix are programmed to be solved (See code in the Appendix 1) and the results are shown in the following table.

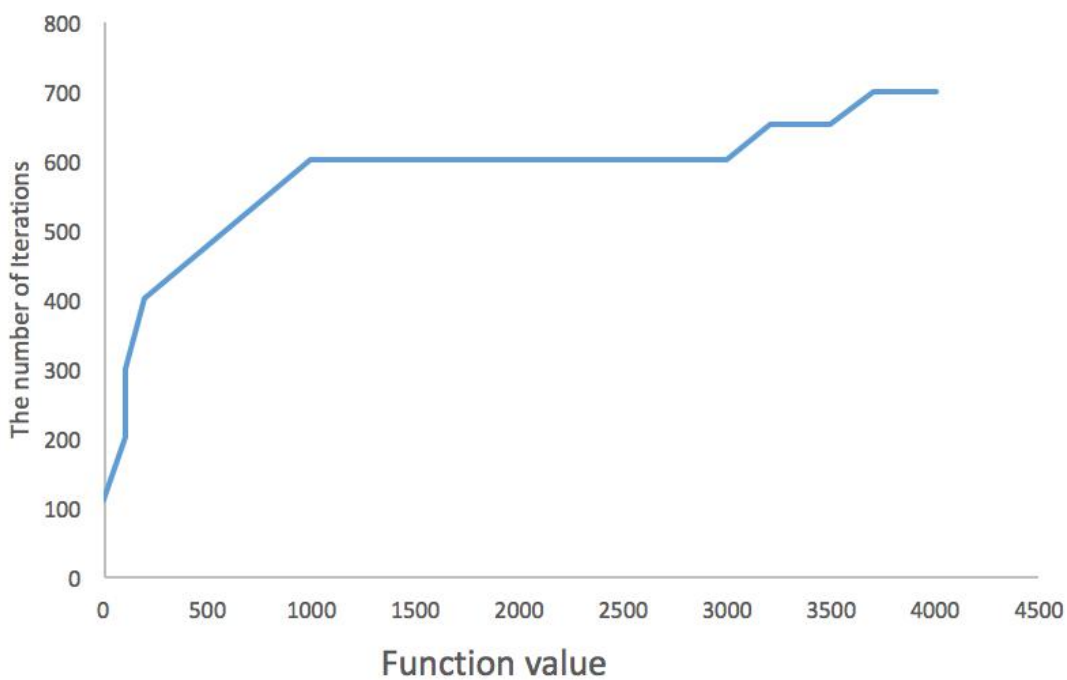
Table 5- 5 Results of PSO–AHP

	w_1	w_2	w_3	w_4	w_5	CIF
Management risk	0.378	0.253	0.172	0.118		0.00180
Technical risk	0.275	0.227	0.191	0.270	0.038	0.00178
Operational risk	0.223	0.329	0.123	0.065		0.01210
Market risk	0.214	0.321	0.057	0.136		0.00217
Fiscal risk	0.037	0.147	0.293			0.00195

Environment risk	0.273	0.727	0.079			0.00000

According to $\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1}$, CI = 0.02 can be obtained (See code in the **Appendix 1**), which means this matrix satisfies consistency. The weight of risk is WA={0.2778 0.1256 0.1846 0.1722 0.5380 0.1398}. This thesis uses MATLAB software (See code in the Appendix 1) to run the algorithm and to apply the PSO–AHP model, where the parameters are set as follows (Xu et al., 2018): population size N=700, c_1=c_2=3 (See equation (5.5)), inertia weight w=0.8298, v=0.5*rand(m,n), maximum number of iterations G_{max}=60. After 2000 iterative search calculations, the relationship between the projection template and the number of iterations could be achieved as discussed in **Figure 5-8**.

Figure 5- 8 Relationship between function value and the number of iterations



Note: The x-axis represents the value of the number of iterations, whereas the y-axis represents the value of the projection objective. When the number of iterations increases, the projective value will also increase.

The results of error analysis are presented in **Table 5-6**.

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Table 5- 6 Error Analysis of Calculation Result

Range	[0,0.05]	[0,0.1]	[0,0.15]	[0,0.2]
Percentage of errors in the interval（%）	35	75	85	90

Range	[0,0.25]	[0,0.3]	[0,0.35]	[0,0.4]
Percentage of errors in the interval（%）	105	120	150	500

Note: The range represents the value of error. The detail meaning of each value, this thesis refers Xu et al. (2018).

Furthermore, given that the optimal weight is WA ={0.2778 0.1256 0.1846 0.1722 0.5380 0.1398}, B is calculated again, which is

$$B = [0.2778 \;\; 0.1256 \;\; 0.0846 \;\; 0.0722 \;\; 0.3398 \;\; 0.1] * \begin{bmatrix} 0.25 & 0.38 & 0.47 & 0.1 & 0.2 \\ 0.37 & 0.48 & 0.21 & 0.2 & 0.1 \\ 0.39 & 0.40 & 0.28 & 0.17 & 0.12 \\ 0.34 & 0.49 & 0.29 & 0.26 & 0.33 \\ 0.03 & 0.29 & 0.117 & 0.01 & 0.35 \\ 0.28 & 0.36 & 0.05 & 0.28 & 0.04 \end{bmatrix}$$

The calculated results are as follows:

B = （0.301748　0.530418　0.328504　0.173578　0.34099）

where the result shows that the maximum membership degree of Matrix B is 0.53 and the overall risk level of the logistics project is medium-high. Moreover, the value in weight vector shows that the fourth risk, which is fiscal risk (See the discussion of risk system in **Chapter 4**), plays the most important role in risk and is consistent with the fact that with the development of economics, cash flow becomes increasingly important in the development of enterprises. The same fact applies to large-scale logistics enterprises, where if such enterprises cannot receive sufficient cash flow when they implement large-scale logistics projects, then for them to keep the project safe is dangerous.

5.4.3 Which One is Better?

From the above example, this thesis notes that when using the AHP method to solve multi-attribute decision-making problems, researchers must first determine the expert judgment matrix. Then the ranking weight vector is calculated according to the judgment matrix. The consistency problem of the judgment matrix is the core problem of the AHP method. Whether the consistency is reasonable or not directly affects whether the final ranking weight vector can truly and objectively reflect the objective ranking among various schemes or attributes. Therefore, the method to modify the inconsistent expert judgment matrix and the consistency test of the judgment matrix have become a core content of the analytic hierarchy process. From this point, PSO method can perform much better than the FCMM method. In terms of the results obtained from these two models using the risk system built in **Chapter 4**, which are shown in **Table 5-7**, this thesis draws the following conclusions.

The results reveal that both methods indicate the overall risk of the project is medium, which is around 0.5. The results are consistent with each other. However, when the weight vector is considered, the results are somewhat different: for FCMM, the highest value in weight vector is 0.31, which is management risk, indicating that in all six risk types, management plays the most important role. When a large-scale logistics project is implemented, attention should be given to the management. The PSO–AHP method shows that fiscal risk plays the most important role considering that the value for weight is 0.3398. Therefore, when large-scale logistics projects are implemented, attention should be given to the fiscal issue. From this example, when methods are used to evaluate risk, only one method cannot be relied upon and different methods should be used to combine the results and observe the outcome. This thesis uses the two methods to evaluate the real situation in **Chapter 6**.[45]

[45]The numerical example given in Chapter 5 is based on the risk system built in Chapter 4. This thesis

Table 5- 7 Results from FCMM and PSO–AHP

Table A

Method	Risk Indicator				
FCMM	0.3327	0.5027	0.33883	0.182	0.2683
PSO–AHP	0.301748	0.530418	0.328504	0.173578	0.34099

Table B

Method	Management risk	Technical risk	Operational risk	Market risk	Fiscal risk	Environment risk
FCMM	0.31	0.18	0.15	0.16	0.1	0.10
PSO–AHP	0.2778	0.1256	0.0846	0.0722	0.3398	0.1

5.5 Summary

In this chapter, details of the two methods and the steps mainly used in this thesis were summarised, the FCMM and PSO-AHP methods. The chapter revealed the results from the two methods for a numerical example built based on the risk system in **Chapter 4**, where both methods indicated the overall risk is medium. There is a large number of research focusing on the use of FCMM to perform risk assessment. Cheng and Xiao (2009) integrated the concepts of AHP and fuzzy consistent matrix method to identify risk factors during bridge construction. Cheng et al. (2008) presented a fuzzy logic-based method, which synthesizes the fuzzy AHP method on the basis of a three-point scale, fuzzy set theory and fuzzy logic which are integrated into a single approach to measure the risk of bridges during construction. However, studies focusing on the use of PSO-AHP method for the risk assessment of large-scale logistics projects are limited. Huang et al. (2011) focus on the combination of AHP and PSO and use it to maximize the value of product updating so as to extend the product life cycle, while this thesis

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does not use the real case to determine the weight for each factor in this risk system. The author of this thesis decides weight by empirical results from some research (Huang et al., 2011; Xu et al., 2018). In Chapter 6, the two methods are applied to perform a risk evaluation for Hanjin Shipping that clearly shows what is the main risk involved that resulted in the bankruptcy of Hanjin Shipping.

combines AHP and PSO and uses WBS together to build the risk indicator system, which is the basis of PSO-AHP method. Therefore, the present study not only uses the FCMM to deal with risk assessment but also employs the PSO-AHP method and then selects the best one according to some criteria. By doing so, this thesis provides an excellent example for researchers to choose between the two models for conducting risk assessment.

Note that for the example illustrated in this chapter, FCMM indicated that the most important part is management, whereas PSO–AHP indicated that the most important issue is fiscal risk. Awad et al. (2011) argued that PSO–AHP has numerous advantages, such as enabling the development of risk information management, supporting effective decision-making for risk management, establishing practical risk organising for organisations and providing valuable analysis data for future estimation. Wang et al. (2012) argued that in the risk evaluation area, given the uncertainty of risk factors, an evaluation of the level of risk via exact quantitative methods is difficult, and thus the use of the FCMM method to change a qualitative question to a quantitative one is meaningful (Chen, 1984; Cheng and Tao, 2010; Xie et al., 2017). The FCMM method has been a popular model in terms of risk evaluation because of this factor (Yazdani et al., 2014). From these arguments, a decision regarding which method is better is difficult to reach. Thus, the following chapter uses both methods to perform the risk evaluation for a real problem and then gives further comparison between these two methods (See the footnote 34).

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Chapter 6 ：

Risk Evaluation and Prevention: Case Studies

Chapter 5 introduced the basic models that the thesis uses and provided a numerical example based on the risk system built in **Chapter 4** of how these models are used when performing the risk evaluation. The FCMM and PSO–AHP methods can evaluate the risk level correctly as indicated from the previous chapter, but the details of each risk weight are different, which means a combination of these two models to perform the risk evaluation seems to be advantageous. In this chapter, the two methods are applied to perform a risk evaluation for Hanjin Shipping to show what is the main risk involved that resulted in the bankruptcy of Hanjin Shipping, which can be considered as novel here, the application of the methods to a case with real data. After the aforementioned discussion, this chapter analyses the definition and division of the modern logistics industry and expounds on the project management model encountered by logistics issues in the transitional period. After showing how to use these two methods to do the risk analysis, this study further analyses and interprets project management in the logistics industry; regulates and annotates the meaning of the project and defines the project's specific operation contents as '5 + 1' (Chen et al., 2010), which collects practical demands and a theoretical foundation of the project risk management mechanism. The case study on this issue is Shandong New Jiahong Company,[46] where a basic explanation regarding how risks can be managed is given. This chapter provides the base and necessity of the project management mode and the risk prevention and control mechanism, further providing the background for **Chapter 7**, where this thesis focuses on the prevention of the risk to the logistics project.

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[46]PSO-AHP could also be applied for Shandong New Jiahong Company. But as this thesis has used Hanjing Shipping as a case to show the application of PSO-AHP for Shandong New Jiahong Company, this thesis focuses on the risk prevention and control mechanism.

6.1 Necessity of Risk Evaluation and Prevention

The concept of logistics first appeared in the 1930s (Ballou, 2006; Chopra and Sodhi, 2004; Dong, 2013; Huang et al., 2011; Geraldi and Lechler, 2012). The concept was introduced in China for about half a century. According to the ‘National Standard of the People's Republic of China - Logistics Terminology’, logistics refers to the flow of goods from the supplier to the receiving entity, including the organic integration of transport, storage, load, offload, handling, packaging, circulation process, distribution and information process based on actual needs. Traditional logistics means ‘physical distribution’ or ‘goods delivery’. Since the 20th century, the logistics industry underwent a transformation from traditional to modern logistics (Dong, 2013), the concept of logistics systematisation was introduced, namely, social and corporate logistics were combined, leading to the integration and extension of both ends of the logistics and ultimately achieving the transformation of logistics from industry activities to a form of integrated organisation management. As a result, project management is upgraded into a basic component of this industry rather than being only one of the management methods; the importance and significance thereof are also increased.

With the acceleration of economic integration and the rise of e-commerce that led to the emergence and considerable development of the logistics industry, traditional logistics has been gradually replaced by modern logistics (Christopher et al., 2011; Disterer, 2002; Huang et al., 2011; Geraldi and Lechler, 2012; Liu and Xu, 2008;). Opportunities and risks created through industry evolution coexist. The bankruptcy of Hanjin Shipping, the Korean logistics firm, illustrates the risk crisis in current logistics projects (Cohen and Kunreuther, 2007; Huang et al., 2011; Liu and Xu, 2008). Hanjin urgently needs reasonable risk evaluation and risk prevention mechanisms to address the various risks facing the logistics industry. Given these problems, scholars have carried out some of the following research work and achieved results from theoretical research: defined life cycle of logistics projects; proposed the advantages of introducing project management into logistics projects; analysed the complexity of system construction in logistics project management; classified preliminarily the risk categories in logistics projects and finalised the direction and mode of risk control mechanisms in logistics projects (Colicchia and Strozzi, 2012; Liu and Xu, 2008; Xu et al., 2018). However, since the project management theory was introduced into the logistics industry has only been a short space of time; research, especially domestic research in China, continues to be in the exploratory stage that failed to establish a mature management system and mode of operation (Denyer and Tranfield, 2009; Disterer, 2002; Huang et al., 2011; Rousseau et al., 2008). A combination of the research of modern logistics, project management and risk prevention and control is necessary to establish a theoretical system of logistics project risk prevention and control, which is suitable, pertinent and applicable for modern enterprises.

Project management theory forms the basis of this chapter. The theories and methods of comparative management, systems engineering, risk management, mathematics and logic are applied adequately and comprehensively in this chapter to perform risk evaluation and prevention (Disterer, 2002; Geraldi and Lechler, 2012; Jayant et al., 2012; Jin and Gao, 2011). Taking the logistics project under project risk evaluation as the research target and the risk prevention and control mechanism as the main topic, this chapter establishes the necessity and importance of the logistics project management mode through analysing the current situation and development trend of the logistics industry. Based on the aforementioned research, this chapter defines and discerns the logistics project risk, analyses cause and consequence of logistics project risk and establishes a set of independent risk prevention and control mechanisms in the logistics project environment according to the attributes and characteristics of logistics project risk. The chapter verifies the appropriateness of the theoretical research direction by analysing the logistics control system of Korea Hanjin Marine Logistics Co., Ltd. as a case study. This study also takes the New Jiahong Logistics Company as a partner case study and experimental target and conducts an experimental operation to confirm the feasibility of the logistics risk control mechanism. The two methods (FCMM and PSO-AHP) are applied to perform a risk evaluation for Hanjin Shipping to show what is the main risk involved that resulted in the bankruptcy of Hanjin Shipping, which can be considered as novel here, the application of the methods to a case with real data. The aforementioned topics are discussed logically and sequentially in the ensuing sections of this chapter.

6.2 Risk Evaluation: Case Study of Hanjin Shipping

6.2.1 Hanjin Shipping Bankruptcy

Hanjin Shipping Company, established in 1977, was the largest shipping company in Korea and one of the world’s top ten shipping companies (ranked seventh). Hanjin Group, the parent holding company, was a global logistics and transportation giant. Hanjin Shipping Company had more than 200 vessels and the total shipping capacity reached seventh in the world, operating more than 60 routes in the global range with the volume of annual transport at more than a few hundred million tons of cargo globally. Hanjin Shipping Company had established a global network of four regional headquarters, more than 200 branches in over 30 companies in the global operational network, with 13 professional wharves and six inland logistics bases, two of which were based in Shanghai and Qingdao in China. Hanjin Shipping's main business was divided into six categories; in addition to ship repair and the ship building business, all other categories involved the logistics projects launched, including: Electronic platform services, freezer business, container business, bulk shipping business and terminal operations. The company’s branches were responsible for a third-party logistics business and had subsidiaries in 25 countries, a total of more than 150 global customers with aviation and maritime transport, inventory management and other transportation services. Hanjin Shipping's operating system involved order, warehouse and transportation management and service management systems, which were the typical new management systems (Huang et al., 2011; Song, 2003; Sun, 2007; Xu and Liu, 2008).

Hanjin Shipping Company was in trouble owing to heavy debt. According to statistics, the company had debt of approximately 40 billion yuan with a debt ratio close to 850% by the end of 2015. The company lost about 2.8 billion yuan in the first half of 2016. Hanjin Maritime filed an application to the court for bankruptcy protection on August 31, 2016, which was reported by the media as 'the largest bankruptcy in the history of global shipping'. After the news, a series of reactions were triggered. A number of cooperative companies of the enterprise, such as China Ocean Shipping, Taiwan Evergreen Marine and Japan Kawasaki Steamboat, swiftly announced a comprehensive suspension of cooperation with Hanjin Shipping. Concerted actions were taken in global ports to not allow Hanjin Shipping's vessels to anchor and or disembark containers, and withholding Hanjin's ships; The enterprise came to a complete standstill and the total loss was valued at about 14 billion US dollars. Shanghai Shipping Exchange researcher Zhou in 2017 said that Hanjin Shipping's bankruptcy had strongly affected the global shipping industry in the short-term, involving the owners, ports, freight forwarders, trailer companies and other industrial chains of various suppliers. For the owners of the goods, the current containers in transit faced the risk of detention or being unable to deliver on time. Another expert believed that the actual impact of Hanjin Shipping's bankruptcy was limited to the logistics industry, but affected the Korean economic development. On September 13, 2016, South Korean President Park Geun Hye said publicly that Hanjin Shipping's bankruptcy led the logistics industry into chaos and Hanjin Group should bear the consequences.

In summary, Hanjin Shipping had a long history, with a strong mode of advanced logistics enterprises. The company's bankruptcy took the entire logistics industry in South Korea into market shock and lack of confidence, which spread globally. Therefore, a study of this case by using the theory of project management is necessary. Analysing the reasons through this thesis behind Hanjin Shipping's bankruptcy and management loopholes should provide a meaningful experience for contemporary logistics enterprises.

6.2.2 Weak Risk Control Made Hanjin Collapse

Experts in the logistics industry believe that the main reasons for Hanjin Shipping's bankruptcy are as follows (Huang et al., 2011; Jayant et al., 2012; Jin and Gao, 2011; Swink et al., 2007; Xu and Liu, 2008):

a) Frequent changes of the president: Hanjin Shipping was founded by Cho Jung-Hoon. In 2003, Cho Jung-Hoon's son Cho Shu-ho took over the president in 2007. Cho Shu-ho passed away and his wife Cuiyin Ying inherited the duties. Cho Yang-ho took over Hanjin in 2013. The frequent changes of CEO made management difficult.

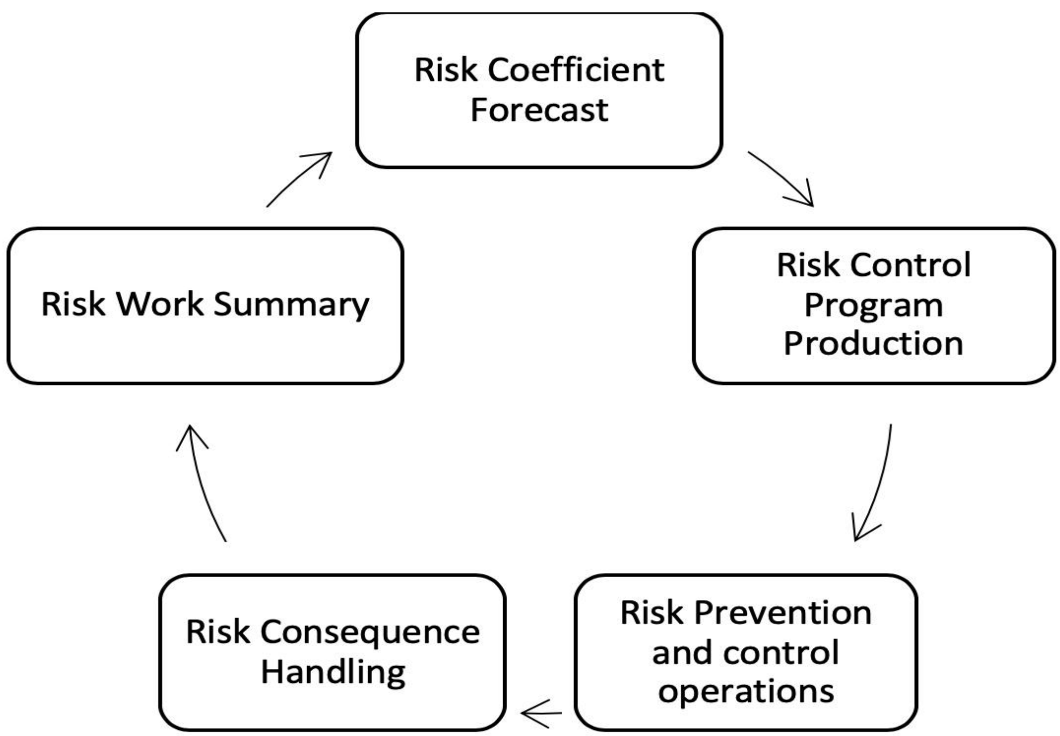
b) The financial crisis: Global trade was affected heavily as a result of the 2008 financial crisis. According to the data at that time, Hanjin Shipping's revenue declined in 2008 and by the first quarter of 2009, the revenue was showing an extremely large loss.

c) Industrial cost adjustment: Before 2008, maritime logistics was in a golden age, which led to the rapid expansion of numerous shipping companies. After 2008, the maritime transport logistics industry was showing signs of overcapacity; shipping enterprises began to enhance the price war to improve competitiveness in the market. Simultaneously, maritime technological progress reduced the cost of shipping logistics, which resulted in freight declining step by step. In contrast, charter costs continued to remain high. In 2015, for example, when Hanjin's seaborne turnover was 7.7 trillion won, the charter costs were at 1.1 trillion won.

d) Failure of a self-rescue plan: Following Hanjin's crisis, the leadership adopted certain post-remedial strategies, such as selling assets, selling shares and applying for loans, but these actions failed to solve the problem. In particular, the 500 billion won self-rescue plan was rejected by creditors, which led to the final crash of Hanjin Shipping.

In accordance with the risk division (**Figure 6-1**), after 2003, Hanjin shipping certainly suffered from management risk under the risk of internal personnel changes (Jayant et al., 2012; Jin and Gao, 2011; Xu and Liu, 2008), a reasonable degree of risk for decision-making, external risk fluctuations in the economic situation, the strength of competitor’s risk, risk of supply and demand change and customer satisfaction problems. Hanjin probably suffered the risk of the quality of management personnel in the internal risk, the risk of decision-making at a feasible degree and the risk of adjustment of policies and regulations in external risk and the enterprise’s adaptability. Hanjin Shipping was subject to the occurrence of all these risks, which run through the entire logistics project of the enterprise's total life cycle (especially after 2008) (Huang et al., 2011; Xu et al., 2018).

Figure 6- 1 Full Life Cycle of Risk Management



From the perspective of probability of occurrence and loss suffered (**Tables 6-1** and **6-2**) since 2008, given frequent changes in the high-level management personnel, Hanjin logistics' probability of management risk is on P5 level (close to inevitable) decided in this thesis according the situations author analyzed. Because of the increased competition in the industry, Hanjin's logistics probability of market risk is P4 level (common). These three risks together caused the loss of market value, loss of customers and social loss (loss of reputation and legal consequences). The ultimate loss level is L5 (disaster level (loss of assets)), which is beyond the enterprise's ability to handle.

Table 6- 1 Project Risk Probability Classification

Level	P1	P2	P3	P4	P5
Probability	Almost no	rarely	Common	Frequently	Almost inevitable

Table 6- 2 Management Risk Classification

Division Basis	Classification	Description
Source of risk	Natural risk	Natural changes or geological disasters, such as rain and snow, geological disasters.
	Human risk	Social or personal factors, such as policy changes, operational errors and so on.
Risk pattern	Static risk	Irregular changes in natural forces or human behaviour errors
	Dynamic risk	Changes in the market environment or social environment risk
Risk opportunity	Pure risk	Cannot bring any profit, the consequences include two aspects, loss or did not cause any damages.
	Speculative risk	Both potentially harmful consequences and the existence of a possible risk of interest, three consequences occurred, namely, leading to profits, resulting in loss and no loss.
Influence level	Acceptable risk	Consequences and effects of risk within the acceptable range, such as individual employee resignation and

		damage to less valued goods.
	Non -acceptable risk	Serious consequences beyond the enterprises' ability to bear, such as disbandment of the core group and the transport system out of control.

Based on the material and literature review this thesis does, Hanjin Marine confirmed that the risk mitigation measures included the following: risk reduction (seeking loan support), risk transfer (selling equity) and risk retention (selling assets to make up for loopholes). These measures are generally remedial, that is, Hanjin Shipping was intended to begin risk management in the early stage when risk occurred, which is against the principle of risk forecasting, prevention and control operations. From the effect perspective, the sale of equity and assets was not enough to cover losses and the search for loan support ended in failure. Therefore, these measures did not play a substantive role and failed to assist the enterprises in completing the objectives or tasks which can make profit.

In summary, Hanjin Shipping's bankruptcy had internal and external factors. According to project management theory (Jayant et al., 2012; Jin and Gao, 2011; Li, 2011), the main mistakes of the enterprise in project risk prevention and control were: Failing to complete the risk factor prediction in time, failing to take the appropriate risk responsive measures, failing to properly address the risk consequence, failure to effectively accomplish and utilise summary of risk prevention and control and failure to match properly and integrate the project life cycle with the risk management process. Hanjin's logistics failed to establish a sound project risk control mechanism that could avoid or respond effectively to the occurrence of the risk, resulting in catastrophic consequences.

6.2.3 Risk Evaluation of Hanjin Shipping

According to Section 6.2.1, the bankruptcy of Hanjin Shipping is due mainly to management risk. The index system this thesis rendered in **Chapter 4** indicates that management risk is one of the risks that requires attention when engaging in logistics projects. **Chapter 5** reveals that management risk is the main risk when using the FCMM method. This section applies mainly the two methods (FCMM and PSO–AHP) to the case of Hanjin Shipping to confirm the usefulness of FCMM and PSO–AHP methods in risk assessment, to observe whether the risk level of Hanjin Shipping is high and whether the main risk that created the bankruptcy of Hanjin Shipping is management risk. This thesis sets 23 indicators shown in Figure 6-2 to evaluate the risk of logistics projects based on the existence of six types of risk.

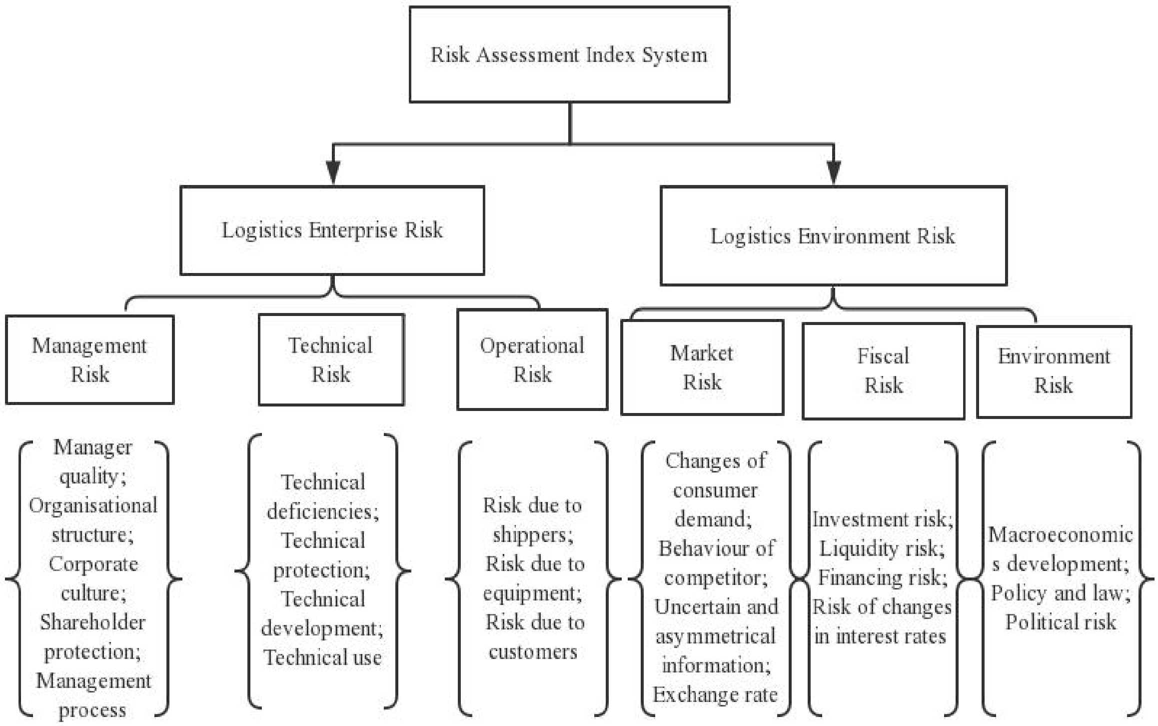
(1) Logistics enterprise risk

a) Management Risk (U_1): Manager quality (U_{11}), Organizational structure (U_{12}), Corporate culture (U_{13}), Shareholder protection (U_{14}) and Management process (U_{15});
b) Technical Risk (U_2): Technical deficiencies (U_{21}), Technical protection (U_{22}), Technical development (U_{23}) and Technical use (U_{24});
c) Operational Risk (U_3) : Risk due to shippers (U_{31}) , Risk due to equipment (U_{32}) and Risk due to customers (U_{33});

(2) Logistics environment risk

a) Market Risk (U_4): Changes of consumer demand (U_{41}), Behavior of competitors (U_{42}), Uncertain and asymmetrical information (U_{43}) and Exchange rate (U_{44});
b) Fiscal Risk (U_5): Investment risk (U_{51}), Liquidity risk (U_{52}), Financing risk (U_{53}) and Risk of changes in interest rates (U_{54});
c) Environment Risk (U_6): Macroeconomic development (U_{61}), Policy and Law (U_{62}) and Political risk (U_{63}).

Figure 6- 2 Risk Assessment Index System



(1) Results of FCMM for this Hanjin Shipping Case [47]

As denoted previously (**Chapter 5**), the risk level is divided into five levels: low risk (V_1), medium-low risk (V_2), general risk (V_3), medium-high risk (V_4) and high risk (V_5). The five evaluation rank elements constitute the evaluation level set V = $\{V_1, V_2, V_3, V_4\ V_5\}$. For six weights of the evaluation indicators, the following weight table can be obtained.[48] It is noticed that the weights can be determined by consensus of a group of experts from companies or universities, like the managers in the company, the stakeholders in the

[47]Details of the FCMM and PSO–AHP methods have been introduced by the author in a paper entitled 'Predict the Logistic Risk: Fuzzy Comprehensive Measurement Method or Particle Swarm Optimization Algorithm? EURASIP Journal on Wireless Communications and Networking, 2018.
[48]The calculation is same as what this thesis has done in Chapter 5. But the values are different, as this thesis chooses a weight vector based on the real situation of Hanjing Shipping in this chapter.

company, the professors in the risk management filed, and so on. The author also has many years of experience as risk management and as part of an action research approach selected some weights as initial attempts to illustrate. The author realizes that the best decisions are group decisions using the most knowledgeable and impacted stakeholders to develop the criteria and to score the alternatives. A group of the impacted stakeholders can be used to better asses the weights for Hanjing Shipping in future research.

Table 6- 3 Weight of Evaluation Index Subset of Logistics Project

Evaluation index subset	U_1	U_2	U_3	U_4	U_5	U_6
Weight	0.49	0.27	0.10	0.23	0.40	0.12

where the weight vector obtained by solid experienced judgement of the author in the field of logistics for risk index are as follows:

$$A_1 = (A_{11}, A_{12}, A_{13}, A_{14}, A_{15}) = (0.4, 0.5, 0.43, 0.6, 0.3)$$

$$A_2 = (A_{21}, A_{22}, A_{23}, A_{24}) = (0.2, 0.1, 0.03, 0.4)$$

$$A_3 = (A_{31}, A_{32}, A_{33}, A_{34}) = (0.4, 0.2, 0.1, 0.1)$$

$$A_4 = (A_{41}, A_{42}, A_{43}, A_{44}) = (0.2, 0.1, 0.3, 0.4)$$

$$A_5 = (A_{51}, A_{52}, A_{53}) = (0.5, 0.4, 0.3)$$

$$A_6 = (A_{61}, A_{62}, A_{63}) = (0.2, 0.1, 0.3).$$

Note that A_{ij} represents the importance of risk factor i over risk factor j.

Table 6-3 indicates that the main risk is management risk, and therefore, the results from FCMM are consistent with the real situation in the Hanjin Shipping case. According to the current situation and development forecast of the logistics project, the evaluation matrices (See **Chapter 5**) are obtained as follows in this thesis:

$$R_1 = \begin{bmatrix} R_{11} \\ R_{12} \\ R_{13} \\ R_{14} \\ R_{15} \end{bmatrix} = \begin{bmatrix} 0.3 & 0.3 & 0.5 & 0.5 & 0.4 \\ 0.2 & 0.4 & 0.5 & 0.6 & 0.4 \\ 0.4 & 0.2 & 0.3 & 0.7 & 0.1 \\ 0.2 & 0.4 & 0.5 & 0.4 & 0 \\ 0.1 & 0.1 & 0.1 & 0.2 & 0 \end{bmatrix} \quad R_2 = \begin{bmatrix} R_{21} \\ R_{22} \\ R_{23} \\ R_{24} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.4 & 0.4 & 0.3 & 0.1 \\ 0.6 & 0.5 & 0.3 & 0.4 & 0 \\ 0.4 & 0.4 & 0.2 & 0.5 & 0 \\ 0.3 & 0.3 & 0.4 & 0.1 & 0.2 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} R_{31} \\ R_{32} \\ R_{33} \\ R_{34} \end{bmatrix} = \begin{bmatrix} 0.3 & 0.4 & 0.4 & 0.3 & 0.1 \\ 0.5 & 0.6 & 0.3 & 0.4 & 0.2 \\ 0.6 & 0.4 & 0.4 & 0.5 & 0.3 \\ 0.3 & 0.5 & 0.1 & 0.3 & 0.1 \end{bmatrix} \quad R_4 = \begin{bmatrix} R_{41} \\ R_{42} \\ R_{43} \\ R_{44} \end{bmatrix} = \begin{bmatrix} 0.4 & 0.4 & 0.4 & 0.4 & 0.5 \\ 0.5 & 0.5 & 0.5 & 0.6 & 0.3 \\ 0.3 & 0.6 & 0.6 & 0.3 & 0.5 \\ 0.6 & 0.2 & 0.4 & 0.4 & 0.3 \end{bmatrix}$$

$$R_5 = \begin{bmatrix} R_{51} \\ R_{52} \\ R_{53} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.4 & 0.5 & 0.3 & 0.1 \\ 0.3 & 0.5 & 0.4 & 0.2 & 0.4 \\ 0.4 & 0.6 & 0.3 & 0.5 & 0 \end{bmatrix} \quad R_6 = \begin{bmatrix} R_{61} \\ R_{62} \\ R_{63} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.4 & 0.3 & 0.4 & 0 \\ 0.3 & 0.6 & 0.5 & 0.5 & 0.1 \\ 0.6 & 0.4 & 0.2 & 0.1 & 0 \end{bmatrix}$$

Apply the mathematical model equation A_i*R_i=B_i, where $B_i = (b_{i1},b_{i2},b_{i3},b_{i4},b_{i5})$ $(i = 1,\cdots,5,\ b_{ij} \in [0,1])$ are the first level results of the comprehensive evaluation (See **Chapter 5**). The results of B_i indicate the percentage of each R_i (i = 1, ···,5) within the scope of the logistics project, which is in the following levels: 'low risk', 'medium-low risk', 'general risk', 'medium-high risk' and 'high risk'.

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} \end{bmatrix} = \begin{bmatrix} 0.57 & 0.59 & 0.18 & 0.49 & 0.10 \\ 0.49 & 0.72 & 0.39 & 0.22 & 0.21 \\ 0.61 & 0.40 & 0.58 & 0.30 & 0.33 \\ 0.45 & 0.31 & 0.29 & 0.41 & 0.69 \\ 0.68 & 0.45 & 0.33 & 0.26 & 0.44 \\ 0.72 & 0.69 & 0.51 & 0.77 & 0.39 \end{bmatrix}$$

The weight vector A = $(A_1,\cdots,A_6)$. Based on the FCMM equation, perform A*R = B, which is the second level fuzzy comprehensive evaluation operation, where B = $(b_1,\cdots,b_5)$ is the overall evaluation result. The largest value of b_{jmax} in b_j, corresponding to the level of V_j is the risk level of the enterprise based on the principle of maximum membership. Then

$$B = [0.59\ \ 0.11\ \ 0.04\ \ 0.13\ \ 0.01\ \ 0.12] * \begin{bmatrix} 0.57 & 0.59 & 0.18 & 0.49 & 0.10 \\ 0.49 & 0.72 & 0.39 & 0.22 & 0.21 \\ 0.61 & 0.40 & 0.58 & 0.30 & 0.33 \\ 0.45 & 0.31 & 0.29 & 0.41 & 0.69 \\ 0.68 & 0.45 & 0.33 & 0.26 & 0.44 \\ 0.72 & 0.69 & 0.51 & 0.77 & 0.39 \end{bmatrix}$$

The calculated results

$$B=(0.5663 \quad 0.5709 \quad 0.2745 \quad 0.4736 \quad 0.2362)$$

where the result reveals that the maximum membership of Matrix B is 0.5663 and the overall risk level of the logistics project is medium-high according to the results obtained in **Chapter 5**, which is consistent with the reason for the decline of Hanjin Shipping. Moreover, the value in weight vector shows that the first risk, which is management risk, plays the most important role in the bankruptcy of Hanjin Shipping, which is consistent with the facts.

(2) Results of PSO–AHP[49]

This thesis considers combining the advantages of AHP and PSO to obtain the PSO–AHP method. As previously stated, according to the risk classification, the comprehensive evaluation system has six layers from top to bottom, which are recorded sequentially as A, B, C, D, E and F layers. The number of elements in each layer is 5, 4, 4, 4, 3 and 3 according to the risk system built in **Chapter 4**, respectively. A is the first layer factor. For the factors of B, C, D, E and F layers, the elements of the above layer are compared with each other according to the criteria. According to the scale of 1–9 of **Table 5-1**, the relative importance of each element and the judgment matrix of each layer is illustrated below.

$$A=\begin{bmatrix} 1 & 6/7 & 4/5 & 1 & 9 \\ 7/6 & 1 & 2/5 & 4/5 & 6/3 \\ 5/4 & 5/2 & 1 & 2/4 & 7 \\ 1 & 5/4 & 4/2 & 1 & 1/2 \\ 1/9 & 3/6 & 1/7 & 2/1 & 1 \end{bmatrix} \qquad B=\begin{bmatrix} 1 & 6/9 & 8/3 & 5/4 \\ 9/6 & 1 & 3/2 & 8/5 \\ 3/8 & 2/3 & 1 & 6/7 \\ 4/5 & 5/8 & 7/6 & 1 \end{bmatrix}$$

[49]This thesis mentions that the values in this chapter are different from the values in Chapter 5. In Chapter 5, this thesis gives an example about how to use these methods. Here this thesis combines these methods with Hanjing Shipping. Thus, the detail of weight, risk index values, etc. are totally different.

$$C = \begin{bmatrix} 1 & 6/7 & 4/3 & 2/5 \\ 7/6 & 1 & 8/6 & 6/4 \\ 3/4 & 6/8 & 1 & 4/3 \\ 5/2 & 4/6 & 3/4 & 1 \end{bmatrix} \qquad D = \begin{bmatrix} 1 & 8/3 & 8/2 & 6/7 \\ 3/8 & 1 & 2/4 & 4/8 \\ 2/8 & 4/2 & 1 & 5/3 \\ 7/6 & 8/4 & 3/5 & 1 \end{bmatrix}$$

$$E = \begin{bmatrix} 1 & 3/5 & 2/8 \\ 5/3 & 1 & 9/4 \\ 8/2 & 4/9 & 1 \end{bmatrix} \qquad F = \begin{bmatrix} 1 & 8/2 & 9/6 \\ 2/8 & 1 & 2/5 \\ 6/9 & 5/2 & 1 \end{bmatrix}$$

Referring to the solution process of the PSO–AHP model in Section 5.3, the weight value and consistency index function value of the given judgment matrix is programmed to be solved (See Appendix in **Chapter 5**). The results are presented in the following table.

Table 6- 4 Results of PSO–AHP

	w_1	w_2	w_3	w_4	w_5	CIF
Management risk	0.820	0.235	0.294	0.433	0.228	0.0002
Technical risk	0.391	0.734	0.720	0.824	0.475	0.001
Operational risk	0.344	0.264	0.242	0.442	0.271	0.0092
Market risk	0.245	0.524	0.452	0.283	0.924	0.00102
Fiscal risk	0.187	0.182	0.423	0.391	0.381	0.0001
Environment risk	0.435	0.331	0.221	0.402	0.229	0.00081

According to $\mathrm{CI} = \frac{\lambda_{max} - n}{n-1}$, CI = 0.013 is obtained, which indicates that this matrix satisfies consistency. The weight of risk is WA={0.5023 0.1352 0.2211 0.341 0.024 0.2834} as calculated in **Chapter 5**, following the steps in Chapter 5 and using the program in the **Appendix 1**, then

$$B = [0.70\ \ 0.02\ \ 0.10\ \ 0.03\ \ 0.05\ \ 0.1] * \begin{bmatrix} 0.57 & 0.59 & 0.18 & 0.49 & 0.10 \\ 0.49 & 0.72 & 0.39 & 0.22 & 0.21 \\ 0.61 & 0.40 & 0.58 & 0.30 & 0.33 \\ 0.45 & 0.31 & 0.29 & 0.41 & 0.69 \\ 0.68 & 0.45 & 0.33 & 0.26 & 0.44 \\ 0.72 & 0.69 & 0.51 & 0.77 & 0.39 \end{bmatrix}$$

The calculated results are

B=（0.5893　0.5682　0.268　0.4797　0.1889）

where the result reveals that the maximum membership of Matrix B is 0.5893 and the overall risk level of the logistics project is medium-high (See **Chapter 5**). Moreover, according to the value in weight vector, the first risk, which is management risk, plays the most important role in risk and is consistent with the facts this thesis discussed in Section 6.2.1.

Based on the results obtained from the analyse of Hanjin Shipping case, this thesis gives the following remarks regarding the two methods proposed in this thesis.

(1) The results reveal that both methods can be used to predict the risk of Hanjin Shipping and indicate that the main risk that Hanjin Shipping encountered is management risk, which is consistent with the facts discussed in Section 6.2.1 such that with the development of economics, management becomes increasingly important in the development of enterprises (Bai et al., 2018; Huang et al., 2011). The results indicate that both methods are useful to assess the logistics projects risks and give consistent results. However, as shown in the paper published by the author with other co-authors (Xu et al., 2018), compared with the FCMM method, the PSO algorithm can further give the results of the influence degree of each index on the identification of the logistic risks, which indicates that the PSO algorithm not only can analyse and identify the risk of logistic comprehensively, but also analyse the main problems existing in each operation of logistic. According to the contribution rate of indicators, researchers can put forward countermeasures to solve the problems so as to provide scientific basis for the further development and improvement of the logistics projects. Therefore, this thesis

recommends the new method based on the particle swarm optimization (PSO) for the logistics project risks assessment in reality.

(2) Note that according to Xu et al. (2018), FCMM is a comprehensive evaluation method based on fuzzy mathematics. This comprehensive evaluation method converts qualitative evaluation into quantitative evaluation based on the membership theory of fuzzy mathematics which is using fuzzy mathematics to make an overall assessment on something or objects subjected to various factors. It has the characteristics of clear results and strong systematicness. It can solve the fuzzy difficulties and quantify the problems. It is suitable for the solution of various non-deterministic problems, such as the logistics risk assessment in this thesis. However, the mathematics process in the fuzzy approach may be challenging for practical use due to the subjective judging during the calculation process. FCMM results are as useful as the subjective inputs given by experts. If an adversarial expert were capable of breaching enemy decision support processes, such as FCMM, their goal would be to increase the miscalculations FCMM provides, see Teague (2013). While for the PSO algorithm, it can present a more focused search calculation process than FCMM, with more emphasis in the exploitation of promising areas than the exploration of the whole search space, because of the way that the position of the particles are updated based on the global and local optima. Note that the consistency problem of the judgment matrix is the core problem of the AHP method. Whether the consistency is reasonable or not directly affects whether the final ranking weight vector can truly and objectively reflect the objective ranking among various schemes or attributes. Therefore, PSO is easy to implement, to make the judgment matrix have substantial consistency, and to improve the weight value. It is good for both continuous optimization problems and discrete optimization problems, especially because their natural real-coded features are suitable for processing optimization. Based on its superiority in solving practical problems, for logistic projects risk analysis, this thesis further recommends the AHP-PSO method because of the advantages of easy implementation, high precision, and fast convergence, see Xu et al. (2018).

6.3 Risk Control Mechanisms

The results reveal that the FCMM and PSO–AHP methods can be used to perform risk evaluation. If the risk can be measured, how then can the risk be prevented? This section focuses mainly on risk control mechanisms and provides a basis for the analysis in **Chapter 7**.

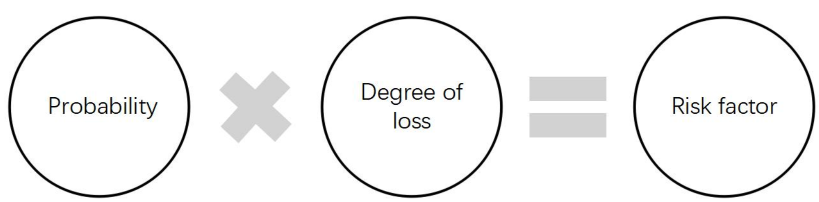
The work system of project risk management is as follows (Jayant et al., 2012; Jin and Gao, 2011; Xu and Liu, 2008): Applying project management ideas, aiming at the objectivity of project risk, adopting the means of identification and analysis to identify and evaluate the type and coefficient of risk; based on the uncertainty of risk, adopt or formulate the relevant technology or measure, formulate the responding plan to address the occurrence of risk and through the implementation of the solution above to minimise the risk degree (Li, 2011; Liu and Xu, 2008). The life cycle of a logistics project is divided into five stages (Huang et al., 2011; Li, 2011; Liu and Xu, 2008). The work procedure of prevention and control of project risk can be divided into five stages: risk factor prediction, risk control programme production, risk prevention and control operations, risk consequence handling and summary of risk control work. This ‘five-step risk control method’ constitutes the entire life cycle of risk management and should be coherent to form an open cycle of the entire mechanism. Among the stages, the risk assessment and risk control scheme production involves numerous disciplines and different elements, which determine the direction and results of risk control work, thereby forming the theoretical basis and key difficulty of the overall work (See also **Figure 6-1**).

Risk management technology can be optimised through an analysis of the risk. The rule of management can be mastered and the handling ability of risk response can be improved. Thereafter, an operational mode and system of risk prevention are formed, which is the risk prevention and control mechanism of the logistics project.

Step 1: Risk Factor Prediction

Risk factor prediction includes risk identification and risk assessment. Risk identification is based on industry conditions and project environment. The possible occurrence of risk within the project cycle can be identified and listed. Risk assessment is based on risk identification, which takes into full account of the external environment and internal factors, the integrated use of probability and statistics theory and method to calculate the occurrence probability, occurrence time and loss degree of project risk (Mobey and Parker, 2002). Risk assessment methods are divided into quantitative and qualitative assessment. Quantitative assessment refers to the quantification of the probability of occurrence and loss of risk, whereas qualitative assessment refers to the creation of the risk rating and risk ranking and is summarised in **Figure 6-3**.

Figure 6- 3 Risk Factor Formulation



A higher risk factor should be given more attention. Comprehensive utilisation of these two methods will result in the risk being listed, sorted and rated comprehensively, thereby laying a solid foundation for the design of a targeted, definite and feasible risk prevention and control scheme.

Step 2: Risk Control Program Production

The key work of the risk control programme production is to develop the corresponding risk response measures based on the data results of the risk assessment; that is, to design the responsive scheme to address the project risk (Qi, 2007; Qin, 2004). The general responsive scheme to the risk in logistics projects includes risk avoidance, risk prevention, risk reduction, risk transfer, risk acceptance and contingency planning (**Table 6-5**).

Table 6- 5 Risk Responsive Measures

Measures	Details
Risk avoidance	Cancelling an undeveloped project, terminating an ongoing project
Risk prevention	Establish regulations and mechanisms to strengthen management and control Carry out thought and experience to improve quality and skills Interpret policy and normative research forms and contexts Improve the technology and methods to carry out public relations and publicity
Reduced risk	Ask for assistance to reduce risk
Risk transfer	Project outsourced or sold for security or insurance
Risk acceptance	Self-incurring losses and the responsibility of internal digestion and apportionment
Emergency plan	Start the risk control release process to restart the risk management process

Step 3: Risk prevention and control operations

In the risk prevention and control operation stage, all participants in the logistics project are actual operational personnel of risk prevention and control and their professional ability and attitude are the key factors in this work stage. A qualified risk control operator should have the following qualities (Qi, 2007; Qin, 2004; Radosavljevic et al., 2016; Wang, 2013): **(1)** high corporate loyalty; **(2)** high passion towards the career; **(3)** extensive professional knowledge; **(4)** strong professional ability; **(5)** focus on the role of risk management; **(6)** familiar with risk management; **(7)** having the quality to obey and adaptability; **(8)** good at thinking and communication and **(9)** able to identify problems and report soonest, and if necessary, make a favourable decision and take reactions.

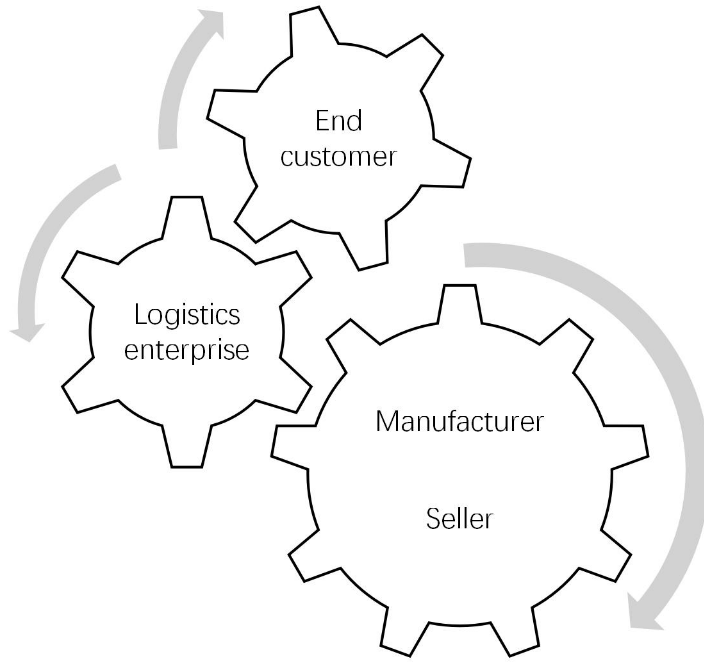
Certain results also showed that risk has the highest probability of occurrence in the early stages of logistics projects, resulting in a relatively high degree of damage. Therefore, the earlier the implementation of risk control operations, the more conducive for enterprises to avoid risk and reduce losses.

Step 4: Risk consequence handling

Risk consequence handling refers to the responsive action taken by the logistics enterprise in the stage of risk consequence. That is, the risk consequence can be evaluated and processed under the condition that the risk has already happened and the consequence has occurred so as to reduce the influence of risk loss as far as possible (Radosavljevic et al., 2016; Wang, 2013).

In addition to logistics enterprises, the main parties involved in the activities in a logistics project are the manufacturers, sellers and end customers. The logistics enterprises in the logistics process have direct contact and interactions with the other entities. The occurrence of risk affects the other entities. Thus, risk handing takes all these three parties' benefits into consideration as indicated in **Figure 6-4**.

Figure 6- 4 Logistics Market Tripartite Relationship

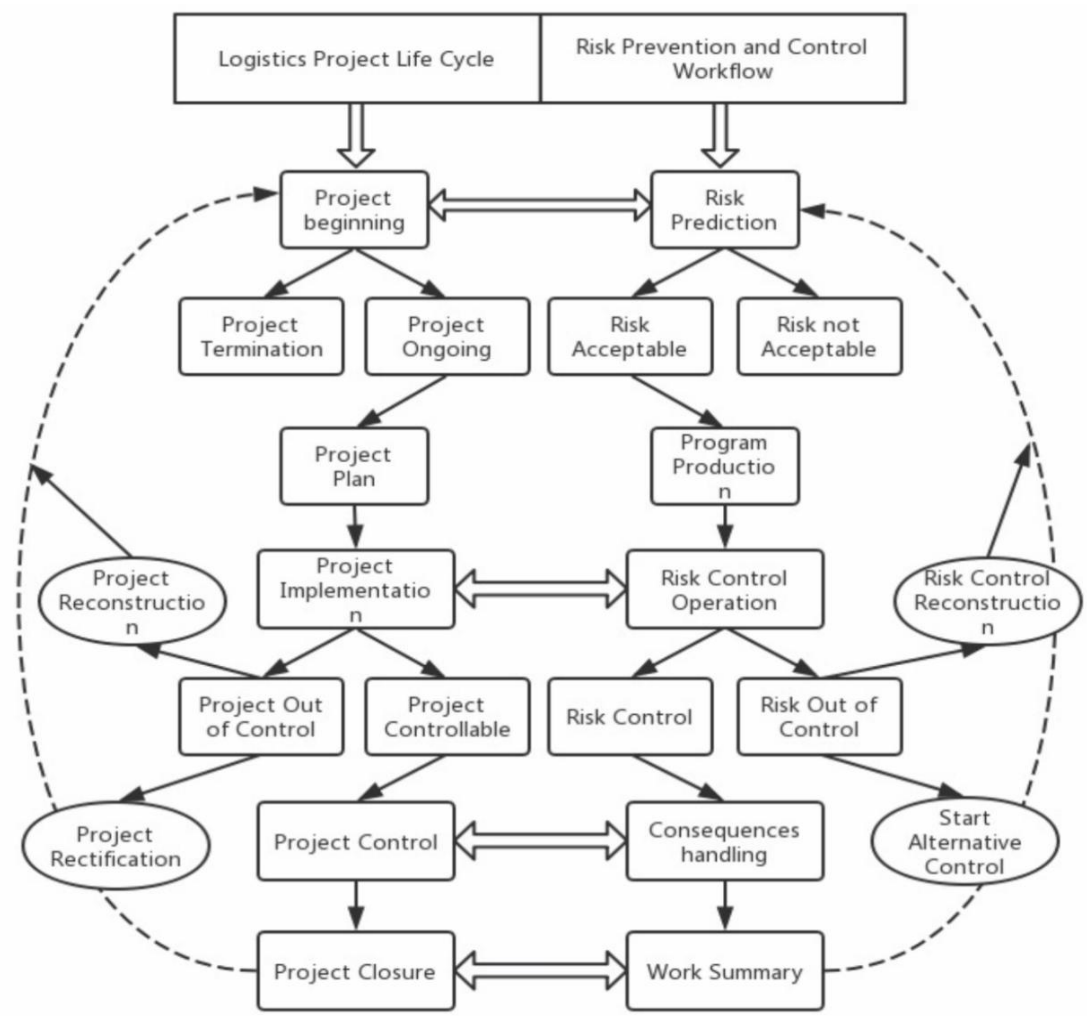


Step 5: 'Network' Risk Control Mechanism

The completion of a logistics project cycle means the end of a round of risk management. In the final stage, the overall work needs to be reviewed, inspected, examined and summarised to learn the lessons through analysing the shortfalls, to gain the experience by analysing the achievement, to make use of the advantages and avoid the disadvantages. This cycle can guide the improvement of the entire working standard of logistics enterprises.

In view of the characteristics of logistics enterprises, each round of the work cycle has a high degree of similarity or comparability. Therefore, a summary of risk control work of the logistics enterprise is particularly important. The logistics project risk prevention and control mechanisms should have the following elements (Weng et al., 2010; Wu et al., 2006): **(1)** Follow the project principles of management principles; **(2)** follow the original intention of risk management; **(3)** suitable for the modern logistics industry model; **(4)** applicable to the main entities that have established the mechanism of logistics enterprises; **(5)** employ fully the management, comparative study and other discipline theories; **(6)** use precisely the skills and methods of mathematics and logic disciplines; **(7)** take full account of the external environment, internal mechanisms and other factors; **(8)** match effectively the entire lifecycle of the logistics project; **(9)** form a cycle of risk management; **(10)** cover all aspects of logistics projects and risk management; **(11)** have the characteristics of preciseness, feasibility and flexibility and **(12)** attempt to control the operational costs of the mechanism that is required for humans and material.

Figure 6- 5 Mesh mode



Based on the above principles, combined with the modern logistics status and project management pattern and with the cyclical pattern of logistics projects and risk management, a complete set of logistics project risk prevention and control mechanisms can be known or determined, which should be an external presentation of a complete cycle with intricately related internal mesh patterns (Zhang and Zhang, 2003). These related theories including project management and risk for logistics are applied to a case study in the next section.

6.4 Risk Control Mechanisms: A Case Study

After introducing how risk assessment and prevention can be conducted, a case study regarding risk control mechanisms is given in this section. Shandong New Jiahong Company is given as a further case study to interpret certain theories presented in previous sections in a logistics enterprise. Shandong New Jiahong Company's predecessor, Jiahong Biology, was a sales company that specialised in biotechnology product sales. Jiahong Biology began its transformation into a logistics company in 2013. The company is headquartered in Heze, China. It has an office area of about 20,000 square metres and approximately 35 employees. The company has eight different types of vehicles used for transport, a conventional warehouse area approximately 5,000 square metres in size and a cold storage approximately 600 square metres in size. In 2015, the turnover was 170 million yuan, which is typical for a small and medium-sized new logistics enterprise. As this thesis applies WBS method to divide the whole projects into several stages when building risk index system, where each stage could be considered as a small or medium-sized logistics projects, the New Jiahong belonging to a medium-sized logistics enterprise could provide some insights on preventing the risks for the large-scale logistics projects.

According to this study and theories considered, the New Jiahong as a case study presented in this section is undergoing the transformation from traditional to modern logistics. The company's core management team attaches great importance to the concept of project management, but they lack management expertise and system concept appreciation. The company's principal leadership endorsed the theory and vision set out in this thesis, agreed to try the mechanism described here and formally commenced trial operation at the company in October 2016. The main resulting work packages are as follows:

a) Establishment of risk control management group; the company's core leadership is responsible directly.

b) Appointed a head of the risk control management group to monitor the logistics project risk prevention and control system.

c) Conducted public and educational activities to educate all employees of the company on project management and risk prevention and control.

d) Introduced the concepts of project management and the theory of risk prevention and control as described in this thesis and designed a set of feasible 'network' risk prevention and control mechanisms according to the specific situation of the company as an interim regulation.

e) According to the feedback from New Jiahong Company, by the end of 2016, the company had already adhered to the trial operation on the new risk prevention and control mechanism for three months. During this period, the company turnover increased by 17%, net profit increased by 23% and customer retention and renewal rate increased by approximately 10%. Through the work of the risk control management group, the company avoided one major degree of loss, two moderate losses and 10 slight degrees of loss. The loss rate decreased by nearly 50%. Taking one of the classic operation case logistics activities and analysing it resulted in the following.

f) In October 2016, the company leadership required the company to participate in a project bidding activity. The risk control group found that in the course of this project, a moderate probability of encountering policy changes could occur, the social risk could result in L4 level degree of loss and the risk could not be transferred. The company leadership decided to give up on the bid. The project was won by a larger rival company called 'L'. In November, during the implementation of the project, the relevant departments made policy adjustments related to the project, which led to a risk of loss for 'L' company.

In December 2016, the company received a single bulk cargo of consignment services. The customer required the goods to be shipped to Yantai within a specific time. The risk control group carried out risk analysis and estimated that the project had a higher probability of natural and customer risks, resulting in a slight loss of L2 level. The risk control group developed an emergency plan for this potential risk. On the day goods had to be dispatched, Shandong Province experienced a large-scale weather haze that resulted in the closure of a certain portion of the highway. The drivers adjusted the departure time and driving routes according to the emergency plan; the marketing department arranged professional staff to communicate with customers and ultimately, the delay time was controlled within the customer's acceptable range. The final result was that the customer gave up on claiming any damages due to the delay and signed a long-term cooperation agreement with New Jiahong Company. In this project, New Jiahong Company employed project management ideas and the risk control mechanism, which transformed the pure risk into speculative risk and the company benefited from such actions.

The leaders of New Jiahong Company have stated that project risk prevention and control mechanism would be adopted from trial to formal implementation and written into the articles of association in February 2017.

6.5 Summary

Risk evaluation is a critical decision for companies in today's competitive environment (Xu et al., 2018). Risk evaluation can bring numerous advantages to a company. In the risk evaluation problem, the effects of each method may be different and these effects may be in conflict with each other. Therefore, these problems present a complex structure composed of tangible and intangible factors. FCMM and PSO–AHP are convenient methods for solving these problems.[50] Based on the index system in **Chapter 4** and methods introduced in **Chapter 5**, the present chapter used Hanjin Shipping as a case to present how risk evaluation can be performed. The results revealed both methods can be used to predict the risk of Hanjin Shipping and indicated that the main risk that Hanjin Shipping encountered was management risk, which was consistent with the facts as discussed in Section 6.2.1. After risk evaluation, this chapter showed in a novel manner how a risk control mechanism that can be used to prevent risk can be constructed. Thereafter, the chapter showed how this mechanism can operate using New Jiahong Company in Shandong as a case. The contents in this chapter provided meaningful results for this thesis, which indicates the methods used in this thesis (FCMM and PSO–AHP) can be also be employed to perform risk measurement. This chapter provided a basis for analysis in the next chapter, which focuses on how risks can be reduced. In the following chapter (**Chapter 7**), this thesis provides several strategies that can improve the management of logistics projects to reduce the change of risk occurrence on the basis of the real situation.

6.6 References

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[50]The advantage of using PSO-AHP can be summarized as follows: this study generates PSO– to-PSO–AHP method in the content of logistics issue, combines it with WBS, and applies it in the risk assessment of large-scale logistics projects. Considerable research focuses on the use of FCMM to perform risk assessment. Cheng and Xiao (2009) integrated the concepts of AHP and fuzzy consistent matrix method to identify risk factors during bridge construction. Cheng et al. (2008) presented a fuzzy logic-based method, which synthesizes the fuzzy AHP method on the basis of a three-point scale, fuzzy set theory and fuzzy logic which are integrated into a single approach to measure the risk of bridges during construction. However, studies focusing on the use of PSO–AHP method for the risk assessment of large-scale logistics projects are limited. Huang et al. (2011) focus on the combination of AHP and PSO and use it to maximize the value of product updating so as to extend the product life cycle, while this thesis combines AHP and PSO and uses WBS together to build the risk indicator system, which is the base of PSO-AHP method. Therefore, the present study not only uses the FCMM to deal with risk assessment but also employs the PSO–AHP method and then selects the best one according to some criteria. By doing so, this thesis provides an excellent example for researchers to choose between the two models for conducting risk assessment.

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Chapter 7 ：

Risk Prevention in Logistics Projects: The Risk Index System

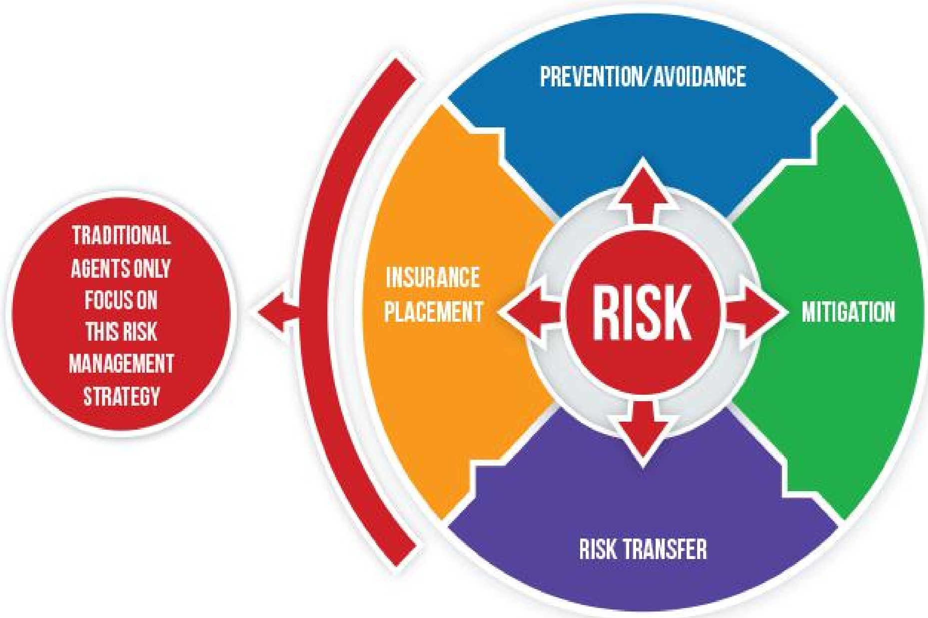
Considerable risks abound in the actual situation of logistics projects, such as the loss of key technical personnel and changes in market conditions, customer expectations or the business conditions of the development organization, among others (Allred et al., 2011; Auramo et al., 2005). A project can be saved if such risks can be predicated in advance and appropriate alleviation measures are taken. Although risk management is not always successful, it increases the possibility of success and prevents project failure as much as possible. In this thesis, the establishment of a risk index system was introduced in **Chapter 4**, the use of the FCMM and PSO-AHP methods for performing risk evaluation was demonstrated in **Chapter 5** and an implementation method was presented in **Chapter 6**. In this chapter, several strategies for improving logistics projects managements to reduce changes in risk occurrences based on actual situation are provided. In terms of large-scale logistics projects, risk measurement is not merely an instrument, as measurement is not the final objective. Each method should be used to provide developmental guidelines for actual situations. Thus, by combining the results obtained from models in the previous chapters, this chapter examines risk prevention and considers it from six dimensions according to the risk index system, namely, management, technical, operational, market, fiscal and environment risk. These risks can be considered as part of the contribution of this thesis, as this chapter identifies several strategies for preventing logistics risks. Moreover, this thesis provides suggestions for the development of Chinese large-scale logistics projects in South Africa, which is discussed in **Chapter 8**, where the main contents are summarised.

7.1 Significance of Risk Prevention

Firstly, scientific development requires the improvement of the resource allocation efficiency of an enterprise as well as its economic development quality. Direct financing under market economy conditions can help improve resource allocation efficiency (Barratt, 2004; Barry et al., 2001; Boehm, 1991). Enterprises must first ensure the effectiveness of the capital market to improve the proportion of direct financing. As the most basic unit of the capital market, the resource utilisation efficiency of an enterprise serves as an effective premise of the capital market. An efficient and successful enterprise maximises shareholder value for investors and stakeholders. Moreover, a company with the greatest social benefits requires its internal control mechanisms and strategic decision-making and risk management improvements to be studied (Aqlan and Lam, 2015; Aloini et al., 2012; Blackhurst et al., 2008; Blome and Schoenherr, 2011; Bowersox and Daugherty, 1987). Therefore, enterprises have faced increased strategic choices. Strategic work is important and requires high-level attention from top management; thus, it is a systematic project that requires the full attention and cooperation of its employees (Cao and Zhang, 2011). In today's rapidly changing environment, the establishment of a long-term company requires enhanced high-level strategic businesses that drive abilities whilst ensuring the continuous monitoring, analysis and feedback of internal and external environments. Hence, business owners can respond promptly and effectively when necessary.

In addition, a company should be able to properly handle and assess its systems. From the perspective of internal control improvement of an enterprise, establishment of a comprehensive risk management control system by analysing the overall risks it faces is important, especially on the basis of risk management (Carter et al., 2015; Zhou and Chan, 2016). Enterprises' strategic decisions are highly related to their environment. Therefore, strategic risk management is an important issue that enterprises cannot avoid (Dalkey and Helmer, 1963; Fawcett et al., 2012; Petticrew and Roberts, 2006). Four general strategies for managing logistics project risks have been identified, namely, prevention/avoidance, mitigation, risk transfer and insurance placement (**Figure 7-1**).

Figure 7- 1 Four Opinions to Manager Logistics Project Risks



Note: Figure 7-1 is adopted from RIRONRISK STRATEGIES: Risk Management Process (Genpact, 2018). (http://www.ironriskstrategies.com/risk-management-process/).

On the basis of the risk index system, this chapter mainly considers logistics risk prevention from six dimensions, namely, management, technical, operational, market, fiscal and environmental risks, excluding three options from **Figure 7-1**. These dimensions can be considered supplemental in the risk evaluation of large-scale logistics projects, as the final objective of risk evaluation is to prevent risks in large-scale logistics projects.

7.2 Six-dimensional Analysis of Risk Prevention

As described in **Chapter 4**, this thesis developed 23 indicators for six types of risks with which to evaluate logistics projects (**Figure 7-2**). Based on the aforementioned six dimensions and according to Sun (2007), this thesis considers risk prevention for large-scale logistics projects. As discussed above, based on the risk index system, the content of this chapter can be considered as supplemental in the risk evaluation of large-scale logistics projects, as the final objective of risk evaluation is to prevent risks in large-scale logistics projects. In other words, this chapter could be considered as part of the contribution of this thesis, as it identifies several methods for preventing logistics risks.

Figure 7- 2 Risk Assessment Index System

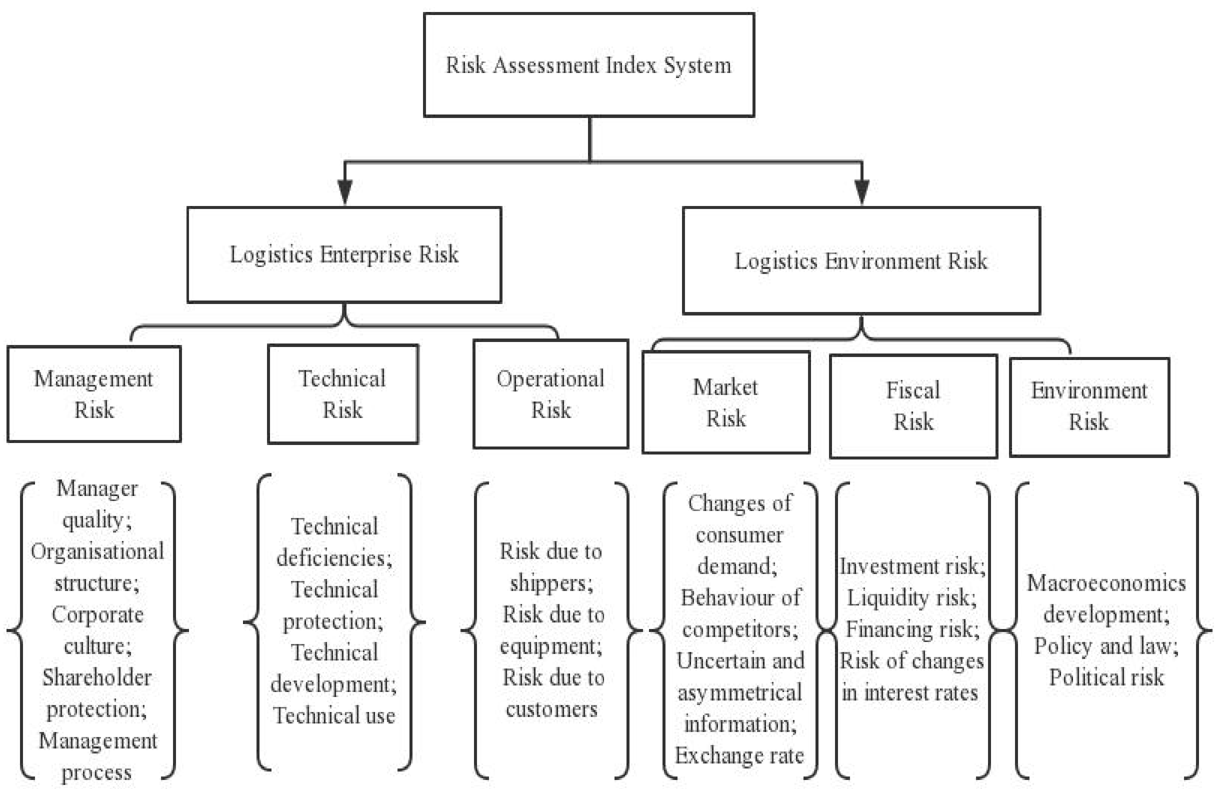


Figure 7-2 is used in this chapter to provide the risk prevention methods, as this chapter considers the six dimensions shown in **Figure 7-2**, namely, management risk prevention, technical risk prevention, operational risk prevention, market risk prevention, fiscal risk prevention and environmental risk prevention. In the analysis below, this thesis will discuss strategies for preventing logistics project risks according to **Figure 7-2**. Specifically, for management risks, this thesis focuses on management quality,

organisational structure, corporate culture, shareholder protection and management process. In terms of technical risks, this thesis focuses on technical deficiencies, technical protection, technical development and technical use. With regard to operational risks, this thesis focuses on risks due to shippers, risks due to equipment and risks due to customers. As for market risks, this thesis focuses on changes in consumer demand, the behaviour of competitors, uncertain and asymmetrical information and the exchange rate. For fiscal risks, this thesis focuses on investment risks, liquidity risks, financing risks and risks in interest rate changes. Finally, for environmental risks, this thesis focuses on macroeconomic development, policies and laws and political risks.

This chapter overemphasises that though these risks can be considered as general risks, they are crucial in large-scale logistics projects. Moreover, several risks, such as those due to shippers, exchange rates, policies and laws and political risks, are considered only in large-scale logistics projects, as they should be conducted in different areas. Moreover, each of these six dimensions can affect the success of large-scale logistics projects (Sun, 2007), as shown in **Figure 7-2**. Thus, this chapter mainly considers these six dimensions.

7.2.1 Management Risk Prevention

The case study in **Chapter 6** showed that management risk is the primary cause of the bankruptcy of Hanjin Shipping. This study indicates the importance of people providing several strategies for its prevention. In logistics enterprises, the manager comprises the core aspect, which focuses on decision making. To a certain extent, the level of leadership and the ability to control a situation determine whether a logistics enterprise's career-development goals can be achieved smoothly (Cassivi, 2006; Cheng et al., 2008; Ireland and Bruce, 2000). Therefore, management cadres should have a deep understanding of the new situations, opportunities and challenges faced by current enterprises to effectively strengthen their own leadership development. In-depth implications of these concepts are presented below.

(1) Increasing managers' responsibility awareness is important. Several measures should be conducted to prevent management risks if logistics enterprises identify managers who are not fully focused on their work (Boyson, 2014; Bradley, 2014; Buhler et al., 2016; Wang, 2015). Responsibility awareness is the soul of team management. Recognising and integrating the development of an enterprise into the key links of a harmonious society is necessary. Managers should continuously enhance their leadership and management abilities, fulfil their duties and be responsible to the enterprise, employees and society. Moreover, managers should prioritise company management and development and deliver satisfactory job performance to ensure the stability of an enterprise.

(2) Logistics enterprises should enhance the efficiency of their organisational structure to avoid risks. The fundamental purpose of organisational structure design is to serve the strategic tasks and business objectives of an enterprise (Aqlan and Lam, 2015; Aloini et al., 2012; Boyson, 2014; Buzacott and Peng, 2012; Wang and Zhang, 2014). According to this principle, when enterprise tasks and objectives change significantly, organisational structure should be adjusted accordingly to meet the requirements of the new tasks and objectives. Therefore, the organisational structure reform of enterprises clearly requires starting from the requirements of the tasks and objectives. Moreover, external environments are constantly changing; thus, an organisation must ensure that operations can continue in an orderly manner when such changes occur. At the same time, corresponding changes must be made according to new situations. Therefore, an organisation should have a certain level of flexibility and adaptability. In addition, establishing a clear command system during organisational restructuring is necessary.

(3) Corporate culture is the soul of an enterprise and requires attention during risk prevention. The creation of corporate culture needs the strong advocacy and support of society and must likewise be implemented in the management practice of each enterprise (Boyson, 2014; Buzacott and Peng, 2012; Camuffo et al., 2007; Pagell and Wu, 2009; Roussean et al., 2008). Meanwhile, a corporate culture with integrity and respect for customers should be created, and its core should focus on an enterprise's basic principles, standards and commitment. Similarly, in most situations or companies, business leaders determine corporate culture (Sun, 2007); thus, corporate leaders are the advocates and organisers of corporate culture. Specifically, their value orientation, moral concept and leadership qualities directly determine the corporate culture and destiny of an enterprise. Thus, the active advocacy of business leaders is an important driving force in determining and forming corporate culture.

(4) Small- and medium-sized shareholders are important components of a company. Protecting the rights of such shareholders not only helps a company achieve internal stability but also improves financing capabilities by strengthening investor confidence. Numerous logistics enterprises face risks mainly caused by insufficient financing, because they generally ignore their small- and medium-sized shareholders (Boyson, 2014; Bradley, 2014; Camuffo et al., 2007; Swink et al., 2007). Therefore, considering the rights and interests of such shareholders when conducting risk prevention is necessary to avoid enterprise management risks.

(5) The management process could likewise present several risks. In the current global economic integration and increasingly fierce market competition, nearly every enterprise is under pressure to improve its performance and enhance its competitiveness. Thus, business management requirements have become increasingly high (Cantor et al., 2014; Ceryno et al., 2015; Chang et al., 2015; Kennedy and Eberhart, 1995). The operation of an enterprise requires various systems. Rights and responsibilities are naturally clear in effective systems, and rules and regulations directly affect the stability and efficiency of an enterprise. Moreover, increasing the operational abilities of a logistics enterprise is similarly important.

7.2.2 Technical Risk Prevention

According to Sun (2007), logistics enterprises should improve their scientific decision making to avoid technical risks. In practice, managers often encounter problems that should be shared with employees to allow them to directly participate in decision making (Boyson, 2014; Chang et al., 2015; Chen et al., 2016; Min et al., 2005). Managers can listen to employee opinions and apply their own wisdom to improve scientific decision making. Moreover, logistics enterprises should focus on the techniques of such improvements to perform the actions described below.

(1) Logistics enterprises should improve their technical abilities to avoid technical deficiencies. To survive, develop and improve their competitiveness, enterprises should improve their independent innovation capability, establish a sustainable technological innovation system, retain market orientation and combine production, study and research. These methods are likewise necessary for enhancing independent innovation capability and building an innovative country (Chang et al., 2015; Chen et al., 2016; Frankel et al., 2002). Logistics enterprises could organise and mobilise scientific and technical personnel from research institutes and universities by providing research funds to develop diversified innovation and entrepreneurial services. For example, Alibaba in China provides abundant funds for university researchers each year. As a long-term service mechanism, technology intermediaries and technology transfer institutions can be employed to establish a two-way information exchange platform for scientific and technical personnel and enterprises. In addition, a group of scientific and technical personnel can be selected from research institutes and universities to join enterprises. Specifically, scientists and technicians are encouraged to bring technology and products into enterprises for promotion and application.

(2) Enterprises can increase investment in technological development and enhance their abilities in independent innovation by establishing technology centres as well as research and development (R&D) institutions. Certain guarantees and inputs for funds are necessary to ensure independent research and development. Enterprises must exert effort to obtain independent intellectual property rights and core technologies (Hartmann et al., 2011; Song, 2003; Tranfield et al., 2003). Meanwhile, enterprises should conduct various system and operational reforms for R&D institutions to improve their independent innovation capability and adapt to the needs of new international products or technological developments. Furthermore, enterprises can implement strategies for technical standards and focus on improving a technology's added value and quality. Enterprises can likewise implement brand strategies to improve corporate patent development and trademark management systems as well as to establish an effective talent incentive mechanism.

(3) Scientific and technological progress and innovation should be considered as the primary driving forces of economic and social development (Chopra and Sodhi, 2004; Christopher et al., 2011). Moreover, the improvement of independent innovation capability, as a major future strategy, is the central link for adjusting economic structures, transforming growth modes, improving national competitiveness and building innovative enterprises (Boyson, 2014; Chen et al., 2016; Harker, 1999; Kahn and Mentzer, 1996). The scientific and technological endeavours of logistics enterprises should adhere to the guiding principles of independent innovation, practice leapfrogging, support developments, and lead the future. Finally, logistics enterprises should insist on improving independent innovation ability in the core positions of all scientific and technological efforts.

(4) Logistics enterprises should enhance public awareness of the legal protection of patent rights to familiarise patentees of laws and regulations related to patent rights, raise awareness of self-protection and implement protection measures, from the application to the authorisation stage (Xie et al., 2017; Yazdani et al., 2014). Furthermore, logistics enterprises should direct their attention to the international protection of patent rights, which is realised through treaties reached between countries. However, for various reasons, patentees in China do not exercise their priority in member states within the time limit prescribed by the Convention (Xie et al., 2017; Yazdani et al., 2014) after a patent application is obtained. Thus, a patent can lose its novelty in the member states, and the interests of patentees will wane without the protection of these countries. Similar losses can be avoided if logistics enterprises attach importance to the international protection of patent rights, including the cost of staff or researchers.

7.2.3 Operational Risk Prevention

Operation comprises the main component of logistics enterprises (Sun, 2007). To avoid operational risks, logistics enterprises should direct their attention to the following issues (Chang et al., 2015; Chen et al., 2016; Sun, 2007; Wang et al., 2012).

(1) Logistics companies can use their distinct logos in packaging, and pickups should be confirmed by internal staff members before removal (Cohen and Kunreuther, 2007; Colicchia and Stozzi, 2012; Wang et al., 2012). Meanwhile, logistics enterprises can establish a relatively complete delivery system, such that when a courier arrives at the designated delivery department, systems data can be updated in real time to enter the express delivery system of the sales department. Packages must be scanned for extraction when customers pick up their items. If the scanned code is not confirmed, the removed shipment should trigger the alarm of the door security system.

(2) Logistics enterprises can establish equipment maintenance requirements and management systems. For example, after a shift, an operator can carefully check and wipe the parts of an equipment and refill the lubricating oil to keep the equipment neat, clean, lubricated and safe (Sun, 2007; Wang et al., 2012).

(3) Customers can search for additional detailed product and service information through various convenient channels, such as the Internet, thereby becoming knowledgeable and less tolerant of passive sales (Chen et al., 2016; Cheng and Xiao, 2009; Craighead et al., 2007; Cruz and Liu, 2011; Day, 2000). Thus, emotional exchange with customers is an important means for companies to maintain customer relationships. Daily visits, sincere greetings during festivals, wedding celebrations and birthdays and a bouquet of flowers can deeply impress customers. The end of a transaction should not mean the end of customer relationships, and keeping in touch with customers after a sale ensures that their satisfaction continues. Customers want to interact with like-minded people and thus wish to establish strong, rather than ordinary, sales relationships with companies. Therefore, companies should efficiently establish satisfactory interactions with customers to provide personalised service (Sun, 2007; Wang et al., 2012).

7.2.4 Market Risk Prevention

Occasionally, risks are decided by the market and cannot be controlled. However, actions can be taken to prevent market risks, as described in the following section (Chang et al., 2015; Chen et al., 2016; Sun, 2007; Wang et al., 2012).

(1) Business owners should understand product content and operational processes, from cognition to mastery, by learning about product materials and grasping the core strengths and selling points of products (Sun, 2007; Wang et al., 2012). Moreover, business owners should understand customers' backgrounds, asset statuses, investment experiences and taboos before implementing logistics projects to determine suitable product plans and arrange products in the recommended order. Business owners should be familiar with common product introduction problems to be able to answer customers' specific questions immediately. In addition, people having their own views and opinions on the macro market is ideal to facilitate easy communication with experienced customers.

(2) Logistics enterprises could similarly consider the following issues to avoid market risks. If a competitor uses square or glass packaging, then an enterprise can consider designing circular or plastic packaging (Cheng and Xiao, 2009; Day, 2000). Consumers can better focus on a product if packaging is changed. Meanwhile, products are also classified. Thus, product category innovation aims to classify products from the perspective of consumers to find new categories that consumers can accept but competitors have yet to consider. Logistics enterprises can visit markets to conduct interviews and obtain new data to avoid risks from asymmetric information.

7.2.5 Fiscal Risk Prevention

Logistics enterprises require considerable cash flow to maintain the operation of projects (Denyer and Tranfield, 2009; Wang et al., 2012). However, different types of enterprises may consider other aspects, such as future development, as large-scale logistics projects may be stopped if cash flow is inadequate. The following measures may help avoid risks from fiscal issues.

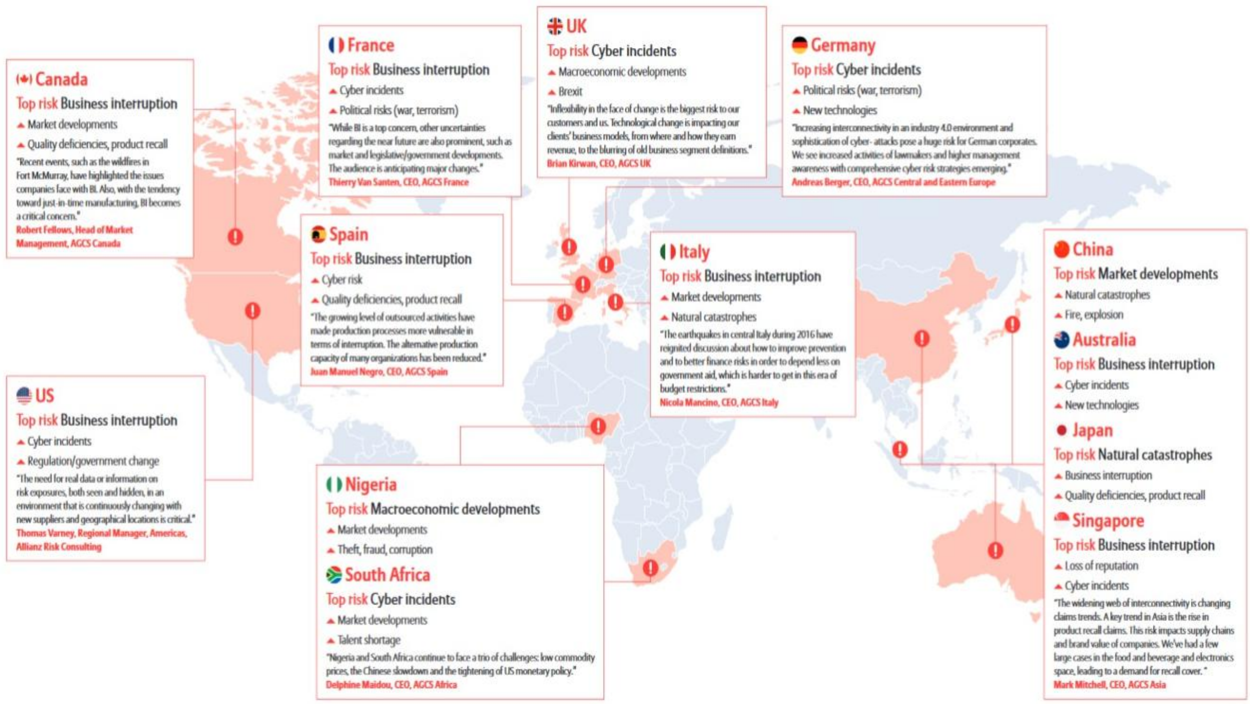
(1) From the perspective of cash management, measures can start from credit management, capital management and assets and liability management to improve capital utilisation efficiency (Chang et al., 2015; Sun, 2007; Wang et al., 2012). Companies with large-scale logistics projects should strive to shorten the capital withdrawal cycle and delay payments to suppliers based on their market capabilities. For example, an original supplier payment of 15 days extended to 30 days is an improvement in accounts payable management (Chang et al., 2015; Chen et al., 2016; Sun, 2007; Wang et al., 2012).

(2) Another important aspect of cash flow management is capital management, which involves the support of capital markets and shareholders (Sun, 2007; Wang et al., 2012). If the listed company of large-scale logistics projects predicts the need for financial support in the future, then the issuance of equity can be considered. Equity capital is generally the most important source of funds for small- and medium-sized enterprises with large-scale logistics projects. In the face of international financial crises, the most direct and effective means for increasing cash resources is to seek capital support from shareholders. Meanwhile, assets and liability management mainly refers to matching the management of assets and liabilities on a balance sheet. In assets management, the cash withdrawal of assets that are not closely related to projects and do not affect core competitiveness is possible.

7.2.6 Environmental Risk Prevention

Logistics enterprises should focus considerable attention to policies and laws to avoid environmental risks. Business risks have increased owing to uncertainties (**Figure 7-3**). Labour relations in several countries differ considerably from those in China, and trade unions represent employee interests to a large extent. In actual operations, Chinese-funded industrial and commercial enterprises should strictly implement relevant labour laws, hire professional lawyers, properly resolve employee and trade union conflicts in production and operation and maintain close contact with semi-official organisations, such as industry associations and chambers of commerce. Furthermore, numerous countries have strict laws and regulations on environmental protection. Thus, enterprises investing in these countries should understand and comply with relevant local environmental protection laws and regulations. Full consideration of environmental protection, infrastructure construction and employee training is necessary in making investment management decisions. In terms of business operations, enterprises should focus on increasing attention on specific environmental protection measures. In a few countries with poor social security, Chinese-funded industrial and commercial enterprises should strengthen their safety training for employees, improve their safety awareness and strengthen safety precautions. In the event of an emergency, employees should call the police immediately and contact the Chinese Embassy or Consulate.

Figure 7- 3 Top Business Risks Around the World



Note: Figure 7-3 is adopted from Business Wire (http://www.businesswire.com/)

7.3 Summary

Based on the results of previous chapters, this chapter mainly provides a few examples of risk prevention methods for large-scale logistics projects. According to the risk index system, the content of this chapter can be considered supplemental in the risk evaluation of large-scale logistics projects, as the final objective of risk evaluation is to prevent risks in large-scale logistics projects. In other words, this chapter can be considered as part of the contribution of this thesis, as it identifies several strategies for preventing logistics risks. Based on risk type, this chapter provides methods for management, technical, operational, market, fiscal and environmental risks. In terms of management risks, it focuses on manager quality, organisational structure, corporate culture, shareholder protection and management processes. The strategies above can substantially reduce risks attributed to management processes (see the case study in **Chapter 6**). With regard to technical risks, this chapter considers technical deficiencies, protection, development and use, which indicates that techniques have played an increasingly important role in logistics projects with economic development. This chapter likewise considers operational risks, including those from shippers, equipment and customers. For market risks, changes in customer demand, competitor behaviour, uncertain and asymmetrical information and exchange rates are considered. As for fiscal risks, this chapter considers investment, liquidity and financing risks as well as those from interest rate changes. Finally, environmental risks are likewise considered. According to the methods described in this thesis, logistics projects can prevent risks in the early stage and avoid a situation similar to that of Hanjin Shipping.

In summary, this chapter describes the contributions implied in **Chapter 1**, which stated that risks in large-scale logistics projects are measured in **Chapter 5** and **6**, and several strategies for improving logistics project management to reduce the occurrence of risks owing to actual situations are identified in **Chapter 7**. This thesis also generates suggestions for the development of large-scale Chinese logistics projects in South Africa, which is described in **Chapter 8**. The last chapter likewise summarises the main contents of this thesis. Risk measurement in large-scale logistics projects is not merely an instrument, as measurement is not the final objective. Each method should be used to provide development guidelines for actual situations. Thus, by combining the results obtained from models and actual situations in China and South Africa, this thesis suggests several strategies for reducing risks in large-scale logistics projects in the two countries in **Chapters 7** and **8**.

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Chapter 8 ：

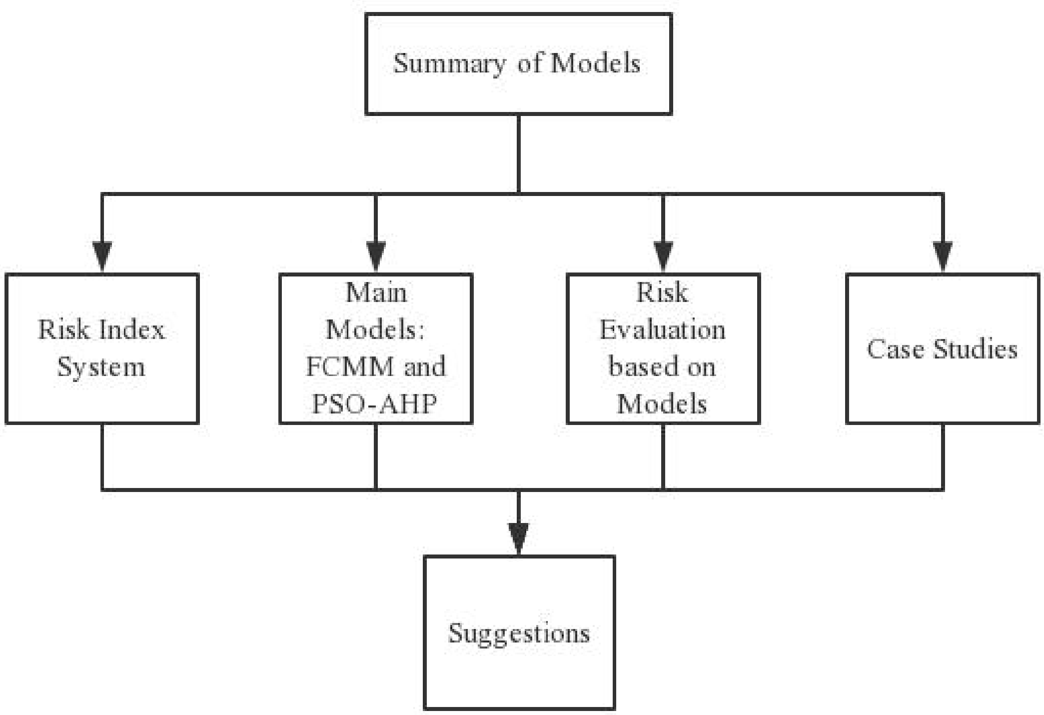
Conclusions and Future Work

Risk assessment has been applied to various fields as an important basis in the decision-making process. In this thesis, risk assessment is applied to large-scale logistics projects characterised as high risk, with high investments and high professionalism. Risk assessment is divided into two levels in this thesis. In the first level, various risk factors in the investment, construction and operation processes of a logistics project are fully considered, and a suitable risk comprehensive evaluation index system is established. Specifically, this thesis judges the degree of each risk and evaluates the overall risk degree of a project by using improved FCMM and PSO–AHP methods. In the second level, combined with the results of the overall project risk assessment, several suggestions for preventing risks in logistics projects are provided. Given the large amount of restrictions on influencing factors, completely quantifying the complex and fuzzy risk identification of logistics enterprises is difficult. Meanwhile, transitive and accumulative risks of logistics enterprises can lead to considerable difficulties in setting up an analytical relationship with the indirect natural logistics enterprise risk index. Thus, to overcome these limitations, a logistics alliance risk identification and analysis method based on the PSO algorithm and a penalty function method is established in this thesis. The result of the risk identification is appropriate and realistic, because this thesis combines FCMM and PSO–AHP methods to analyse and calculate the optimisation problem. This chapter will summarise the work conducted in this thesis and provide several directions for future research.

8.1 Summary of Models

Risk evaluation has been widely used in numerous fields and has important implications for decision making in the early stages of a project. On the basis of the characteristics of logistics projects, this thesis applies suitable risk assessment methods to analyse and evaluate project risks step by step (Allred et al., 2011). In addition, this thesis combines the AHP and PSO methods for the analysis, which is divided into two parts. The first part uses the AHP method to confirm that several project risks require attention to meet the minimum risk requirements of a logistics project. In other words, a product needs to maintain its basic operation and functions; thus the AHP method is initially used. The second part sets up parameters for developing a risk evaluation model and an optimisation algorithm based on the PSO method to utilise its outstanding performance to help identify the best model. The main work related to the models can be summarised as follows **(Figure 8-1)**.

Figure 8- 1 Summary of Models



(1) Risk identification is a prerequisite of risk analysis. The different types and causes of risks are introduced in this thesis. Only by first revealing the risk factors of a project can the severity and probability of occurrences be determined through further evaluation to identify crucial risk factors and propose correlative risk measures (Auramo et al., 2005; Sabath and Fontanella, 2002; Zacharia et al., 2011). Specifically, based on the principles presented in this thesis, risks in large-scale logistics projects are divided into two types, namely, logistics enterprise and logistics environmental risks. The former mainly includes management, technical and operational risks, whereas the latter includes market, fiscal and environmental risks. The details of each risk are presented in **Table 8-1**.

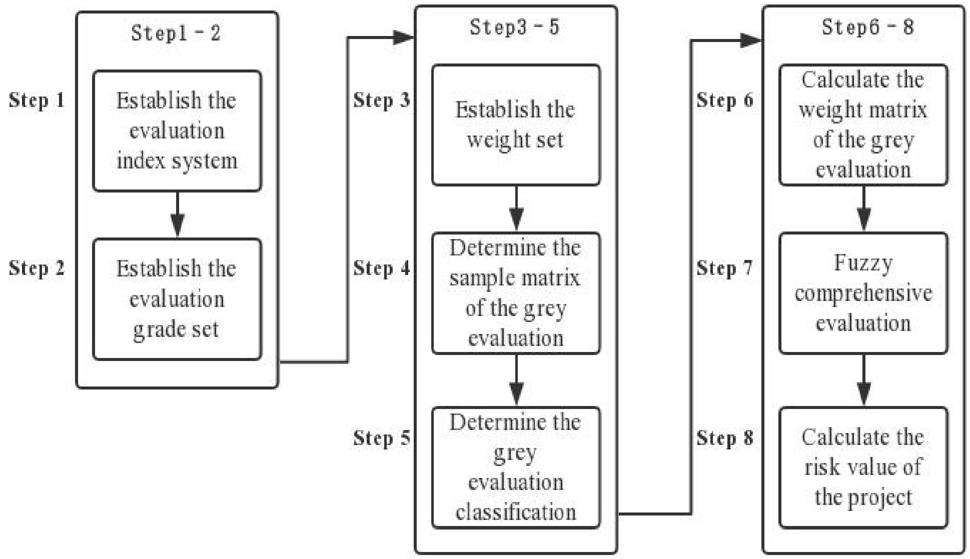
Table 8- 1 Details of Logistics Enterprise Risks

Types	Risk Elements	Element Meaning
Management Risk	Manager quality	Whether senior managers can review the situation, grasp the changes in the environment, seize the opportunities and have the courage to conduct risk decisions.
	Organisational structure	The logistics project can include most things in the society, thus an enterprise's organisational structure can make the project activities smooth, reduce conflicts and friction, avoid unnecessary coordination and improve the efficiency of the project.
	Corporate culture	Corporate culture can bring employees together and form a strong centripetal force to ensure that employees are united and consistent and strive to achieve their goals.
	Shareholder protection	The shareholders of the logistics enterprise can influence the project activities, thus protecting their rights is meaningful.
	Management process	Management process refers to the purpose of controlling risk, reducing cost, improving service quality, working efficiency and response to the market and ultimately upgrading customer satisfaction and market competitiveness to achieve maximum profit and improve

		operating efficiency.
Technical Risk	Technical deficiencies	Within the environment of economic development, numerous logistics enterprises cannot receive sufficient financial support to update their technical operations immediately, thereby resulting in technical deficiencies risk.
	Technical protection	Although China's government has made efforts to protect techniques, the risk that techniques may be acquired by other enterprises remains.
	Technical development	During the process of logistics projects, if one technique cannot be achieved in time, then such a delay may affect the entire logistics project.
	Technical use	If logistics enterprises cannot deal with other enterprises regarding copyright or technique, this inability may cause risk for the entire logistics project.
Operational Risk	Risk due to shippers	During the process of shipping, if shippers do not have a basic sense of responsibility, then they may not pay sufficient attention to the goods they are shipping, which can result in damaged goods.
	Risk due to equipment	During the operation process of logistics projects, if the equipment has certain problems, then these problems affect the entire logistics project.
	Risk due to customers	During the process of operation, if customers suddenly change their minds or are not willing to continue the contract, then the failure of logistics projects will occur.
Market Risk	Changes in consumer demand	As consumers' demand preferences for logistics services from a certain company may change, which can lead to market risk.
	Behaviour of competitor	With the development and improvement of the economy, the degree of market competition is increasing. Logistics enterprises face the competitive pressure of their original competitors and encounter the threat of potential competitors.
	Uncertain and	Lack, asymmetry and inaccuracy of information can lead to

	asymmetric information	mistakes and market failures in logistics enterprises decision-making.
	Exchange rate	During the debt period, due to the influence of inflation, a change of loan interest rate and the increase of interest rate can inevitably increase the logistics enterprise's capital cost, thus offsetting the expected return, which can result in fiscal risk.
Fiscal Risk	Investment risk	Investment risk is due mainly to the uncertainty caused by the business activities from the financial results of the logistics enterprises.
	Liquidity risk	Liquidity risk refers to the possibility that the assets of the logistics enterprise cannot transfer cash through a normal and certain method, or the debt and the payment obligation cannot be performed normally.
	Financing risk	Financing risk refers to the uncertainty caused by the fiscal of enterprises from the financial results due to changes in the supply and demand markets of funds and the macroeconomic environment.
	Risk of changes in interest rates	The same or similar as the exchange rate.
Environment Risk	Macroeconomic development	Logistics projects include most things in society. If the macroeconomics of a country proceeds well, sizeable opportunities for logistics enterprises to develop their projects will occur, otherwise, the development of logistics projects may be affected because of the effect of numerous other activities.
	Policy and law	Policy and law risks refer to the government's major changes in the policies of the relevant logistics enterprises or the introduction of important measures and regulations, which cause fluctuations in the price of the logistics market.
	Political risk	Political risk is the uncertainty caused by the political environment of the host country or the political relationship between the host country and other countries.

Figure 8- 2 Risk Assessment using FCMM

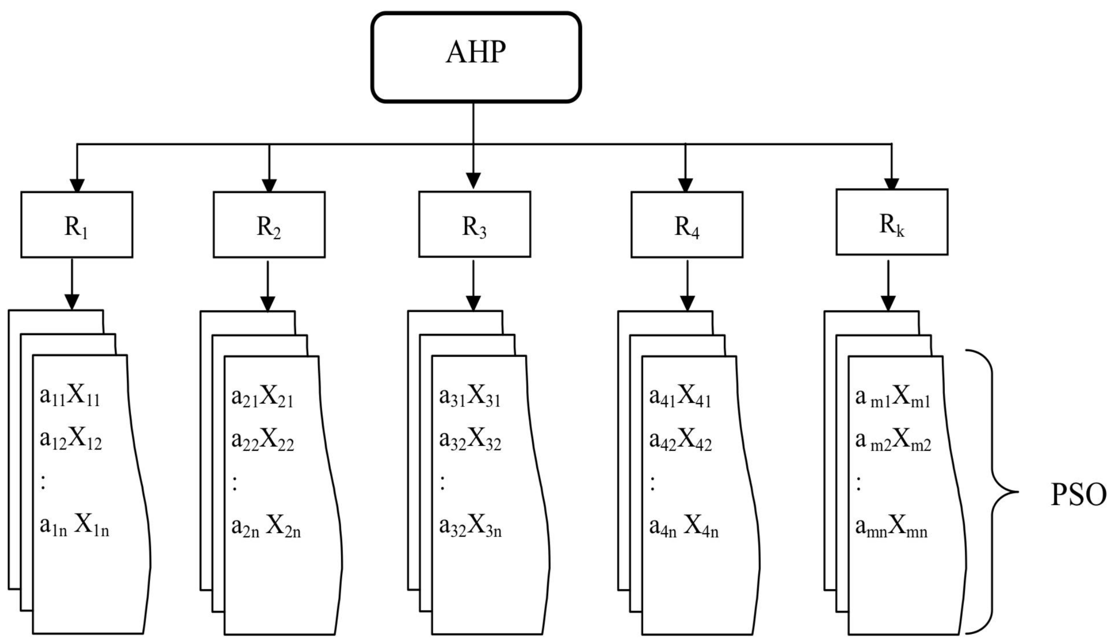


Note: This figure is adapted from Li et al. (2017) and clearly indicates the use of the FCMM method to conduct risk evaluation.

(2) This thesis identifies risks, builds the risk index system and uses the FCMM and PSO–AHP methods to evaluate overall project risks. Firstly, this process establishes an index evaluation system on the basis of the risk characteristics of a logistics project based on Autry and Golicic (2008). Secondly, using the judgment method, the evaluation matrix of each index is obtained through in-depth investigation and calculation. The risk level is obtained after further computation. This thesis considers logistics risk identification and measurement as the research content, systematically examines the theoretical basis of logistics risk identification and measurement as well as the conceptual framework of logistics risk management and analyses the characteristics of logistics risks. Specifically, the FCMM is a comprehensive evaluation method based on fuzzy mathematics (Clandinin, 1989; Zhang and Huo, 2013) that transforms qualitative evaluation into quantitative evaluation according to membership degree theory. Specifically, fuzzy mathematics is used to conduct an overall evaluation of elements or

objects subject to various factors. The FCMM method presents clear results and possesses a strong system that can solve fuzzy and difficult-to-quantify problems and is suitable for solving various non-deterministic problems. Meanwhile, according to Li et al. (2016), when weight is determined by the AHP method, its consistency and weight are likewise determined once the judgment matrix is determined, and no method exists to improve both. To maximise the original information of decision makers and improve judgment matrix consistency as well as weight value when the judgment matrix is determined, this thesis considers combining the advantages of AHP and PSO to obtain the PSO–AHP method (**Figures 8-2 and 8-3**).

Figure 8- 3 AHP System Plan



Note: This figure is directly obtained from Awad et al. (2011).

(3) This thesis considers using the two models to perform risk evaluation in an actual situation after they are introduced. The two methods were applied in **Chapter 6** to evaluate the risks of Hanjin Shipping. The analysis clearly shows which risk is the main cause of the company bankruptcy. This thesis analyses the definition and division of modern logistics in the logistics industry after risk evaluation and expounds the project management model utilised by logistics issues in the transitional period. This study further analyses and interprets project management in the logistics industry, regulates and annotates the meaning of a project and defines specific operation content as '5 + 1' (Chen et al., 2010), which extracts the theoretical basis and practical needs of the project risk management mechanism. The case study for this issue involves the Shandong New Jiahong Company, and this thesis provides a basic explanation on how to manage these logistics project risks.

8.2 Main Innovation and Answering Research Questions

8.2.1 Main Innovation

The theory and method of logistics risk identification and measurement are the premise and bases of logistics risk management. However, research on this specific topic is limited. This thesis takes logistics risk identification and measurement as its research object to study the use of models for risk evaluation and to provide suggestions for risk prevention. Different reasons may cause the formation of risks in the logistics industry. Risk-generated costs are important factors that cannot be ignored in enterprise risk management; thus, a theoretical and methodological framework is necessary for identifying and measuring logistics risks. Moreover, this thesis extends logistics risk identification from the traditional financial insurance field. Logistics risks are an important concept in the field of logistics risk management. This thesis enriches and develops risk management theory, opens up new horizons for theoretical research and enhances the research value of risk evaluation. In addition, it lays the foundation for further studies on other functions and logistics risk management methods and creates a broad research space for logistics risk cost management practices. The main innovation of this thesis can be summarised as follows (**Figure 8-4**).

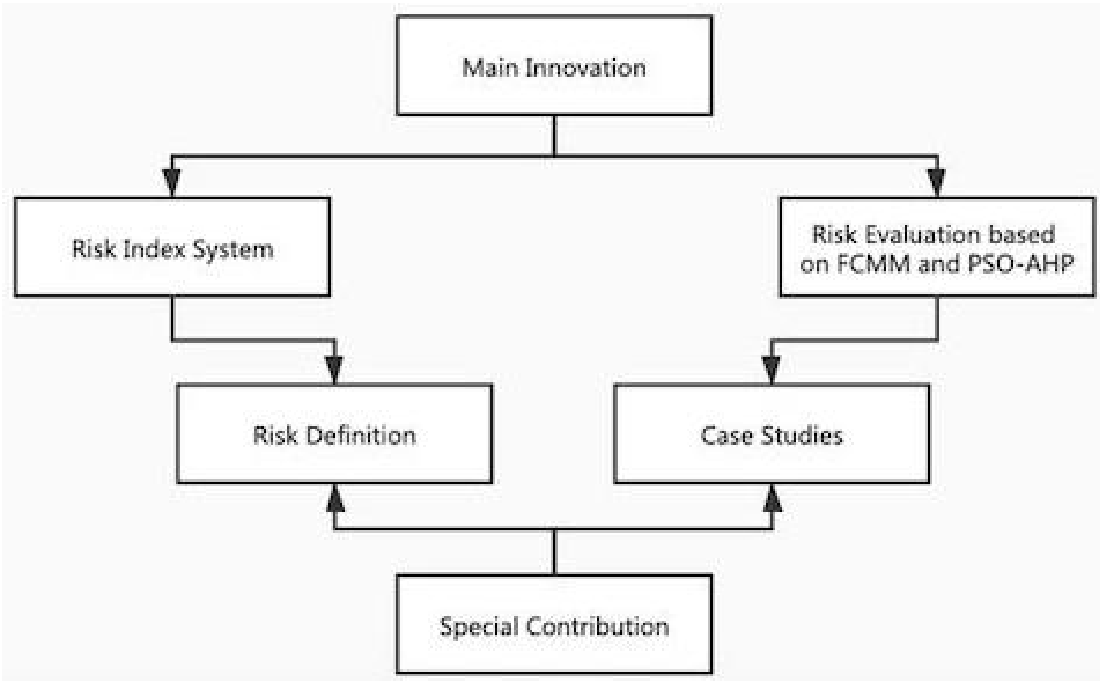
(1) This thesis states that the objective of logistics risk management, referring to the logistics industry and the operation of its services, is to maintain safe operations and prevent or reduce the risk of operational services arising from related expenses. Logistics risks are well known to have uncertain characteristics. Thus, this thesis provides and applies a specific definition of risk to better understand its nature.

Large Scale Logistics Projects Risk is a negative activity or event and a potential consequence that people do not want, including (1) the probability of loss or gain and its measurable size;(2) it is an event that can cause the occurrence of another event that is unrelated to the other, multiple simultaneous events or an ongoing event.

Taking logistics risks as the research object, this thesis explores the new field of risk research, comprehensively classifies the content system of logistics risks and constructs a logistics risk identification and measurement framework. Specifically, the content of logistics risk management is defined according to the risk characteristics of the logistics industry. The identification of uncertainty risks is divided into six types according to degree of certainty, with which this thesis builds a risk index system.

(2) Uncertainty is the primary and basic characteristic of logistics risks. Given the dynamic internal structure of logistics risks, risk certainty and uncertainty are relative, and uncertainty and determination can be transformed. This feature helps identify logistics risks and construct measurement methods scientifically and accurately. On such basis, this thesis constructs a conceptual logistics risk management framework as a systematic framework. Next, the FCMM and PSO–AHP methods are introduced to overcome the limitations of the FCMM and other existing research methods. Meanwhile, a logistics alliance risk identification and analysis method based on the PSO and penalty function method is proposed. Combined, the two methods increase the accuracy and feasibility of the logistics risk identification result by analysing and calculating the risk analysis optimisation problem of logistics projects.

Figure 8- 4 Main Innovations and Special Contributions



8.2.2 Answering the Research Questions

This thesis introduced two research questions in **Chapter 1**, the answers to which are as follows.

How can one qualitatively and quantitatively analyse the risks of logistics projects to comprehensively determine the influence of various risk factors on project objectives to illustrate the economic goals of investments and the possibility of realisation?

Answer: The main objective of this thesis is to measure and analyse the overall risks in large-scale logistics projects. The first step involves setting up different factors that may affect such risks. To achieve this goal, this thesis mainly applies the WBS method, which can group project elements based on the purpose of deliverables. In the risk identification of large-scale logistics projects, this method can transform large systems into small ones, decompose complex objects into simple and easy-to-know ones and clearly show the hierarchical relationship of risks. Next, this thesis uses the FCMM and PSO–AHP methods separately to measure the risks in large-scale logistics projects. Fuzzy theory can solve problems with large amounts of fuzzy information in various risk assessment activities and improve the scientific basis and reliability of risk assessment results. However, the PSO–AHP method can achieve better results than the PSO algorithm used in most studies.

How can one compare two models that can assess logistics risks, choose the best one and promote it to different countries or for other logistics objectives?

Answer: In today's competitive environment, risk evaluation is a critical decision for companies and brings significant advantages. The effect of each method on the risk evaluation problem may differ and conflict with one another. Therefore, these problems represent a complex structure composed of tangible and intangible factors, and the FCMM and PSO–AHP methods provide convenient solutions. According to the index system presented in **Chapter 4** and the methods introduced in **Chapter 5**, Hanjin Shipping was used as a case study in **Chapter 6** to demonstrate how risk evaluation is performed. The results show that both methods could be used to predict risks in Hanjin Shipping and that management risks are the main risks faced by the company, which is consistent with predicted results. The contents of this thesis have provided meaningful results for actual cases, which indicates that the FCMM and PSO–AHP methods can be used to perform risk measurements.

The use of these models in other countries is discussed in Section 8.4.

8.3 Main Contribution and Limitations

8.3.1 Main Contributions

As argued in **Chapter 1**, numerous studies have conducted risk analysis on different projects, such as that of Min et al. (2005), who developed the idea of identifying risk management issues in large-scale sporting events from the perspective of organising committee members and stakeholders. Rousseau et al. (2008) considered the value and risk assessment of supply chain management improvement projects, among others (refer to **Chapter 2** for additional details). However, research on risk assessment of large-scale logistics projects is limited. The following section identifies the main contributions of this thesis.

a) This thesis pays special attention to the risk analysis of large-scale logistics projects on the basis of China's Belt and Road strategy.[51] Given the development of Chinese economics and its special relationship with South Africa, cooperation in numerous aspects, in which logistics projects play a considerable connecting role, has become increasingly important for these two countries. Thus, ensuring low risks among China's large-scale logistics projects has become extremely important. The methods and results of this thesis may possibly also be applied to large-scale logistics projects in South Africa.

b) This thesis applies the WBS method to determine risk factors in logistics construction projects. Previous studies on risk assessment issues favoured the Delphi method for identifying risk factors. However, this method has certain

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[51]The Belt and Road Strategy is a global development strategy adopted by the Chinese government in 2013 involving infrastructure development and investments in nearly 70 countries and international organizations in Asia, Europe, and Africa, see Wang (2016), World Bank (2019), Yu (2016). To accomplish this strategy, China must increase its investments in the countries involved, which may bring large risks for many logistics projects. For example, while Chinese logistics projects bring strong technical expertise to the table, the companies or managers may lack local expertise, which causes the environmental risk. The Chinese enterprises with large-scale logistics projects must consider the requirements of environmental protection before engaging in local sustainable investing in a country with stringent environmental standards (Xu and Chung, 2018; Yu, 2017). Besides this, during the Belt and Road strategy investment, the companies who brings a large-scale logistics projects may have social risk, such as poverty, social crime, employment rate, and so on. Good social order is a basic condition for the development of the projects (Chen, 2016; Xu and Chung, 2018). Finally, the Chinese enterprises with large-scale logistics projects should consider the governance risk, like corruption control, political stability, legal system construction, and so on (Hayes, 2017; Xu and Chung, 2018; Yu, 2017). All these risks could be modeled through a risk index and analysed via the methods proposed in this these. Thus, this thesis can offer some insights on assessing and preventing risks for these logistics projects based on the Belt and Road Strategy.

disadvantages, including experts' personal judgment, which is limited by their knowledge, ability and experience, and the recognition result, which is influenced by the subjective factors of the experts. Rather than using this method, this thesis utilises the WBS method, which can provide a reasonable risk index system.

c) This thesis transforms the PSO into the PSO–AHP method, which is then applied to the risk assessment of large-scale logistics projects. Numerous studies have focused on the use of the FCMM method for risk assessment, such as that of Cheng and Tao (2009), who integrated the concepts of the analytical hierarchy process and fuzzy consistent matrix method to identify risk factors in bridge construction. Moreover, Chen et al. (2015) presented a fuzzy logic-based method that synthesises the fuzzy analytical hierarchy process based on a three-point scale, fuzzy set theory and fuzzy logic into a single integrated approach to measure risks in bridge construction. However, limited research has focused on the use of the PSO–AHP method for the risk assessment of large-scale logistics projects. This thesis utilises not only the FCMM but also the PSO–AHP method to perform risk assessment and chooses the best one according to certain criteria. By doing so, it provides a novel example for choosing between the two models when conducting risk assessment.

d) This thesis measures and analyses risks in large-scale logistics projects and provides several strategies for improving logistics project management to reduce the chance of risk occurrences in China based on actual situations. In addition, it provides suggestions for the development of large-scale Chinese logistics projects in South Africa. Risk measurement in large-scale logistics projects is not merely an instrument, as measurement is not the final objective. Each method should be used to provide guidelines for the development of actual projects. Thus, by combining the results obtained from models and actual situations in China and South Africa, this thesis presents several strategy suggestions that may reduce risks in large-scale logistics projects in both countries.

Table 8- 2 Main Contributions

Contribution 1	This thesis pays special attention to the risk analysis of large-scale logistics projects on the basis of China's Belt and Road strategy.

Contribution 2	This thesis applies the WBS method to determine risk factors in logistics construction projects, which can provide a novel and reasonable risk index system in the context of large-scale logistics projects.
Contribution 3	This thesis transforms the PSO into the PSO–AHP method, which is then applied to the risk assessment of large-scale logistics projects.
Contribution 4	This thesis measures and analyses risks in large-scale logistics projects and provides several strategies for improving logistics project management to reduce the chance of risk occurrences in China based on actual situations. In addition, this thesis provides suggestions for the development of large-scale Chinese logistics projects in South Africa.

8.3.2 Limitations

At present, numerous deficiencies and shortcomings remain in the field of logistics risk evaluation. This thesis attempts to comprehensively study the identification and measurement as well as the analysis of logistics risks and constructs a scientific and reasonable identification and measurement system to enrich risk management theory and practice (Mena et al., 2013; Moberg and Speh, 2003). However, as a completely new field, research results have yet to be systematised, and the results and information available for reference are scarce. Therefore, though this thesis attempts to conduct a pioneering research, achieving the desired effect is difficult. The application of risk management in this thesis is relatively shallow, which means that the depth and breadth of the analysis are far from complete and that other logistics risk management functions are not covered. The two main limitations of this thesis can be summarised as follows.

(1) The establishment of the evaluation index system in the risk assessment of logistics projects is an extremely important factor. The evaluation indicators proposed in this thesis are imperfect and not detailed owing to limited time and data and are only for Chinese logistics enterprises. Moreover, no distinction between different types of logistics companies is made.

(2) This thesis uses the FCMM and PSO–AHP methods. Although the results indicate few significant differences between the two models, other models, such as the BP network, are not considered.

Table 8- 3 Main Limitations

Limitation 1	The evaluation indicators proposed in this thesis are imperfect and not detailed owing to limited time and data and are only for Chinese logistics enterprises. Moreover, no distinction between different types of logistics companies is made.
Limitation 2	Other methods for performing analysis can be considered.

8.4 Generalisations of Findings to South Africa

Risk prevention in South Africa is briefly introduced in this section. South Africa, which is located on the African continent (one of the fastest growing economies in the world), has continued to drive its economic growth globally without proper assistance. However, conducting business in such a complex environment can be difficult. The economic growth rate in sub-Saharan Africa is predicted to considerably exceed the global average in the next 3 years. According to the World Bank forecast, the country's economic growth rate may exceed 5% as investments increase. South Africa is a strong African country, and its rapid development is backed by a strong driving force. In addition, the country has the most advanced and broadest economic system, and its infrastructure has reached the same level as that of developed countries. Thus, the main risks faced by logistics enterprises in South Africa are as follows (the following arguments are from the Chinese context).

(1) Firstly, former President Zuma was forced to resign from the National Assembly in February 2018, and Vice President Ramaphosa succeeded him. The South African economy under the Zuma administration was relatively weak, and the non-national public opinion support rate for the ruling party similarly showed a downward trend.

(2) South Africa is a country with considerable power resources. However, South African power companies may be unable to meet the growing domestic demand for electricity owing to a number of factors including maintenance and development of the power system and the possible effect of the economic crisis.

The following suggestions are presented from the Chinese context to possibly prevent risks in South Africa.

(1) Labour relations in South Africa highly differ from those in China, and trade unions represent the interests of employees to a large extent. In actual operations, Chinese-funded industrial and commercial enterprises should strictly implement relevant labour laws, hire professional lawyers, properly resolve production and operation conflicts between employees and trade unions and maintain close contact with semi-official organisations, such as industry associations and chambers of commerce.

(2) Attention should be directed to environmental protection. South African laws and regulations on environmental protection are extremely strict. Enterprises investing in South Africa should understand and comply with relevant local environmental protection laws and regulations. Investment management decisions should fully consider environmental protection, infrastructure construction and employee training. In business operations, enterprises should pay considerable attention to specific environmental protection measures.

(3) Awareness and prevention of security risks should be increased. Thus, Chinese-funded industrial and commercial enterprises should strengthen safety training for employees, improve safety awareness. In the event of an emergency, employees should call the police as soon as possible and contact the Chinese Embassy or Consulate in South Africa.

Table 8- 4 Risk and Suggestions for South Africa

Risks	Suggestions
The political situation	Strictly implement relevant labour laws.
The social security problem	Focus on protecting the environment.
South African power companies are unable to meet the growing domestic demand for electricity.	Increase awareness and prevention of security risks.

8.5 Further Research

As discussed in Section 8.3.2, two main limitations exist in this thesis. Thus, the following suggestions can help enrich future research.

(1) The identification of logistics risks is the basis and precondition of logistics risk measurement. Moreover, it should rely on the systematic research of various logistics risks that can help confirm risk costs scientifically and accurately. However, given that the focus of this thesis is logistics risks, the study is relatively shallow, as it only qualitatively examines the recognition of logistics risks. In the future, researchers can try to quantitatively describe the identification method and validate the relevant experimental data to better identify and confirm risks (Clarke and Oxman, 2001). Quantitative analysis requires the support of large amounts of data and complex mathematical models; however, these are not included in this thesis. Thus, it can be a potential research direction in the future.

(2) Logistics risk measurement is the core of logistics risk management. The choice of measurement model in this thesis draws on relevant risk management measurement models, namely, the FCMM and PSO–AHP methods. Although these two methods have been adapted to the logistics industry, other methods could also be considered in the future. Meanwhile, the logistics risk management system is complete, including identification, measurement, accounting, control, transfer and evaluation (Cooper and Ellram, 1993; Habib et al., 2015). However, this thesis studies only the identification and measurement of logistic risks owing to its limited depth and length. Thus, the extension of its content could be a future research direction. Moreover, the guts of the PSO-AHP is the selection and weighting of criteria, and the application of these weighted criteria to the alternatives we are considering. How to choose the weights in PSO-AHP method is an important direction that deserves to be researched further. For example, in future research a consensus and focus group of experts can be used to better asses the weights for Hanjing Shipping.

(3) Research on logistics risk management requires a large number of typical cases for promoting and conducting in-depth follow-up surveys in representative logistics enterprises. Such cases can provide important suggestions and practical tools for logistics risk management (Haker, 1999; Mishra and Shah, 2009). Although this thesis presents examples for support, the strict sense of logistics risk management has yet to be implemented in the field. Thus, researchers can focus their attention to this direction in the future.

8.6 References

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Appendix 1 MATLAB CODE

1 Code for FCMM[52]

According to the argument in Zhou and Chan (2016), the steps for FCMM could be divided into the following steps:

Step 1: Determining the set of evaluation factors;

Step 2: Determining the set of appraisal grades;

Step 3: Setting the fuzzy mapping matrix;

Step 4: Determining the weight of each evaluation factor;

Step 5: Getting the overall appraisal result.

Then this thesis develops the following code based on https://chiang97912.github.io/2018/09/02/ to run the FCMM algorithm:

```
function fuzzy_method
A1=[0.31 0.18 0.25 0.16 0.29 0.10];
    A2=[0.29 0.17 0.25 0.11 0.30 0.12];
    R=[0.25 0.38 0.47 0.1 0.2;
        0.37 0.48 0.21 02 0.1;
        0.39 0.40 0.28 0.17 0.12;
        0.34 0.49 0.29 0.26 0.33;
        0.03 0.29 0.117 0.01 0.35;
        0.28 0.36 0.05 0.28 0.04];
    fuzzy_comprehensive_evaluation(1,A1,R)
    fuzzy_comprehensive_evaluation(1,A2,R)
end
function B=fuzzy_comprehensive_evaluation(model,A,R)
    B=[];
    [m,s1]=size(A);
    [s2,n]=size(R);
    if(s1~=s2)
         disp('A? column is not equal to R? row');
    else
        if(model==1)
            for(i=1:m)
                for(j=1:n)
                    B(i,j)=0;
```

[52]It refers https://chiang97912.github.io/2018/09/02/.

```
                for(k=1:s1)
                    x=0;
                    if(A(i,k)<R(k,j))
                        x=A(i,k);
                    else
                        x=R(k,j);
                    end
                   if(B(i,j)<x)
                       B(i,j)=x;
                   end
                end
            end
        end
elseif(model==2)
        for(i=1:m)
           for(j=1:n)
               B(i,j)=0;
               for(k=1:s1)
                   x=A(i,k)*R(k,j);
                   if(B(i,j)<x)
                       B(i,j)=x;
                   end
               end
           end
        end
elseif(model==3)
           for(i=1:m)
              for(j=1:n)
                 B(i,j)=0;
                 for(k=1:s1)
                     B(i,j)=B(i,j)+A(i,k)*R(k,j);
                 end
               end
            end
 elseif(model==4)
            for(i=1:m)
                for(j=1:n)
                    B(i,j)=0;
                    for(k=1:s1)
                        x=0;
                        x=min(A(i,k),R(k,j));
                        B(i,j)=B(i,j)+x;
                    end
                        B(i,j)=min(B(i,j),1);
                end
             end
   elseif(model==5)
             C=[];
             C=sum(R);
             for(j=1:n)
                for(i=1:s2)
                    R(i,j)=R(i,j)/C(j);
                end
             end
             for(i=1:m)
                 for(j=1:n)
```

```
                        B(i,j)=0;
                        for(k=1:s1)
                            x=0;
                            x=min(A(i,k),R(k,j));
                            B(i,j)=B(i,j)+x;
                        end
                    end
                end
            else
                disp('Not correct');
            end
    end
end
```

2 Code for PSO[53]

The PSO algorithm consists of just three steps:

Step 1: Evaluate fitness of each particle;

Step 2: Update individual and global bests;

Step 3: Update velocity and position of each particle.

Then one could use the following code to run the PSO algorithm:

```
c1=3;
c2=3;
Dimension=10;
Size=40;
Tmax=1000;
Velocity_max=1200;

F_n=3;

Fun_Ub=500;
Fun_Lb=-500;
Position=zeros(Dimension,Size);
Velocity=zeros(Dimension,Size);
Vmax(1:Dimension)=Velocity_max;
Vmin(1:Dimension)=-Velocity_max;
Xmax(1:Dimension)=Fun_Ub;
Xmin(1:Dimension)=Fun_Lb;
[Position,Velocity]=Initial_position_velocity(Dimension,Size,Xmax,Xmin,Vmax,Vmin);

Pbest_position=Position;
Gbest_position=zeros(Dimension,1);
for j=1:Size
    Pos=Position(:,j);
    fz(j)=Fitness_Function(Pos,F_n,Dimension);
```

[53]It refers https://blog.csdn.net/google19890102/article/details/30044945.

```
end
[Gbest_Fitness,I]=min(fz);
Gbest_position=Position(:,I);

for itrtn=1:Tmax
time(itrtn)=itrtn;

Weight=1;
r1=rand(1);
r2=rand(1);
for i=1:Size

Velocity(:,i)=Weight*Velocity(:,i)+c1*r1*(Pbest_position(:,i)-Position(:,i))+c2*r2*(Gbest_position-Position(:,i)
);
end

for i=1:Size
      for row=1:Dimension
            if Velocity(row,i)>Vmax(row)
                  Veloctity(row,i)=Vmax(row);
            elseif Velocity(row,i)<Vmin(row)
                  Veloctity(row,i)=Vmin(row);
            else
            end
      end
end

Position=Position+Velocity;

for i=1:Size
      for row=1:Dimension
            if Position(row,i)>Xmax(row)
                  Position(row,i)=Xmax(row);
            elseif Position(row,i)<Xmin(row)
                  Position(row,i)=Xmin(row);
            else
            end
      end
end

   for j=1:Size
        P_position=Position(:,j)';
        fitness_p(j)=Fitness_Function(P_position,F_n,Dimension);
        if fitness_p(j)< fz(j)
              Pbest_position(:,j)=Position(:,j);
              fz(j)=fitness_p(j);
        end
        if fitness_p(j)<Gbest_Fitness
              Gbest_Fitness=fitness_p(j);
        end
   end
   [Gbest_Fitness_new,I]=min(fz);
     Best_fitness(itrtn)=Gbest_Fitness_new;
     Gbest_position=Pbest_position(:,I);
end
```

```
plot(time,Best_fitness);
xlabel('number');ylabel('P_g');

function [Position,Velocity] = Initial_position_velocity(Dimension,Size,Xmax,Xmin,Vmax,Vmin)
   for i=1:Dimension
         Position(i,:)=Xmin(i)+(Xmax(i)-Xmin(i))*rand(1,Size);
         Velocity(i,:)=Vmin(i)+(Vmax(i)-Vmin(i))*rand(1,Size);
   end
end

function Fitness=Fitness_Function(Pos,F_n,Dimension)
 switch F_n
      case 1
            Func_Sphere=Pos(:)'*Pos(:);
            Fitness=Func_Sphere;
      case 2
            res1=Pos(:)'*Pos(:)/4000;
            res2=1;
            for row=1:Dimension
                  res2=res2*cos(Pos(row)/sqrt(row));
            end
            Func_Griewank=res1-res2+1;
            Fitness=Func_Griewank;
end
```

3 PSO–AHP Code[54]

According to the argument of Di et al. (2018), the steps of PSO–AHP can be summarised as follows:

Step 1 Generate the initial solution of particles;

Step 2 Calculate the fitness of the initial particle;

Step 3 Update the particle iterations;

Step 4 Determine whether the updated particles meet the constraint conditions;

Step 5 Calculate the fitness levels of the updated particles;

Step 6 Judge whether the optimal solution meets the iterative termination condition;

Step 7 Calculate the consistency ratio value corresponding to the judgment matrix.

Then one could use the following code to run the PSO–AHP algorithm:

```
import java.util.Random;
import java.math.BigDecimal;

public class Pos_AHP {
            private final double[][] A = new double[][]
                  {
```

[54]It refers https://github.com/MirrorHuang/ PSO–AHP.

```
        { 1, 6/5, 3/2, 1, 7 },
        { 5/6, 1, 6/5, 4/5, 6},
        { 2/3, 5/6, 1, 3/4, 5};
        {1, 5/4, 4/3, 1, 7};
        {1/7, 1/6, 1/5, 1/7, 1};
        };    //
  private final int n=A.length;
  private final int step=3000;
  private final int PosNum=70;
  private double w;
  private final double c1=2;
  private final double c2=2;

  private double[] g_best;
  private double[] p_best=new double[n];
  private double[][] p_v=new double[PosNum][n];
  private double[][] p_pos=new double[PosNum][n];

  private Random random=new Random();

 public static void main(String args[])
 {
      Pos_AHP pos=new Pos_AHP();
      pos.Initialize();
      pos.Search();
 }

 public void Initialize()
 {
      int r=random.nextInt(n);
      for(int i=0;i<PosNum;i++)
      {
           for(int j=0;j<n;j++){
                p_pos[i][j]=random.nextDouble();
           }
           p_pos[i]=nor(p_pos[i]);
           for(int j=0;j<r;j++){
                p_v[i][j]=random.nextDouble()/10-0.1;
           }
           for(int j=r;j<n;j++){
                p_v[i][j]=random.nextDouble()/10;
           }
      }
      p_best=p_pos[0].clone();
      for(int i=1;i<PosNum;i++){
           if(function(p_best)>function(p_pos[i]))
            {
                p_best=p_pos[i].clone();
            }
      }
      g_best=p_best.clone();
 }

 public void Search()
 {
```

```
		for(int j=0;j<step;j++)
		{
			w=0.9-(j/step)*0.5;
			for(int i=0;i<PosNum;i++)
			{
				for(int k=0;k<n;k++){
p_v[i][k]=w*p_v[i][k]+c1*random.nextDouble()*(p_best[k]-p_pos[i][k])+c2*random.nextDouble()*(g_best[k]-p_pos[i][k]);
					p_pos[i][k]+=p_v[i][k];
				}
			}
			p_best=p_pos[0].clone();
			for(int i=0;i<PosNum;i++){
				if(function(p_best)>function(p_pos[i]))
				{
					p_best=p_pos[i].clone();
				}
			}
			/* for(int i=0;i<PosNum;i++)
			{
				System.out.print(p_best[i]+" ");
			}
			System.out.println("***");
			for(int i=0;i<n;i++){
				System.out.print(g_best[i]+" ");
			}
			System.out.println("******");*/
			if(function(g_best)>function(p_best))
			{
//				System.out.println("global?"+function(g_best)+" "+function(p_best));
				g_best=p_best.clone();
			}


//			for(int i=0;i<PosNum;i++)
//			{
//				for(int k=0;k<n;k++){
//					System.out.println( p_v[i][k]+" "+p_pos[i][k]);
//				}
//			}
		}


		g_best=nor(g_best);
		for(int i=0;i<n;i++){
			g_best[i]=round(g_best[i],4);
			System.out.print(g_best[i]+" ");
		}
		System.out.println("*****************");
		System.out.println(function(g_best));
	}
	public double function(double[] x)
	{
		double y=0;
```

```
            double tmp=0;
            for(int i=1;i<n;i++){
                for(int j=1;j<n;j++){
                    tmp+=A[i][j]*x[j];
                }
                y+=Math.abs(tmp-n*x[i]);
            }
            return y/n;
        }

        public double[] nor(double[] x)
        {
            double sum=0;
            for(int i=0;i<x.length;i++){
                sum+=Math.abs(x[i]);
            }
            for(int i=0;i<x.length;i++){
                x[i]=Math.abs(x[i])/sum;
            }
            return x;
        }
        /**
         *
         * @param v
         * @param scale
         * @return
         */
        public double round(double v, int scale) {
            if (scale < 0) {
                throw new IllegalArgumentException(
                        "The scale must be a positive integer or zero");
            }
            BigDecimal b = new BigDecimal(Double.toString(v));
            BigDecimal one = new BigDecimal("1");
            return b.divide(one, scale, BigDecimal.ROUND_HALF_UP).doubleValue();
        }
    }
import java.util.Random;
    import java.math.BigDecimal;

    public class Pos_AHP {
        private final double[][] A = new double[][]
            {
            { 1, 6/5, 3/2, 1, 7 },
            { 5/6, 1, 6/5, 4/5, 6},
            { 2/3, 5/6, 1, 3/4, 5};
            {1, 5/4, 4/3, 1, 7};
            {1/7, 1/6, 1/5, 1/7, 1};
            };
        private final int n=A.length;
        private final int step=3000;
        private final int PosNum=70;
        private double w;
        private final double c1=2;
        private final double c2=2;
```

```
  private double[] g_best;
  private double[] p_best=new double[n];
  private double[][] p_v=new double[PosNum][n];
  private double[][] p_pos=new double[PosNum][n];
  private Random random=new Random()
 public static void main(String args[])
 {
      Pos_AHP pos=new Pos_AHP();
      pos.Initialize();
      pos.Search();
 }
 public void Initialize()
 {
      int r=random.nextInt(n);
      for(int i=0;i<PosNum;i++)
      {
           for(int j=0;j<n;j++){
                p_pos[i][j]=random.nextDouble();
           }
           p_pos[i]=nor(p_pos[i]);
           for(int j=0;j<r;j++){
                p_v[i][j]=random.nextDouble()/10-0.1;
           }
           for(int j=r;j<n;j++){
                p_v[i][j]=random.nextDouble()/10;
           }
      }
      p_best=p_pos[0].clone();
      for(int i=1;i<PosNum;i++){
           if(function(p_best)>function(p_pos[i]))
            {
                p_best=p_pos[i].clone();
            }
      }
      g_best=p_best.clone();
 }
 public void Search()
 {
      for(int j=0;j<step;j++)
      {
           w=0.9-(j/step)*0.5;
           for(int i=0;i<PosNum;i++)
           {
                for(int k=0;k<n;k++){

p_v[i][k]=w*p_v[i][k]+c1*random.nextDouble()*(p_best[k]-p_pos[i][k])+c2*random.nextDouble()*(g_best[k]-
p_pos[i][k]);
                     p_pos[i][k]+=p_v[i][k];
                }
           }
           p_best=p_pos[0].clone();
           for(int i=0;i<PosNum;i++){
                if(function(p_best)>function(p_pos[i]))
                {
                     p_best=p_pos[i].clone();
                }
```

```
			}
			/* for(int i=0;i<PosNum;i++)
			{
				System.out.print(p_best[i]+" ");
			}
			System.out.println("***");
			for(int i=0;i<n;i++){
				System.out.print(g_best[i]+" ");
			}
			System.out.println("******");*/
			if(function(g_best)>function(p_best))
			{
//				System.out.println("global?"+function(g_best)+" "+function(p_best));
				g_best=p_best.clone();
			}
//			for(int i=0;i<PosNum;i++)
//			{
//				for(int k=0;k<n;k++){
//					System.out.println( p_v[i][k]+" "+p_pos[i][k]);
//				}
//			}
		}
		g_best=nor(g_best);
		for(int i=0;i<n;i++){
			g_best[i]=round(g_best[i],4);
			System.out.print(g_best[i]+" ");
		}
		System.out.println("*****************");
		System.out.println(function(g_best));
	}
	public double function(double[] x)
	{
		double y=0;
		double tmp=0;
		for(int i=1;i<n;i++){
			for(int j=1;j<n;j++){
				tmp+=A[i][j]*x[j];
			}
			y+=Math.abs(tmp-n*x[i]);
		}
		return y/n;
	}
	public double[] nor(double[] x)
	{
		double sum=0;
		for(int i=0;i<x.length;i++){
			sum+=Math.abs(x[i]);
		}
		for(int i=0;i<x.length;i++){
			x[i]=Math.abs(x[i])/sum;
		}
		return x;
	}
	/* @param v
	 * @param scale
	 * @return
```

```
     */
    public double round(double v, int scale) {
        if (scale < 0) {
            throw new IllegalArgumentException(
                    "The scale must be a positive integer or zero");
        }
        BigDecimal b = new BigDecimal(Double.toString(v));
        BigDecimal one = new BigDecimal("1");
        return b.divide(one, scale, BigDecimal.ROUND_HALF_UP).doubleValue();
    }
}
```