DEVELOPING THE SITUATION AWARENESS MODEL OF EMERGENCY LOGISTICS FOR TROPICAL CYCLONE DISASTERS IN GUANGXI CHINA

GUOYOU YUE

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Doctor of Philosophy in Logistics and Supply Chain
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By Guoyou Yue

has been approved by the Graduate School as partial fulfillment of the requirements for the Doctor of Philosophy in Logistics and Supply Chain of Naresuan University

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Title	DEVELOPING THE SITUATION AWARENESS MODEL OF EMERGENCY LOGISTICS FOR TROPICAL CYCLONE DISASTERS IN GUANGXI CHINA
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ABSTRACT

This thesis selects the data of tropical cyclone (TC, or typhoon) disaster events as the logical starting point of the research. Through the analysis and deconstruction of the data of tropical cyclone disasters (TCD) events in Guangxi, data mining and other methods are used to build the requirements prediction model of emergency supplies (RPMES), the location model of emergency supplies reserve center (LMESRC) and the emergency supplies dispatching model (ESDM) based on the data of TCD. Finally, the functions of these three models are integrated to form the situational awareness model of emergency logistics (EL) for TCD in Guangxi, which provides a series of schemes for Guangxi governments at all levels to carry out TCD relief in Guangxi.

The main research objectives and research finding of this thesis is as follows:

(1) Structured data processing of TCD events in Guangxi. Fifty-one severe TCD suffered by Guangxi during 2005-2022 were selected as the research object to

analyze the types, sources, characteristics, and major disaster data of TCD events in Guangxi. It mainly includes TC number, name in both Chinese and English, maximum wind speed extreme value (m/s) in Guangxi, duration of impact on Guangxi (hours), direction entering Guangxi, affected population, emergency relocation and resettlement of population, number of collapsed houses, the affected area of crops, direct economic losses and other data. Through the statistical analysis of the data of TCD in the past 18 years, it can be seen that TCD has caused great losses to the economy and society of Guangxi every year. This will provide data support to construct three situation awareness models of EL for TCD in Guangxi.

(2) Developing a RPMES for TCD in Guangxi. The RPMES is the premise of emergency supplies (ES) reserve and ES collection. At present, there is still a lack of effective methods to accurately determine the requirements of ES, and it is urgent to carry out exploration in this aspect. In this paper, 51 severe TCDs suffered by Guangxi from 2005 to 2022 were selected as the research object. The number of emergency relocations and resettlement among the characteristic elements of disaster data was selected as the independent variable, and the extreme central wind speed during the TC in Guangxi. The duration of its impact on Guangxi, the number of collapsed houses, and direct economic losses were selected as the dependent variables. The MLRM was used to construct the RPMES for TCD in Guangxi. Matlab was used for data analysis and optimization calculation, and finally a practical MLRM with significant relationship between the independent variable and the four dependent variables was obtained. This model can provide reference for all levels of Guangxi government to make ES reserve plan and purchase decision.

(3) Developing a LMESRC for TCD in Guangxi. On average, Guangxi experience 2 severe TCD yearly. A large number of disaster victims need governments at all levels to raise enough ES to carry out effective relief. However, there is no proper reserve center for TCD storage and collection of ES in Guangxi, so it is urgent to choose a suitable location to build the ESRC for TCD in Guangxi. To collect data on 16 severe TC suffered by 14 prefecture-level cities in Guangxi from 2014 to 2021 and rescue data. An optimal LMESRC for TCD in Guangxi was established using the improved center of gravity method (CGM) based on GIS. After

four iterations of calculation, the longitude and latitude coordinate S^5(108.64, 21.98) were used as a suitable site to construct the ESRC for TCD in Guangxi to ensure the fastest and lowest cost delivery of ES to the disaster areas in Guangxi. According to the map of Tiandi, the actual place corresponding to this coordinate is near Liuwu Village next to Qinzhou East Railway Station, Qinnan District, Qinzhou, Guangxi. This location coordinate S^5 can provide a reference for the Guangxi government to select a suitable address to construct the ESRC for TCD in Guangxi. The improved center of gravity location model based on GIS can also provide a reference for other provinces or cities to carry out ESRC locations.

(4) Developing an ESDM for TCD in Guangxi. The typical TC No. 1409 Super typhoon "Rammasun" and No. 1822 Super typhoon "Mangkhut" are selected as cases. Extract the characteristic elements of ESD (including the distribution and location information of the ES storage repositories at the provincial, prefectural, and county levels, various traffic lines and distances between the ES storage repositories and the disaster areas, and the ES storage data of the ES storage repositories, etc.). In view of such ESD problems of multi-supply points to multi-demand points, The traditional provincial → prefecture-level city → county ESDM and provincial → county direct supply ESDM for TCD in Guangxi were constructed respectively by linear programming model and operation method on the graph. By comparing the calculation results of the two models, it is found that the traditional provincial → prefecture-level city → county-level ESDM adopted by the Guangxi government is simple and convenient, but the cost is high. The cost of the improved provincial → county direct supply ESDM is lower, which can save 31.72% and 16.56% in the two disaster cases, and the dispatching effect is better. The direct supply model of ES from province to county can provide a reference for the emergency management departments of Guangxi governments at all levels to formulate ESD plans for TCD.

(5) Combining the situation awareness model of EL for TCD in Guangxi. The severe TCD events suffered by Guangxi during 2005-2022 are selected as the basis of data analysis of EL, and the RPMES, the LMESRC and the ESDM are developed based on the data of TCD. Finally, the function of the three models is integrated to form the overall situation awareness model of EL for TCD in Guangxi.

The aim is to solve a series of urgent problems faced by emergency management departments of Guangxi governments at all levels when facing TCD.

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Guoyou Yue

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ABBREVIATIONS

EL	=	Emergency Logistics
Guangxi	=	Guangxi Zhuang Autonomous Region
TC	=	Tropical Cyclone(s)
TCD	=	Tropical Cyclone Disaster(s)
ES	=	Emergency Supplies
ESRC	=	Emergency Supplies Reserve Center
ESD	=	Emergency Supplies Dispatching
ESDM	=	Emergency Supplies Dispatching Model
RPMES	=	Requirements Prediction Model of Emergency Supplies
LMESRC	=	Location Model of Emergency Supplies Reserve Center
MLRM	=	Multiple linear regression method
CGM	=	Center of Gravity Method
LP	=	Linear Programming
OMG	=	Operation Method on the Graph

CHAPTER I

INTRODUCTION

1. Research Background

In March 2018, The State Council established the Ministry of Emergency Management in institutional reform. The newly established Ministry of Emergency Management is responsible for more than 10 government departments, including The General Office of the State Council for Emergency Management, the Ministry of Public Security for fire control, the Ministry of Civil Affairs for disaster relief, the China Earthquake Administration for earthquake emergency rescue, and the Ministry of Water Resources for flood and drought disaster prevention. The establishment of the Ministry of Emergency Management of The State Council will greatly integrate all kinds of emergency management resources nationwide and improve the level of emergency management. Immediately following the establishment of the Ministry of Emergency Management of the State Council, all provinces, autonomous regions, and municipalities will set up emergency management offices in accordance with The State Council's institutional reform plan. In October 2018, the Guangxi Zhuang Autonomous Region (Guangxi) government also established a new departmental emergency management office. Subsequently, prefecture-level cities and counties also set up emergency management bureaus accordingly. Emergency management departments of governments at all levels in Guangxi will further integrate emergency management resources in the region to enhance disaster response capabilities.

According to statistical analysis, from 1979 to 2018, nearly 80 tropical cyclones (TC, generally referred to as typhoons in China) entered Guangxi. Guangxi is affected by TC several times a year. The statistics of typhoons entering the inland of Guangxi from 1970 to 2013 show that there were 89 typhoons in Guangxi in 44 years, with an average of 2 typhoons per year (*Li Jing, Qi Liyan, 2015*). From 2005 to 2022, a total of 51 severe TC affected Guangxi. These tropical cyclone disasters (TCD) caused a large number of casualties and economic losses in Guangxi. No. 0606 Typhoon "Pipian" entered Guangxi from Yulin, causing 5.76 million people affected in 74 counties (cities and districts) in Guangxi, 34 people died, and the direct economic loss was 7 billion yuan (Li Jing et al., 2007). According to the report of the Civil Affairs Department of Guangxi, as of 7:10 a.m. on July 20, 2014, No. 1409 super typhoon "Rammasun" landed in the Fangchenggang area of Beibu Gulf, causing a total of 4,330,361 people in 57 counties (cities and districts) in 11 cities such as Beihai and Fangchenggang. Ten people died in the disaster, and 320,621 must be relocated urgently. 770,787.41 hectares of crops were affected, 10,167 houses collapsed and direct economic losses amounted to 13,898,639,400 RMB yuan. According to the report of the Civil affairs department of Guangxi, the No. 1822 strong typhoon "Mankhut" entered Guangxi at around 23:00 on September 16, 2018, bringing strong winds and torrential rain to Yulin and Guigang. As of 8 o 'clock on September 18, 2018, the typhoon affected 1,479,397 million people in 55 counties (cities and districts) in 13 cities of the region, with one death, 137,910 people needed to be urgently relocated, 106,869.98 hectares of crops affected, and 1,451 houses collapsed. The direct economic loss of 850,518,883 yuan.

Faced with the impact of about two severe TC every year, the emergency management departments of governments at all levels in Guangxi have been stepping up efforts to integrate emergency relief resources at all levels since their establishment in October 2018. However, there is a lack of systematic research on how to efficiently determine the annual requirements for emergency supplies (ES) in response to TCD, how to choose appropriate addresses to build emergency supplies reserve center (ESRC), and how to carry out emergency supplies dispatching (ESD) efficiently. The ability to make scientific decisions is insufficient.

2. Research Motivation

2.1 Government emergency management departments need to integrate emergency management resources

The establishment of the Ministry of Emergency Management of The State Council and the Emergency Management Department of provinces, autonomous regions, and municipalities directly under the Central government shows that the government is actively integrating emergency resources scattered among more than 10 departments. The management and ownership of dispersed emergency resources, the construction of ES reserve, the procurement and storage of ES, and the dispatching and arrangement of ES all require coordination among government departments at all levels, clear responsibilities, and proper handling on the integration of various ES.

2.2 Guangxi urgently needs to strengthen research on emergency logistics for TCD

Although domestic and foreign experts and scholars on various kinds of disaster emergency rescue work research results are more, there are very few research results on TCD and emergency rescue work in Guangxi. Guangxi suffers an average of 2 TCD every year, causing huge losses to Guangxi's economy and society. Therefore, it is urgent to strengthen the relevant theory, technology, and application research of emergency logistics (EL) for TCD in Guangxi.

2.3 Emergency management departments of governments at all levels in Guangxi urgently need to strengthen their scientific decision-making ability

When Guangxi is faced with TCD, can the emergency management departments of governments at all levels predict the requirements for ES for TCD in advance and do a good job in the reserve and procurement of ES? Can we establish a sound ES reserve system? Is it possible to develop a quick and low-cost plan for ESD? All these works are real problems facing the emergency management departments of governments at all levels. It is urgent for the relevant government thinks tanks and researchers to carry out scientific research on these problems and propose efficient and reasonable solutions to provide intellectual support for the emergency management departments of governments at all levels to formulate scientific response plans for TCD.

3. Research Objectives

The research goal is to develop the situation awareness model of EL for TCD. To help the government emergency management departments make EL and emergency rescue decision-making scheme quickly and efficiently. In order to achieve this goal, mainly achieve the following three objectives.

3.1 Developing a Requirements Prediction Model of Emergency Supplies (RPMES) for TCD in Guangxi

In this paper, 51 severe TCDs suffered by Guangxi from 2005 to 2022 were selected as the research object. The number of emergency relocation and resettlement populations among the characteristic elements of disaster data was selected as the independent variable. And the extreme central wind speed during the TC in Guangxi, the duration of its impact on Guangxi, the number of collapsed houses and direct economic losses were selected as the dependent variables. The Multiple Linear Regression Method (MLRM) was used to construct the requirements prediction model of emergency supplies (RPMES) for TCD in Guangxi. Matlab was used for data analysis and optimization calculation, and finally, a practical MLRM with a significant relationship between the independent variable and the four dependent variables was obtained.

3.2 Developing a Location Model of Emergency Supplies Reserve Center (LMESRC) for TCD in Guangxi

The 16 severe TCD and rescue data suffered by 14 prefecture-level cities in Guangxi from 2014 to 2021 were collected, and an optimal location model of ESRC for TCD in Guangxi was established by using the improved Center of Gravity Method (CGM) based on GIS. After four iterations of calculation, the longitude and latitude coordinate S^5 (108.64, 21.98) were used as a suitable site to construct the Emergency Supplies Reserve Center (ESRC) for TCD in Guangxi to ensure the fastest and lowest cost delivery of ES to the disaster areas in Guangxi. According to the map of Tianditu, the actual place corresponding to this coordinate is near Liuwu Village next to Qinzhou East Railway Station, Qinnan District, Qinzhou City, Guangxi. This location coordinate S^5 can provide a reference for the Guangxi government to select a suitable address for the construction of ESRC for TCD in Guangxi.

3.3 Developing an Emergency Supplies Dispatching Model (ESDM) for TCD in Guangxi

The typical TC No. 1409 Super typhoon "Rammasun" and No. 1822 Strong typhoon "Mangkhut" are selected as cases. Extract the characteristic elements of ESD (including the distribution and location information of the ES storage repositories at the provincial, prefectural, and county levels, various traffic lines and distances between the ES storage repositories and the disaster areas, and the ES storage data of the ES storage repositories, etc.). In view of such ESD problems of multi-supply points to multi-demand points, The traditional provincial → prefecture-level city → county ESDM and provincial → county direct supply ESDM for TCD in Guangxi were constructed respectively by Linear Programming (LP) model and Operation Method on the Graph (OMG). By comparing the calculation results of the two models, it is found that the traditional provincial → prefecture-level city → county-level ESDM adopted by the Guangxi government is simple and convenient, but the cost is high. The cost of the improved provincial → county direct supply ESDM is lower, which can save 31.72% and 16.56% in the two disaster cases, and the dispatching effect is better. The direct supply model of ES from province to county can provide a reference for the emergency management departments of Guangxi governments at all levels to formulate ESD plans for TCD.

4. Research Questions

Through searching academic paper databases or journal websites, such as Scopus, ISI, WOS, ScienceDirect, CNKI, etc., experts and scholars from various countries have produced few research results on TC and emergency rescue work in Guangxi. How to make EL decisions related to TCD and emergency rescue in Guangxi has become an important problem to be solved urgently. This study intends to solve the three following problems:

(1) How to predict the requirements of various ES scientifically?

(2) How to establish an appropriate ES reserve system to solve the problem of the location of ESRC?

(3) Prepare all kinds of ES according to the predicted requirements. How timely, accurately, and effectively deliver all kinds of ES to the disaster areas and distribute them to the victims?

5. Research Scope

5.1 Research area

(1) EL and emergency supply chain

EL and emergency supply chain management is the theoretical basis of this study, and is also the main research field of this thesis.

(2) TCD in Guangxi

TCD in Guangxi is the research object of this thesis, the main purpose of this thesis is to solve several major problems when the Guangxi governments at all levels in the face of TCD urgent.

(3) Requirements prediction of ES

Requirements prediction of ES is an important problem to be solved in this thesis, and it is also the first problem to be solved by governments at all levels when dealing with TCD.

(4) LMESRC

LMESRC is another important problem to be solved in this thesis, and it is also the key for governments at all levels to establish ES reserve system.

(5) ESD

ESD is another important problem to be solved in this thesis, and it is also a key link for all levels of government to carry out emergency rescue.

5.2 Research data

(1) TC data

TC number, TC type, TC name, start and end time, landfall time, location and basic information, maximum near-center wind speed (m/s), central typhoon pressure, etc.

(2) Disaster data

The number of people affected, the number of people killed, the number of people in emergency relocation and resettlement, the area affected by crops, the number of houses collapsed, direct economic losses, etc.

(3) ES data

Daily necessities: disaster relief food, drinking water, water purification facilities, disaster relief grain and oil, and lighting equipment.

Life-saving supplies: lifeboat, life jacket, life jacket, exploration instruments, blasting tools, jacking equipment, crane.

Medical supplies: medical supplies, first aid drugs, water purification machinery and purifiers, disinfectant, and anti-epidemic drugs.

Heating and cooling supplies: quilts, single cotton tent, blankets, fuel and fuel, heating and cooling felt.

(4) Data on emergency facilities

Location information of ESRC in each city. The distance between the ESRC and the rescue station in each city. Freight and transit time between emergency facilities.

5.3 Research time

Time: 2005 to 2022.

5.4 Source of data

(1) TC Yearbook 2005 to 2022.

(2) The report of the Guangxi disaster situation by the Civil Affairs Department of Guangxi and the Emergency Management Department of Guangxi

(3) China Weather Typhoon Network

(4) China Meteorological Science data sharing Service Network

(5) China Meteorological Bureau TC Information Center

(6) China Typhoon Network

(7) Guangxi Water Resources Bulletin and China disaster Network

(8) The other data of TCD in Guangxi and the previous research data

6. Research Framework

According to the research objectives, the research framework of this thesis is determined as shown in **Fig. 1-1**.

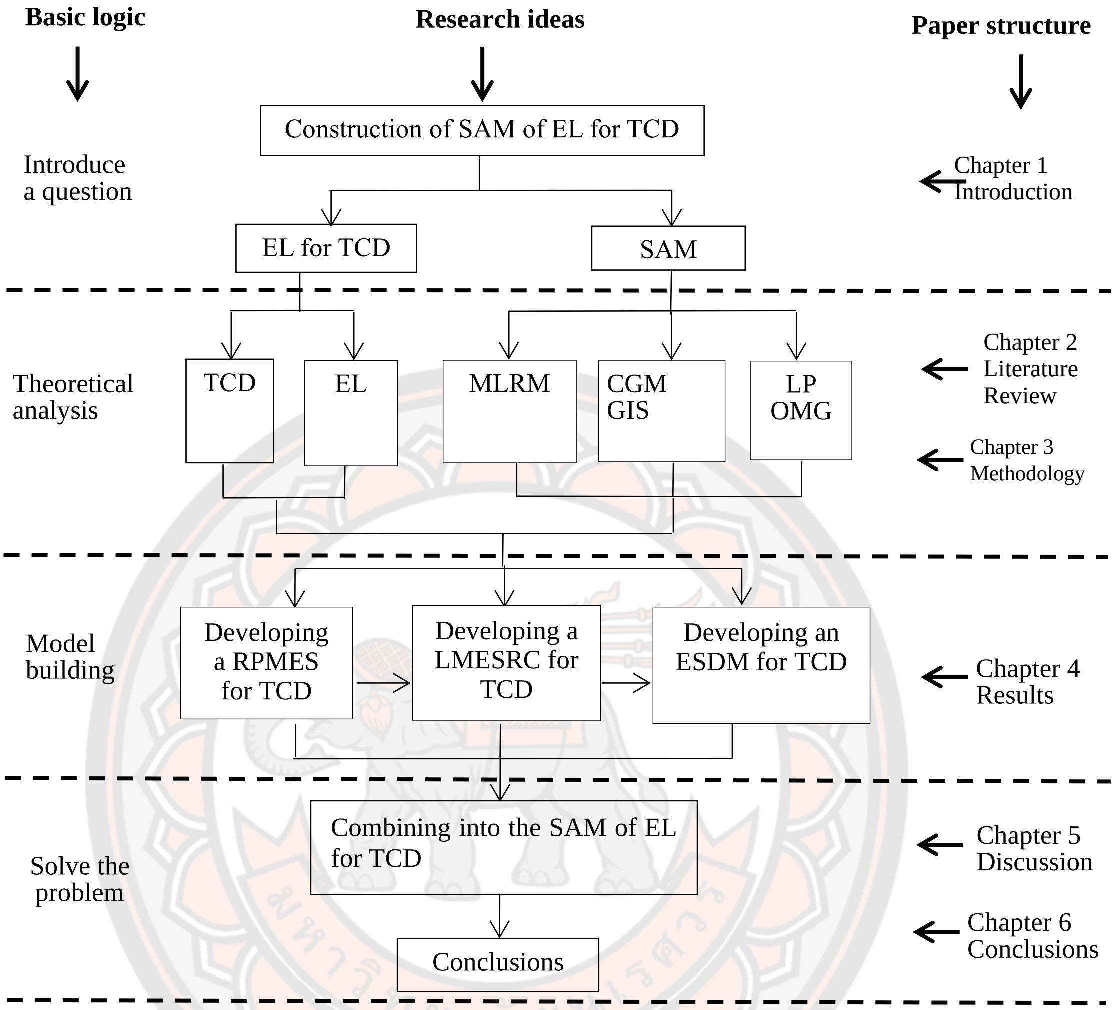

Figure 1 Research Framework

Notes:

EL: Emergency Logistics

TCD: Tropical Cyclone Disasters

SAM: Situation awareness model

MLRM: Multiple linear regression method

CGM: Center of gravity method

LP: Linear programming

OMG: Operation method on the graph

RPMES: Requirements prediction model of emergency supplies

LMESRC: Location model of emergency supplies reserve center

ESDM: Emergency supplies dispatching model

7. Research Flowchart

According to the research objectives, the research flowchart of this thesis is determined as shown in **Fig. 1-2**.

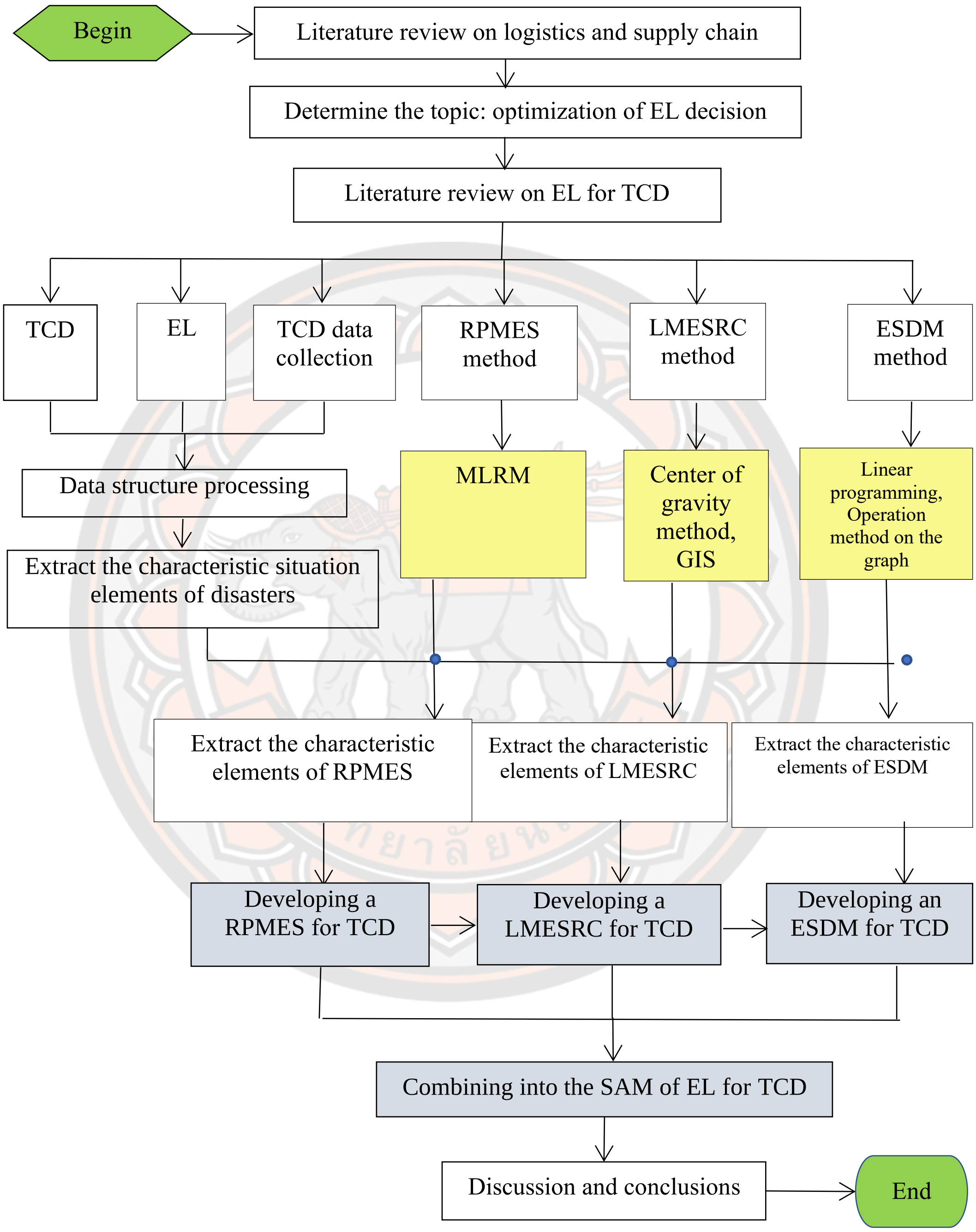

Figure 2 Research Flowchart

Notes: EL: Emergency Logistics TCD: Tropical cyclone disasters

SAM: Situation awareness model

RPMES: Requirements prediction model of emergency supplies

LMESRC: Location model of emergency supplies reserve center ESDM: Emergency supplies dispatching model

CHAPTER II

LITERATURE REVIEW

By searching academic paper databases such as SCOPUS, Web of Science (ESCI), ISI, ScienceDirect, ResearchGate, and CNKI, a large number of academic research literature related to EL was found, which can be summarized into the following major research fields. The first is related to natural disasters and management; the second is related to EL and management; the third is related to the RPMES; the fourth is related to the LMESRC; the fifth is related to the model of ESD.

1. Research status of TCD

This study summarizes the literature related to TCD into the following five subareas. See Fig. 2-1.

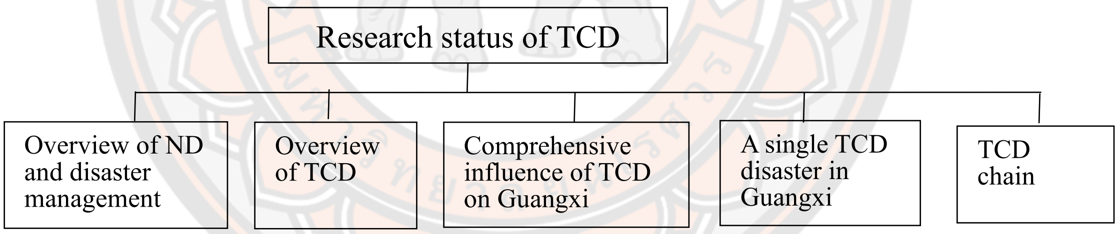

Figure 3 Research status of TCD

1.1 Overview of natural Disaster and disaster management

There are many kinds of natural disasters. The 5200 disaster data from 1963 to 1992 illustrates the dangers of global natural disasters and distribution characteristics. And come to the conclusion that floods, TC, droughts, and earthquakes are the most serious types of natural disasters in the world and the focus of disaster reduction (*Yuanchang zheng, 2000*).

Disaster management is an important function of government. The Chinese government has continuously explored in the field of disaster management and formulated the strategy for disaster management of "prevention is the main, disaster prevention, disaster resistance, and disaster relief combined ". Mainly from the following eight aspects to strengthen disaster management work: First is to stay focused on leadership, unified command, disaster classification management of disaster management system, and emphasize the comprehensive coordination in the process of disaster management. Second, we will build a disaster prevention and reduction engineering system and integrate disaster prevention, disaster resistance, and disaster relief into the overall social and economic development plan. Third, we will improve the work system for early warning and forecasting of disasters and strengthen scientific prevention of disasters. Fourth, establish a disaster emergency response mechanism to ensure the timely delivery of disaster relief measures. Fifth, we will improve the working mechanism for disaster preparedness and social mobilization after the disasters and provide solid material support for disaster relief. Sixth, improve the mechanism for providing assistance to the people affected by disasters in their daily lives and for restoring and managing their reconstruction to ensure their basic livelihood. Seventh, attach importance to the application of science and technology in disaster management and improve the timeliness and accuracy of disaster information reports. Eighth, pay attention to the construction of laws and regulations in the field of disaster management, raise the legal level of disaster management, and enhance the government's ability to manage disasters according to the law (*Xuejiu Li, 2004*).

There are three governmental levels involved in disaster management: local, regional, and national authorities (*Oscar Rodríguez-espíndola, et al., 2018*).

1.2 Overview of TCD

1.2.1 China is one of the countries most affected by TC in the world

The analysis results show that typhoon disasters affecting China have the characteristics of high frequency, strong suddenness, significant cluster occurrence, wide influence range, and large disaster intensity, which are mainly caused by the storm, rainstorms, storm surge, and the disaster chain caused by the typhoon. The typhoon disaster not only caused a large number of casualties but also had a serious impact on various economic sectors in China. The direct economic losses caused by the typhoon tend to increase year by year. Since the 1990s, the average annual losses have reached more than 10 billion Yuan (*Biqi Liang, 1995*).

In recent years, research on climate change of TC and typhoons that cause serious disasters has made new progress. The comparison of observation data in the past 60 years shows that due to the lack of offshore observation means, the reliability of early data is relatively low, and the reliability of observation data in the past 30 ~ 40 years is relatively reliable, and the reliability of observation data increases with the increase of TC intensity. The calculation and analysis of the observed data from six ocean regions around the world show that the inter-generational variability of TC exists, and the activities of strong and super TC have been increasing since about 1970 (*Zongci Zhao, Ying Jiang, 2010*).

1.2.2 TC classification

China has a habit of calling Tropical cyclones that develop over the tropical ocean where the water temperature is higher than 26℃ typhoons. Since 1989, China has adopted the International Standard for the name and classification of TC. According to the notice of the China Meteorological Administration on the implementation of the National Standard for TC Classification (GB T 19201 -- 2006), it has been officially implemented since June 15, 2006. According to the national standard of TC Classification, China classifies TC occurring in the western North Pacific and the South China Sea into six grades according to their intensity: tropical depression, tropical storm, strong tropical storm, typhoon, strong typhoon, and super typhoon. The detailed classification data of each grade are shown in Table 1.

Table 1 TC grade

TC grade	Abbreviation	Maximum wind speed grade	Central maximum wind speed
Tropical Depression	TD	Grade 6-7	10.8-17.1 m/s
Tropical Storm	TS	Grade 8-9	17.2～24.4m/s
Severe Tropical Storm	STS	Grade 10-11	24.5 ～32.6m/s
Typhoon	TY	Grade 12-13	32.7m/s~41.4m/s
Severe Typhoon	STY	Grade 14-15	41.5m/s~50.9m/s
Super Typhoon	Super TY	≥Grade 16	≥51.0m/s

Data source: China Meteorological Administration on the implementation of the National Standard for TC Classification (GB T 19201 -- 2006).

1.2.3 Comprehensive Classification of Typhoon (TC) Disaster

(1) Classification of Typhoon (TC) Disaster Single Index

The meteorological industry standard *Comprehensive Classification of typhoon disaster* (QX/T ****-2009) of the People's Republic of China draws lessons from the grey correlation degree theory to select the common typhoon (TC) disaster indexes that are easy to collect. Through the normalization and dimensionless treatment of each disaster index, the fast evaluation criteria for the comprehensive grade of typhoon (TC) disaster in China are established.

The number of dead, the number of buildings damaged, the number of crops affected, and the number of direct economic losses are selected as the single statistical index to judge the degree of typhoon disaster. According to each statistical index, the typhoon (TC) disaster is divided into five grades: super large, large, medium, small, miniature, and different statistical indexes corresponding to different disaster grades. See Table 2.

Table 2 Standard for single index grade of typhoon (TC) disaster

	Super-large	Large	Medium	Small	Miniature
Crop disaster area (ha.)	$(10^6, +\infty)$	$(10^5, 10^6)$	$(10^4, 10^5)$	$(10^3, 10^4)$	$(10^2, 10^3)$
Number of deaths (persons)	$(10^2, +\infty)$	(30, 100)	(10, 30)	(3, 10)	(1, 3)
Inverted housing (space)	$(2*10^5, +\infty)$	$(10^5, 2*10^5)$	$(3*10^4, 10^5)$	$(3*10^3, 3*10^4)$	$(1, 3*10^3)$
Direct economic losses (yuan)	$(10^9, +\infty)$	$(10^8, 10^9)$	$(10^7, 10^8)$	$(10^6, 10^7)$	$(10^5, 10^6)$

Data source: The meteorological industry standard *Comprehensive Classification of typhoon disaster* (QX/T ****-2009) of the People's Republic of China.

(2) Comprehensive Classification of Typhoon (TC) Disasters

A single index conversion function is established (The conversion function is shown in Appendix A) to convert the number of dead persons, the number of buildings damaged, the number of crops affected by disasters, and the number of direct economic losses so that the value range of every single index after conversion is (0, 1). The corresponding relationship between the single index disaster grade and the value of the single item conversion function is shown in Table 3.

Table 3 Corresponding relation table between the typhoon (TC) disaster grade and the value of the single conversion function

	Super-large	Large	Medium	Small	Miniature
Monomial conversion function value	(0.8, 1)	(0.6, 0.8)	(0.4, 0.6)	(0.2, 0.4)	(0, 0.2)

Data source: The meteorological industry standard *Comprehensive Classification of typhoon disaster* (QX/T ****-2009) of the People's Republic of China.

Grey correlation analysis method, the reference sequence is set, and the correlation coefficient $\lambda_{oi}(i)$ between the value sequence of each item conversion function and the reference, the sequence is calculated, which makes each index sequence dimensionless. The calculation method of the correlation coefficient is shown in Appendix B. The correlation degree is obtained by synthesizing the correlation coefficient of each single index. The formula of correlation degree is (1).

$$\alpha_{oi} = \frac{1}{M}\sum_{i=1}^{M} \lambda_{oi}(i) \qquad (1)$$

In the formula, α_{oi} is the correlation degree, $\lambda_{oi}(i)$ is the correlation coefficient, M is the number of selected single indexes, and in this paper, the value is 4.

The degree of correlation is used to evaluate the grade of typhoon (TC) (see Table 4).

Table 4 Comprehensive index grade of typhoon (TC) disaster

	Super-large	Large	Medium	Small	Miniature
correlation degree α_{oi}	(0.9, 1)	(0.8, 0.9)	(0.7, 0.8)	(0.6, 0.7)	(0.5, 0.6)

Data source: The meteorological industry standard *Comprehensive Classification of typhoon disaster* (QX/T ****-2009) of the People's Republic of China.

1.3 Comprehensive influence of TCD on Guangxi

The type of typhoon path into Guangxi and its affected area are different.

The climatic distribution characteristics of disastrous typhoon Gale in Guangxi are more in the southeast and less in the northwest. It is the result of the interaction between the structure of the typhoon flow field and the geographical and topographic conditions of Guangxi and is related to the typhoon's active path and central wind force. The peak of large and medium-scale wind disasters occurred in July, and that of small-scale wind disasters appeared in August. Typhoon winds in southwest Guangxi, south Guangxi and central Guangxi are mainly caused by type 1 typhoon tracks, but typhoons of type 1 and 2 are affected by typhoons in southeast Guangxi and east Guangxi. Large-scale wind disasters are entering the northern Gulf of Beibu Sea with strong typhoons (*Huiwen Zhou, et al., 2007*).

The typhoons affecting the Beibu Gulf area occurred from July to September. Compared with the South China Sea typhoon, the western Pacific typhoon caused more heavy rain in the Beibu Gulf area. The typhoon of type II and type I from Zhanjiang to Qinzhou caused the greatest probability of regional rainstorm weather in the Beibu Gulf area. Almost all the typhoons in the South China Sea with Class III landfall do not affect this area, no matter what the path, causing heavy rain in the coastal area of Beibu Gulf, the center of typhoon depression must enter or approach this area (*Xiaojuan He, Zhiying Ding, 2007*).

Three types of typhoons entering Guangxi (coastal type, southeast Guangxi type, and northeast Guangxi type) were analyzed statistically. Statistics 1970-2013 into the interior of Guangxi typhoon, typhoon in Guangxi, 44 years a total of 89 a year on average 2, among them, the I class path (coastal) typhoon a total of 30, the average every year 0. 7;II class path (southeast) typhoon a total of 46, one per year on average;III class path (northeast) for 13 total wind, the average every year 0. 3. The results show that the typhoon entering the inland of Guangxi from southeast Guangxi is the most serious, and the influence of heavy rainfall is the most serious. Typhoon from the coast to the inland of Guangxi has the most extensive range of disastrous gales, and the frequency of causing super large and large disasters is the highest. However, a typhoon entering the inland of Guangxi from northeast Guangxi is the weakest of the three types of track typhoons, and the disaster caused by the typhoon is mainly a medium disaster (*Jing Li, Liyan Qi, 2015*).

According to the above literature, there are three main TC paths entering Guangxi, as shown in Fig. 4.

Figure 4 Three TC paths into Guangxi

Notes: The data based on the references as follow: (1) *Huiwen Zhou, et al., 2007*. (2) *Xiaojuan He, Zhiying Ding, 2007*. (3) *Jing Li, Liyan Qi, 2015*.

Typhoon rainstorm is an important factor that induces geological disasters in the Beibu Gulf Economic Zone of Guangxi. Through the analysis of stratigraphic lithology, mechanical properties, fracture structure, human engineering activities, rainfall, and slope, which affect the development of geological disasters, Quantitative analysis of factors such as topographic fluctuation and the division of geological hazard-prone areas. Based on the statistical analysis of professional monitoring data of geological hazards, the effective rainfall and critical effective rainfall of geological hazards are obtained, and the risk assessment model of geological disasters is constructed. It has been proved that the model has certain timeliness and can provide a certain foundation and application in the early warning and forecasting of geological hazards in Beibu Gulf Economic Zone (*Weigang Zeng, Fu Wu, 2017*).

1.4 A single TCD in Guangxi

Every year, Guangxi is affected by several strong TC, which cause great disasters to its economy and people.

Jing Li, et al. (2007) pointed that Typhoon No. 0606 “Prapiroon” entered Guangxi from Yulin city, causing 74 counties (cities and districts) to suffer disaster, with a population of 5.706 million, 34 people died in the disaster, and 7 billion yuan of direct economic loss in Guangxi.

Yun Yu, et al. (2014) pointed out that the strong super typhoon No. 1409 "Rammasun" had caused serious disasters to banana-producing areas in Guangxi. It is suggested that active and effective post-disaster management should be carried out, the site should be chosen reasonably in future production management, the consciousness of windbreak and wind resistance should be improved, and field management should be strengthened.

Changfa Zhou & Le Wang (2016) analyzed the damage that the strong super typhoon No. 1409 "Rammasun" cased to the transmission line in Guangxi and further analysis and verification of the correctness of the basic wind speed values of a proposed transmission line.

Zhuo Huang & Xueping Liao (2017) pointed out that typhoon No. 1621 "Sarika," has the characteristics of a frontal attack on Guangxi with a wide range of wind and rain and heavy local rainfall intensity. According to statistics from the civil affairs department of Guangxi at 20:00 on October 21, 2016, a total of 352,100 people were affected by the disaster in 6 cities and 20 counties (cities and districts), including Beihai, Fangchenggang, Nanning, Qinzhou, Chongzuo and Guigang. The disaster area of crops was 17.76×1000 hm2, of which the disaster area was 4.44×1000 hm2. 205 houses collapsed, 77 houses were seriously damaged, and 244 houses were generally damaged. Direct economic losses totaled 235 million yuan, including 124 million yuan in agricultural losses.

Changyuan Wang et al. (2018) pointed that forty-six people were killed and 25 others are missing after floods, storms, mudslides, and other disasters occurred in "Rammasun", according to a statement on the ministry of civil affairs website and data from the civil affairs departments of Guangdong, Guangxi, Hainan and Yunnan provinces. In 144 counties (cities and districts), 9.966 million people were affected, 628,000 were relocated, and 252,000 needed emergency assistance. An area of 1,898.7 million hectares was affected by the disaster, of which 250.3 million hectares were lost. Direct economic losses amounted to 33.65 billion yuan. According to reports by the People's Daily Online, China News Network, International Online and the official website of affected provinces, losses were mainly in the following six areas: agriculture, forestry, animal husbandry and fishery, municipal facilities, industrial parks, collapsed residential buildings and traffic, ports and shipping.

According to the above literature, it can be concluded that all kinds of losses caused by typical TCD are shown in Table 5.

Table 5 Losses caused by typical TCD

No	Name	Number of Casualties (people)	Number of victims (million people)	Crop disaster area (million hectares)	Collapsed and severely damaged houses (room)	Direct economic losses (billion yuan)
0606	Prapiroon	34	5.706	0.0273	11670	7.0
1409	Rammasun	5	9.966	1.8887	2933	33.65
1621	Sarika	1	0.3521	1.776	282	0.235

Notes: (1) No. 1409 refers to TC No. 09 of 2014. The first two Numbers refer to the year, and the last two Numbers refer to the number of TC that occurred in the year. (2) The data is based on the TC yearbook of 2006, 2014, 2016.

1.5 TCD chain

The formation of the typhoon disaster chain is the main cause of serious large-scale disasters. The typhoon that affects China is not only caused by strong winds and heavy rains. The surge will cause disasters and often form a chain of disasters due to its chain effect, forming a cluster of disasters. Typhoons and rainstorms can cause floods and then cause debris flows, landslides, and catastrophic soil erosion, and storm surge caused by seawater flooding may form waterlogging, resulting in salinization of the land (*Biqi Liang, et al., 1995*).

According to the sequence of disasters, natural disasters can also be divided into direct disasters, secondary disasters, and derivative disasters. Direct disasters refer to the first disasters in the associated disasters, such as earthquakes and floods, which lead to direct disasters. Secondary disasters refer to disasters that follow direct disasters, such as earthquakes, typhoons, floods, fires, landslides, mudslides, and so on. Derivative disasters are associated disasters that occur after secondary disasters. For example, after a major earthquake causes secondary disasters, it causes social disorder and the destruction of family structures, or because of the sharp deterioration of the health environment, many people are killed and injured. Thus causing plagues and other disasters (*Huaming Duan, Min Liu, 2000*).

Besides the collapse of many buildings and mass damage to critical lifeline engineering infrastructure, earthquakes usually also trigger a series of secondary derivative disasters such as landslides, fires, floods, plagues, and social unrest. For the reliable, effective emergency management of earthquakes, secondary disasters should be taken into account in management strategies. However, the occurrence of each specific secondary event depends on the local geological conditions, economic development, cultural identity, political factors, and so on. The secondary disaster chain is a complex system that is difficult to predict accurately. This paper proposes a scenario-based model to estimate possible evolutions of earthquakes. This model aims to evaluate earthquake emergency management effectiveness (*Y. Zhang, W.G. Weng, et al., 2018*).

Based on the above literature and the reference to the relevant TCD data, common TCD includes three kinds of initial disasters, such as strong wind, rainstorm and storm surge, and produces many secondary and derivative disasters. In these disasters, the relationship between these initial disasters, secondary and derivative disasters, and damage results as follows. For the TCD chain see Fig. 5.

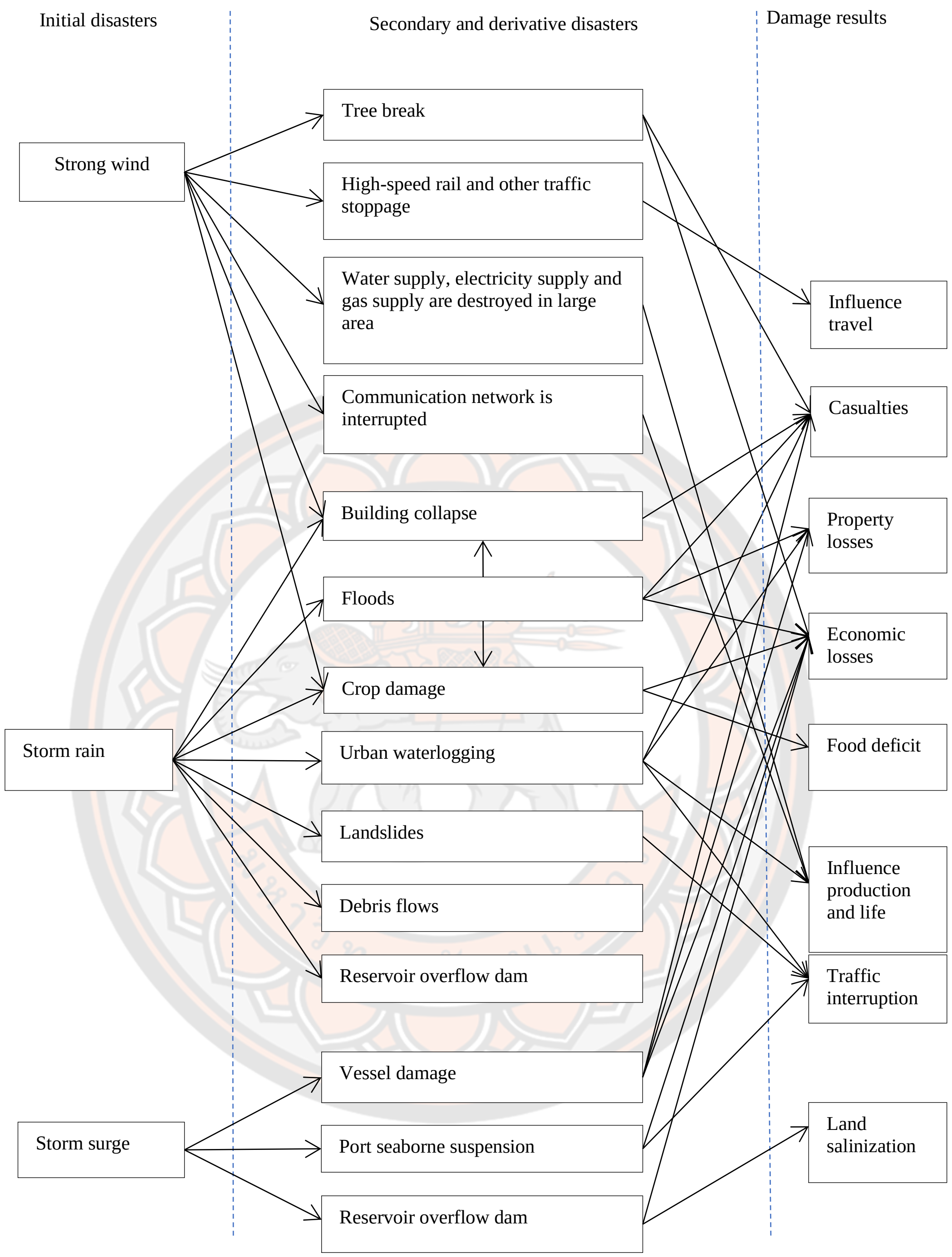

Figure 5 TCD chain

Notes: The data based on the references as follow: (1) *Biqi Liang, et al., 1995*. (2) *Huaming Duan, Min Liu, 2000*. (3) *Y. Zhang, W.G. Weng, et al., 2018*.

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2. Research status of EL and management

EL has emerged as a global concern theme as natural disasters ubiquitously occur around the world. This study summarizes the literature related to EL into the following four subareas. See Fig. 6.

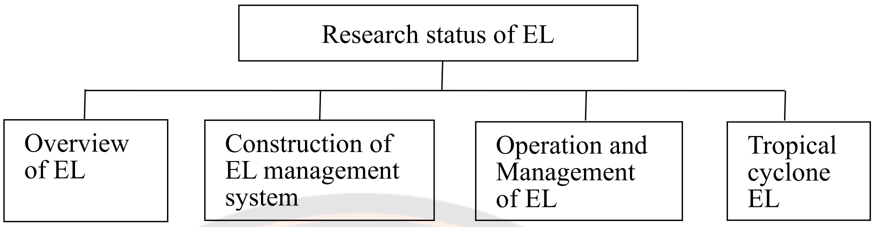

Figure 6 Research status of EL

2.1 Overview of EL

Putting forward EL is a special logistics activity. Its purpose is to provide needed ES for sudden natural disasters, sudden public health events, and other events. Its goal is to maximize time's benefits and minimize the disaster's loss. EL, like general logistics, is composed of fluid, carrier, flow direction, flow rate, flow rate, and other elements and has spatial effects, temporal effects, and qualitative effects (*Zhixue Liu, 2002*).

In recent years, a series of problems of material delivery and management have been exposed in natural emergencies. Among the huge casualties and property losses caused by sudden natural disasters, the losses caused by inefficient EL distribution account for about 15%~20% of the total losses. For example, the total loss caused by SARS is 17.6 billion us dollars, and the loss caused by EL is about 3 billion us dollars (*Xiaoyan Liu, 2010*).

2.2 Construction of EL management system

Putting forward the construction of a natural disaster EL management system, including EL is the integration of classification and grading, staging and coordination management, EL management system running the risk identification and evaluation, evaluation of EL management system running ability, the construction of early warning and EL management system, the construction of EL public information platform, and the effective measures such as the construction of EL management system (*Qi Cheng, 2010*).

The disaster EL system mainly includes three levels: ES collection center, ES distribution center, and disaster relief center (*Ping Xia, 2010*).

Xiaoyan Liu (2010) proposed to establish an organization and command organization of EL. EL itself has the characteristics of a weak economy and public welfare, which inevitably requires the government to play an important role in the construction and implementation of the EL system. It is suggested to integrate relevant national military and local organizations and establish a professional EL command center according to the establishment of Chinese government institutions and logistics operation process.In peacetime, the work of the EL command center is mainly to do a good job in forecasting and budgeting disaster relief materials, carry out network maintenance, fully understand the situation of each joined logistics center and enterprise, and establish the supplier file.In case of emergency, according to relevant policies and emergency plans, the EL command center calls some or all of the equipment and personnel of each franchisee to form a realistic EL center and put them into emergency rescue work.The center is in charge of the overall situation, but it does not directly carry out specific business such as material purchase, storage, and transportation. It is mainly responsible for guiding the procurement, storage and transportation of materials of each joined logistics center according to the information collected so as to ensure the efficient and orderly operation of the whole emergency system.

The location and layout of the EL base of Guangxi Beibu Gulf Economic Zone can be considered as follows: taking Nanning as the EL center and transportation hub, and we can establish "321" core EL areas, first of all, including three ports of Fangchenggang, Qinzhou and Beihai, followed by two major border port cities of Dongxing and Pingxiang, and finally Yulin. Among the three ports, Fangcheng Port is one of the key ports in China, a gateway to Southwest China, the largest port along the southwest coast of China, and the most convenient port for ASEAN to land in mainland China. Beihai is the largest coastal central city in Guangxi and the important port city around Beibu Gulf; it can give full play to the advantages of land, sea, and air three-dimensional transportation hub and the leading advantage of information level, and vigorously develop EL and domestic regional EL services. Qinzhou is in the south defense railway and north-south highway intersection, with a deep-water port conducive to the international EL channel. The second is Dongxing and Pingxiang. Dongxing is the border port city that meets along the western coast of China and is one of the important logistics centers of the border trade between China and Vietnam. Pingxiang is the largest port city on the border between China and Vietnam and is China's frontier economic cooperation zone open to the outside world. Finally, Yulin is a large industrial city in Guangxi and a national heavy industrial production base, with complete industry, developed transportation and complete logistics infrastructure. Yulin is one of the distribution centers of goods, which can be used as an EL distribution center (*Jingmin Wang, Bowen Sui, 2011*).

Guangxi Beibu Gulf port EL system is constructed from five aspects: EL command, EL operation, EL information, EL assistance, and EL resources. The EL activities of Guangxi Beibu Gulf port, such as ES purchase, ES transportation, ES storage, ES circulation and processing, ES distribution, and ES recovery, are explained in detail (*Shihong He, 2014*).

Using Thailand as a case for an application, the author has developed a more comprehensive assessment tool for early warning systems and disaster management at the national level. This comprehensive instrument adopted an indicator-based approach for six sub-themes: National Policy, Legislative and Institutional Environment; National Disaster Management Office (NDMO) – Department of Disaster Prevention and Mitigation; Related Ministries/ Departments/ Institutions; Military/Police; NGOs/IOs/Civil Society; and Current System Capacity that makes up country's disaster management system (*S.H.M. Fakhruddin, Y. Chivakidakarn, 2014*).

Based on the above literature, the EL management command system model shown in Fig. 7 can be built.

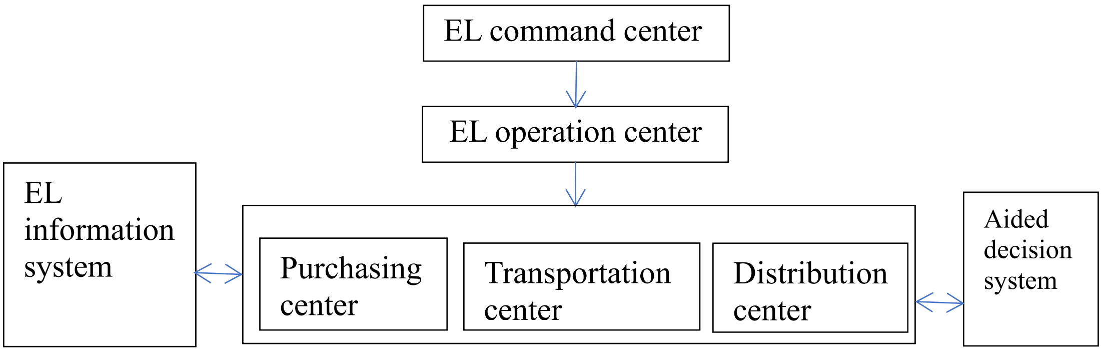

Figure 7 EL management command system model

Notes: The data based on the references as follow: (1) *Qi Cheng, 2010*. (2) *Ping Xia, 2010*. (3) *Xiaoyan Liu (2010)*. (4) *Jingmin Wang, Bowen Sui, 2011*. (5) *Shihong He, 2014*. (6) *S.H.M. Fakhruddin, Y. Chivakidakarn, 2014*.

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2.3 Operation and management of EL

Jiuh-Biing Sheu(2010) presented a dynamic relief-demand management model for EL operations under imperfect information conditions in large-scale natural disasters. The proposed methodology consists of three steps: (1) data fusion to forecast relief demand in multiple areas, (2) fuzzy clustering to classify affected areas into groups, and (3) multi-criteria decision-making to rank the order of priority of groups.

With the emergence of big data and new data sources, a challenge posed to today's organizations consists of identifying how to align their decision-making and organizational processes to data that could help them make better-informed decisions. This paper presents a study in the context of disaster management in Brazil that applies oDMN+, a framework that connects decision-making with data sources through an extended modeling notation and a modeling process. The study results revealed that a framework is an effective approach for improving the understanding of how to leverage big data in the organization's decision-making (*Flávio E.A. Horita, et al., 2017*).

2.4 TC EL

Identifies and analyses some key success factors in the emergency relief chain and the overall emergency relief effort of the disaster of Cyclone Larry in

Australia. In the paper describes Cyclone Larry in terms of its impact and physical, social, and economic characteristics and identifies some KSFs in its ERC and in the management of the cyclone (*Richard Oloruntoba, 2010*).

3. Research status of RPMES for TCD

In this study, the literature related to the RPMES for TCD are summarized into the following four subareas. See Fig. 2-6.

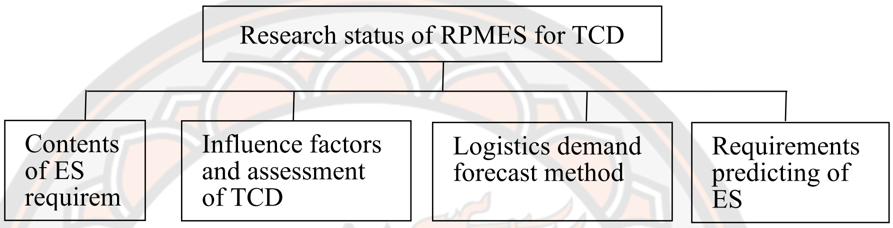

Figure 8 Research status of RPMES for TCD

3.1 Contents of ES requirements

The ES requirements refer to the minimum supply requirements for the state to respond to emergencies effectively. The so-called effective means that the efficiency of responding to emergencies should be high and the use efficiency of supplies should be high. The minimum refers to the minimum quantity required to respond to emergencies successfully. It can be seen that the determination of supplies requirements contains the idea of optimization, that is, under the given conditions, such as the type and intensity of emergencies, the minimum supply requirements for the successful response to emergencies. Supplies requirements is mainly expressed and measured from two aspects: one is the supplies requirements type, and the other is the supplies requirements quantity. The scale, scope and degree of natural disasters are different, and the quantity of supplies required is different. In general, the higher the level of natural disasters, the greater the scope of impact, and the greater the population density around the accident, the greater the economic and social losses caused, and the greater the amount of ES required (*Ping Xia, 2010*).

There are many kinds of ES and different classification methods. Relief supplies are generally divided into three categories. One is the lifesaving class, including lifeboat, life buoy, lifejacket, life detection instruments, demolition tools, jacking equipment, small lifting equipment, et al. The other category for life includes clothing, blankets, convenience food, disaster tents, water purification equipment, water purifier, et al. The third category is medical devices and drugs (*Xing Wang, 2007*).

The reserve of major disaster relief goods can be divided into 4 major categories and 33 minor categories. The first category is living goods, including food, drinking water, clean water facilities, grain and oil, and lighting equipment for disaster relief. The second category is lifesaving items, including lifeboats, life preservers, life rings, life jackets, exploration instruments, demolition tools, jacking equipment, cranes and so on. The third category is medical products, including medical supplies, first-aid drugs, water purification machinery and water purification agents, disinfectant, epidemic prevention drugs and so on.The fourth category is heating and cooling goods, including quilts, single (cotton) tents, blankets, fuel and fire appliances, cold blankets, et al. (*Ping Xia, 2010*).

According to the above literature, ES requirements can be classified as shown in Table 6.

Table 6 Classification of ES requirements

Supplies categories	**Major items of ES**
Living goods	food, drinking water, clean water facilities, grain and oil, lighting equipment.
Lifesaving items	lifeboats, life preserver, life rings, life jackets, exploration instruments, demolition tools, jacking equipment, cranes, et al.
Medical products	medical supplies, first-aid drugs, water purification machinery and water purification agents, disinfectant, epidemic prevention drugs.
heating and cooling goods	quilts, single (cotton) tents, blankets, fuel and fire appliances, cold blankets, et al.

Notes: The data based on the references as follow: (1) *Ping Xia, 2010*. (2) *Xing Wang, 2007*.

The institute of geology of the state seismological bureau of China did a research project on the information sharing of natural disasters in 2015. The research information system established a quantitative model of the earthquake's demand for relief materials and personnel. According to the urgency and importance of the needs, the rescue needs are divided into three categories: important needs, medium important needs and general needs.

(1) Important needs

Tent (top) =0.25* homeless * seasonal coefficient

Mobile toilet (station) =0.02* total population of disaster area

The emergency period of clean drinking water (kg) = area coefficient *2* total population of the disaster area *10 days

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(2) Medium importance needs

Lime powder for epidemic prevention (ton) =1*0.002* total population of disaster area

Ten drops of water (pipe) for epidemic prevention = area coefficient *0.3* total population of the disaster area

Bandage (axis) = area coefficient *0.998* number of injuries

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(3) General needs (slightly slower in time)

Red mercury (g) = area coefficient *55.4* number of injuries

Tetanus antitoxin (tetanus) = area coefficient *1.66* number of injured

Livestock forage (yuan) = area coefficient *2* total livestock

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For other types of natural disasters, we can refer to the earthquake model to establish a quantitative model of ES requirements for various common natural disasters, which is convenient for the prediction of disaster relief logistics, and provides a decision-making basis for the early warning function of the disaster relief logistics system.

3.2 Influence factors and assessment of TCD

According to the situation of disaster losses, the ministry of civil affairs of the People's Republic of China has set four response levels for natural disasters, with the first, second, third and fourth levels decreasing step by step. The classification is based on the number of dead, the number of emergency relocations and resettlement and the number of collapsed houses. As long as one of the indicators is met, the corresponding response level should be activated (*Lan Xue, Kaibin Zhong, 2005*).

Selected casualties and flooding in the fields and houses collapsed as a measure by using the collected complete disaster data of 57 typhoons, the data conversion into a normalized index to measure the damage of the influence of typhoons in Shanghai for 50 years by degree. And study the changing rule for the typhoon in Shanghai, analysis of typhoon disaster hazard factors, probing into the hazard degree of typhoons and the relationship between hazard factors (*Fei Meng, et al., 2007*).

Fuzzy mathematics is used to establish an evaluation model. We are introducing the characterization of typhoon’s formative factors (including the lowest pressure, maximum wind speed, the maximum precipitation process, and astronomical tide index), hazard-affected body (including the population density, impact area of cultivated land area), hazard-inducing environment (including geological disaster risk) and disaster prevention and mitigation capacity (including regional disaster reduction ability) of eight factors as the model input indicators. Using Analytic Hierarchy Process to determine the weight of impact factors, the comprehensive evaluation index of each typhoon in the case set was calculated. The comprehensive evaluation index is fitted with the typical disaster loss indicators such as the affected population, the affected area of crops and the direct economic loss rate. The regression equation of the optimal power function is obtained by fitting the weight of the influencing factors appropriately so as to achieve the quantitative pre-evaluation of the typhoon disaster (*Fei Zhao, et al., 2011*).

Jie Yin et al. (2013) conducted a comprehensive risk rating assessment on typhoon based on 8 indicators, including areas affected by crops, areas not harvested by crops, affected population, dead population, injured population, emergency resettlement population, collapsed houses and direct economic losses.

In order to study the correlation between typhoon disaster situation (including affected population, dead population, crop affected area, collapsed houses, direct economic losses) and disaster source (including maximum wind speed, minimum pressure, storm duration, and extreme storm value), disaster bearing body (including GDP per unit area, population density, total sown area of crops, urban per capita living area and rural per capita living area), disaster prevention and mitigation (including per capita GDP, employment, college students per 10,000, road network density, beds per 10,000, doctors per 10,000, telephone penetration), and select important impact factors to pre-evaluate the disaster level (*Yanxuan Chen, 2017*).

According to the above literatures, the major influencing factors of TCD assessment are shown in Table 7.

Table 7 Major influencing factors of TCD assessment

References	Major influencing factors of TCD assessment
Lan Xue, Kaibin Zhong, 2005	Dead, emergency relocation and resettlement, collapsed houses.
Fei Meng, et al., 2007	Casualties, flooding in the fields, and houses collapsed.
Fei Zhao, et al., 2011	affected population, affected area of crops, and direct economic loss rate. maximum wind speed.
Jie Yin et al., 2013	areas affected by crops, areas not harvested by crops, affected population, dead population, injured population, emergency resettlement population, collapsed houses, and direct economic losses.
Yanxuan Chen, 2017	affected population, dead population, crop-affected area, collapsed houses, and direct economic losses. Maximum wind speed.

3.3 Logistics demand forecast method

The common quantitative calculation methods of logistics demand forecasting include the prediction method based on time series and the prediction method based on cause of formation. The representative methods and viewpoints are as follows.

Grey forecasting is widely used in logistics demand forecasting. *Guohua He (2008)* puts forward the content of regional logistics demand forecast and the corresponding evaluation index, and uses the Grey forecast model to forecast the railway freight volume of three provinces in northeast China. *Zheng Yang, et al. (2017)* determined the prediction types of agricultural products according to the development situation of Guangxi agricultural products, established the GM (1,1) model of grey prediction for prediction, and tested the accuracy of the prediction results through the posterior difference method and MAPE. The results showed that the prediction accuracy of the model was high. *Zhikai Jiang，Xiaohua Chen. (2017)* conducted forecasting and analysis on the cold chain logistics demand of aquatic products in Lianyungang city based on the Grey model.

Multiple linear regression analysis method is also widely used in logistics demand forecasting. *Junbo LI, Lina Sun (2011)* used multiple linear regression analysis to forecast the demand for cold chain logistics of aquatic products in China. Multiple linear regression method is also used to carry out logistics demand forecasting. *Liangjie Wang (2016)* preliminary screening using Grey correlation analysis the key factors influencing the Shaanxi fruit cold chain logistics demand and establish the fruit index system of cold chain logistics, and then using the trend extrapolation to effect the independent variables of Shaanxi fruit cold chain logistics demand curve fitting, and using the regression analysis method to select the optimal model to predict the dependent variable, and analysis of Shaanxi fruit cold chain logistics gap according to the results of the prediction. *Yan Liang, Huihui Yang, Huihui Su (2018)* used multiple regression method to forecast and analyze the demand of agricultural products cold chain logistics in Tianjin.

Neural network model is also a common method in logistics demand forecasting. *Zhongyuan Niu (2006)* based on the time series statistical data of logistics demand, established the neural network prediction model for freight volume, the neural network prediction model for the proportion of logistics cost and the neural network prediction model for the total value of logistics in China's logistics industry by applying the multi-step prediction and rolling prediction methods of artificial neural network.

The support vector machine (SVM) model is also applied in logistics demand forecasting. *Xiaoping Wang，et al. (2018)* for agricultural products cold chain logistics demand system with nonlinear, less historical data, affected by many factors such as complex characteristics, the introduction of support vector machine model, from the supply of agricultural products, the development of social economy, cold chain, the humanities, the scale of logistics demand five Angle to construct the index system of towns in Beijing agricultural cold chain logistics demand forecast.

Bo Lu, Shouyang Wang, Haibo Kuang (2017) built a regional logistics gravity model to forecast the logistics demand in Ordos, Inner Mongolia. It reveals the inner connection mechanism between the agglomeration ability of central cities to hinterland goods and the agglomeration effect of the spatial economy and extends the research idea of forecasting to the new field of spatial economy.

A three-step approach is developed by combining the autoregressive distributed lag model with economic scenarios to capture the potential impact of specific risks. The empirical analysis is based on an annual time series (1995–2017) for the total container throughput measured in twenty-foot equivalent units for the main ports within the Hamburg-Le Havre (H-LH) range and a number of economic indices *(Yasmine Rashed, Hilde Meersman, et al.,2018)*.

Some scholars also use a variety of demand forecasting methods to build a new forecast model to optimize the forecast results. *Lei Huo (2014)* established the Grey multiple regression combination prediction model by using the Grey correlation method, multiple regression prediction model and Grey prediction model. Based on the established index system and the combined forecast model, the cold chain logistics demand for aquatic products in Yantai city is empirically studied. *Rok Hribar, Primož Potočnik, et al. (2019)* through the establishment of a recurrent neural network model and the linear regression model to predict the natural gas demand of urban residents in the city of Ljubljana, Slovenia.

Some scholars use a variety of demand forecasting methods to calculate and compare the same logistics problem to determine the optimal prediction model and results. *Xiaoping Wang and Fei Yan (2018)* established a demand forecasting model for agricultural products cold chain logistics based on Grey model, support vector machine, BP neural network, RBF neural network and genetic neural network. By studying the model on the relationship between variables between the ability and the accuracy of two factors, the five types of model analysis of agricultural cold chain logistics demand in found the ability to sort as follows: genetic neural network model > RBF neural network model > BP neural network model > support vector machine model > Grey model, the results show that the genetic neural network is used for agricultural cold chain logistics demand analysis has the superiority. *Yandong Yang (2015)* based on different prediction models, several Regional Freight

Transportation Demand Prediction Models (RFTDPMs) have been constructed by using Multiple Linear Regression (MLR), Non-Linear Regression (NLR), and Simple Linear Regression (SLR). According to the fitting efficiency, the simulation results show that the RFTDPM based on NLR offers superior performances in predicting RFTD compared with the other regression models. However, if the validation rates of the RFTDPMs are taken into consideration, the SLR based model outperforms the other two prediction models.

3.4 Requirements prediction of ES for TCD

The requirements prediction of ES is the premise and foundation of ES distribution decision. And it is an effective means to carry out rescue work continuously and effectively. At present, the requirements prediction of ES is still judged by experts' experience, and there is no mature forecasting method. It is easy to cause the relative excessive or insufficient of subsequent rescue and the waste of economic resources due to the unclear demand. Therefore, it is urgent to use scientific forecasting methods to realize the modeling of requirements prediction of ES. The location, duration, intensity, and scope of the TC directly affect the requirements for ES. Additional requirements for ES and even major changes in the primary tasks and objectives of disaster EL may result from unexpected variables. The non-routine and uncertain characteristics of TC make it more difficult to predict the requirements for ES (*Ping Xia, 2010*).

The forecasting methods of ES requirements are various. The distribution of emergency resources based on demand analysis in disaster EL is studied. He proposed based on multiple regression models for requirements prediction of ES and based on support vector machine (SVM) models for requirements prediction of ES, taking the Wenchuan earthquake as an example, whose effectiveness is verified by simulation experiments, provide technical method support for scientific resources demand forecast (*Ping Xia, 2010*). Studied the time-varying and reliability problems of earthquake disaster EL. The key for the earthquake relief from the disaster area during the period of a number of different relief demand information sources of information chaos and uncertainty puts forward a dynamic relief demand information to identify the reliability of the model. This model is used to estimate the time-varying rescue demand, which is convenient for the dynamic distribution and resources distribution of rescue resources (*Jianming Cai, 2012*).

4. Research status of LMESRC for TCD

There has been a long history of research on the location of logistics centers. After searching relevant literature, it is found that there is literature on the location of general logistics centers and the location of ES storage or distribution centers. Specific location selection methods include the CGM, multi-objective programming, uncertain demand model, random demand model, etc.

4.1 CGM

CGM site selection is the most commonly used single-facility site selection method. *Fei Liu (2009)* established a mathematical model with the modified CGM and solved the location optimization of chain supermarket logistics distribution centers according to the characteristics and conditions of the distribution center location problem. *Guoyou Yue and Zuochang Zhang (2013)* conducted an empirical analysis of the gravity center method, the traditional single-facility location model of the logistics center. They found that the traditional gravity center method had problems, such as the impracticality of calculating the distance between the logistics center and the demand point. They proposed the single facility location model of the logistics center based on GIS and optimized the problems of the gravity center method model. *Weihong Ni and Tai Chen (2021)* ensure the rationality of the location of EL distribution centers and the timely supply of ES in disaster-stricken areas, took Hubei Province during the COVID-19 outbreak as an example and built the location model of Hubei's first-level EL distribution center with the clustering and gravity center method.

4.2 Multi-objective programming

The multi-objective optimization model considering time and cost minimization is popular in the location selection algorithm. *Stefan Rath and Walter J. Gutjahr (2014)* established a multi-objective optimization model of LRP for ES transfer facilities and proposed a sub-heuristic algorithm based on analyzing optimization problems of the two-level ES distribution system after disasters. *Jiuh-Biing Sheu and Cheng Pan (2014)* constructed an emergency supply chain in response to sudden natural disasters by integrating three sub-networks: shelter network, medical network, and distribution network. Moreover, a mixed integer LP model is proposed based on multiple objectives, such as transportation distance minimization, operation cost minimization, and cost minimization. *Wenjing Cong (2020)* conducted a systematic study on the location of ES storage based on the meteorological disaster scenario of a typhoon. After analyzing the characteristics of the problem, optimization objectives and constraint conditions were proposed, and a multi-objective optimization model was established. Non-dominant sorting genetic algorithm (NSGA-II) with an elite strategy was designed to solve the model. Dealing with the problem of location selection and integration of materials transportation for post-disaster ES storage centers, *Xia Zheng and Liang Ma (2020)* built a multi-objective optimization model of location selection and routing problems for ES storage centers. This model considers three main objectives: maximum population coverage at disaster sites, minimum total emergency rescue cost, and minimum total unmet demand for ES at disaster sites. An improved differential evolution biogeography optimization algorithm was designed for testing, and the results showed the feasibility and effectiveness of the new model and its algorithm. Facing the problem of material allocation in the event of sudden disasters, *Lunhui Xu et al. (2020)* applied the immune optimization algorithm to the location problem of the logistics distribution center. They also established an integrated solution for location selection - scheduling, and distribution of the ES center and established a mathematical model of the location problem of the logistics distribution center and multi-objective material scheduling problem. An immune optimization algorithm was adopted to obtain the optimal location scheme of the ES center. *Yajie Wang et al. (2022)* proposed a multi-objective optimization model for storing and locating logistical emergency assistance and rescue resources in the South China Sea. Three components comprise the proposed model: geographical environment impact, emergency rescue response time, and emergency resource allocation cost. The fuzzy comprehensive evaluation method introduced and calculated the comprehensive impact index of the interference factors on the South China Sea storage candidate spots. The emergency response time is reduced by 83.71 percent compared to the current emergency resource supply system, emergency response time is reduced by 83.71 percent compared to the current emergency resource supply system, and the emergency resource allocation cost is reduced by 1.2% -- 8.02%.

4.3 Uncertain demand model

There are also appropriate approaches to location problems in uncertain environments. *Fangfang Zhao and Yankui Jin (2007)* studied RDC's location selection under an uncertain environment. Bo Wang (2006) established an uncertain multi-attribute decision model for the application of logistics center location. *Tao Jiang and Jinfu Zhu (2007)* discussed the robust optimization method of the central location in the case of weight uncertainty. Considering the randomness and uncertainty of disasters, *Wuyang Yu (2021)* proposed a two-stage pre-disaster location and storage model to hedge against such disasters. The reliability problem of facilities in the framework of robust optimization was investigated by linking the damage strength of a disaster to the partial capacity loss of an emergency facility. The proposed model is applied to a simplified Sioux Falls transportation network to illustrate the effectiveness of combining randomness and robustness in the model.

4.4 Random demand model

There are also many achievements in the study of site selection under random demand. *Lei Wang and Xiaobo Zhao (2008)* study location selection and location inventory pooling against the background of random demand. The research on dynamic location selection of logistics distribution centers on random demand is more relevant to disaster relief scenarios. *Yi Wen and Shiwei He (2007)* continued the mainstream of site selection research by studying the comprehensive optimization of logistics site selection and vehicle path problems under random demand. *Carmen G. Rawls and Mark A. Turnquist (2010)* established a two-stage random mixed integer programming model for emergency reserve location and used the Lagrange L-type algorithm to solve it. To effectively use the reserve resources of both military and civilian sides to reduce the reserve cost, *Qingwen Li et al. (2022)* put the military storage facilities into the layout scheme of the ES reserve and built a two-stage stochastic programming model of ES location-allocation optimization. An improved whale optimization algorithm with more strategies is designed to solve the model. The model's applicability is proved via a real-world case study in Tangshan, China.

4.5 Other methods for the location of ESRC

There are many other ways to locate emergency storage centers. *Abbas Afshar and Ali Haghani (2012)* based their EL structure proposed by the US Federal Emergency Management Agency (FEMA). This paper analyzes four factors in coping with natural disasters: facility location, ES distribution, vehicle scheduling, and route selection, establishing a multi-cycle integrated supply chain optimization model with mixed integer programming method and adopting CPLEX software to solve it. *Wenpeng Jiang and Yunlou Qian. (2021)* studied the optimization of reserve points based on theoretical analysis by introducing an evaluation model, Voronoi diagram, platform software, and other digital means to locate emergency supply reserve points. *Shen Xu (2020)* adopted the two-stage decision-making method, considered the damage to the road network, and gradually studied the site-path problem of distribution center failure from the perspective of coping with the failure risk of a distribution center. When the EL distribution center has not failed, a more stable EL distribution network was found to prevent the failure risk of the distribution center. *Xu W. et al. (2022)* analyze the siting of community-centered relief supply facilities. Design/ methodology/ approach combining grey relational analysis, complex network, and relative entropy, a new multi-criteria method is proposed. The method proposed in this study is beneficial to improve the decision-making ability of urban emergency departments using complex networks and comprehensive evaluation techniques.

According to the above research literature on the location of ESRC, methods such as the Gravity Center Method, multi-objective planning, uncertain demand model, and random demand model are all commonly used. The location problem of the ESRC is similar to the conventional location problem, but its background, optimization objectives, and constraints are different from the conventional location problem. The location of the ESRC has a higher requirement on the timeliness of the rescue, and the cost is second. Few studies on the location of ESRC for TCD appeared in the above literature. The problem to be solved in this paper is to find an address suitable for the construction of ESRC for TCD in Guangxi; considering the impact of rescue time efficiency and transportation cost, the location selection method based on GIS is more suitable for solving this problem.

5. Research status of ESDM for TCD

In this study, the literature related to the ESDM for TCD are summarized into the following three subareas. See Fig. 9.

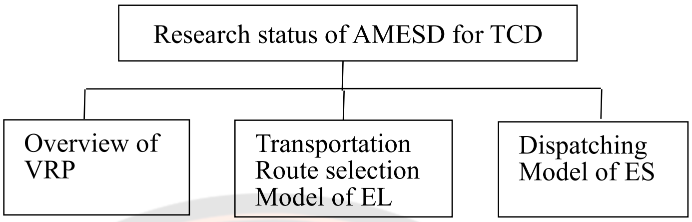

Figure 9 Research status of ESDM for TCD

5.1 Relevant research literature on ESD scheme and measures

There are many literature on the ESD scheme and measures. *Equictal (1996)* studied the problem of combined transportation and vehicle scheduling in the supply chain, aiming to select the optimal number of transportation and the number of vehicle allocations under a certain number of supply points. *Trevor Haleand and Christopher R. Moberg (2005*) established a quantitative model by selecting EL supply nodes according to the storage capacity of ES of each node type. *Yongling Zhang (2010)* pointed out that the reserve of emergency relief resources for emergencies is an important basis and guarantee for implementing emergency relief and temporary resettlement of victims. Emergency relief materials involve storage of all kinds of disaster relief materials, assembly and storage of emergency equipment and facilities so as to prevent all kinds of sudden accidents and respond to accidents and disasters. *Yang Peng et al. (2015)* Based on multiple means and methods of major disaster emergency management, Combining the two can reasonably determine the supply quantity of various emergency resources in different disaster areas. *Chongchong Qu et al. (2018)* mentioned in their research that after various emergencies, emergency relief materials must be distributed to EL centers economically, efficiently and quickly, the scheduling and transportation path selection of ES from a single supply point to multiple different demand points and disaster relief points, and the assignment and selection of multi-supply point scheduling schemes, etc. According to the time point and cycle of each material scheduling management decision, it can be classified into dynamic and static alternative emergency relief materials management and scheduling. *Shuhua Niu (2020)* mentioned in his study that in order to ensure the high efficiency of ES in emergencies, it is necessary to establish a joint conference system for ES reserve and do a good job in ES reserve and regional division of labor.

5.2 Overview of vehicle routing problem (VRP)

There is a lot of literature on vehicle routing problem of EL.

M. Desrochers et al. (1990) proposed a classification scheme of models that arise in the area of vehicle routing and scheduling. Each type of VRP is classified according to several characteristics: (i) addresses (demand locations to be satisfied, their number, sets of demand clusters to be satisfied et al.); (ii) vehicles (homogeneous/heterogeneous fleet, fixed or variable fleet size, time windows for vehicle availability); (iii) service strategy (issues such as split delivery, mixed delivery, precedence constraints between demand locations, time windows); and (iv) objectives (address penalty implying the deviation from preferred service level, or, vehicle penalty implying fleet size and costs).

Extensive discussions of heuristic and optimization algorithms are given in *Gilbert Laporte (1992)* for a variety of vehicle routing problems. *Miller-Hooks & Mahmassani (1998)* studied the choice of the shortest path in the case of major emergencies.

Ajay K. Rathi et al. (1992) consider supply logistics in conflict or emergency situations. The authors develop LP models where routes and the amount of supply to be carried on each route are pre-determined between each origin-destination pair. Their problem is identifying the optimal number of vehicles to be assigned to each route, which becomes an assignment problem. Real-valued optimal numbers of vehicles are rounded up to the next integer since the number of available vehicles in the system is assumed to be non-restrictive. This setting is far less complex than the emergency logistic planning problem considered here.

Recent examples of local search heuristics (e.g., simulated annealing, tabu search, et al.) designed for solving the VRP can be found in *Philippe Badeau et al. (1997)* and *Patricio Rodríguez et al. (1998)*. *Luisa Equi et al. (1997)* consider a combined transportation and scheduling problem in a supply chain where the transportation problem aims to identify the optimal number of trips to satisfy demand (customers) from a given number of supply nodes (plants). The scheduling problem, however, identifies the number of trucks (of homogeneous capacity) that must be allocated to make the trips. Again, the routes are pre-specified and a vehicle assignment problem is solved rather than a routing problem.

Solomon (1988) explored heuristic solving algorithms for vehicle routing problems with time Windows, providing references for the study of transportation routing problems. *Tong Zhao et al. (2010)* studied the vehicle routing optimization problem of ES distribution with time window, established a capacity-constrained route optimization model with the shortest vehicle path as the goal, and solved it through ant colony algorithm.

The problem at hand is related to the vehicle routing problem (VRP) discussed extensively in the literature. In the VRP, a number of customers (each represented as a destination node) are served by m identical vehicles located at a depot. Each vehicle returns to the depot after completing its trip (tour). The load of a vehicle cannot exceed its capacity on any tour. Furthermore, a customer can be visited only once and it is assumed that a vehicle's load capacity exceeds every customer's demand. The aim is to determine vehicle routes resulting in the minimum total travel distance. The definition of the VRP implies that the quantity of commodity to be transported to every destination pair is known and sufficient supply is always available at the depot to satisfy all customer demand (*Linet Özdamar et al., 2004*).

Rodrigo A. Garrido, et al., (2015) presents a model to assist decision-makers in the logistics of a flood emergency. The model attempts to optimize inventory levels for ES as well as vehicles' availability, in order to deliver enough supplies to satisfy demands with a given probability.

Chansiri Singhtaun and Harit Piyapornthana (2022) address the customer set and delivery route problem focused on identifying a mixed fleet that will not return to the warehouse after serving the last customer on the route. A mathematical model and method for solving heterogeneous fleets' open vehicle routing problem are presented. This model collects orders for each target warehouse and creates a cluster of target warehouses and an optimal vehicle route. Firstly, the warehouse is clustered to deal with the overload demand, and then the branch-cut algorithm is used to solve the problem.

5.3 Transportation Route selection Model of EL

Rathietal (1993) proposed the LP model, and the problem that needs to be solved is the assignment problem, that is, assigning vehicles to each route to achieve the optimal.

According to early by air after an earthquake EL system optimization problem, considering the network interruption, respectively set up by using genetic algorithm always takes at least as the goal of single stage and two-level emergency facilities location-route problems (LRP) model. Shaoren Wang (2010) studied LRP problem in post-earthquake EL system optimization. Considering the characteristics of post-earthquake EL systems, such as timeliness and road network connectivity, an improved genetic algorithm is applied to establish a multi-objective optimization model of fuzzy LRP with time window. Thinking of the multi-stage post-earthquake EL system, multi-level complex networks, such as demand priority features, and application of the improved genetic algorithm to establish a multi-stage multi-objective optimization model of a multi-stage fuzzy LRP.

Jianming Cai (2012) analyzed the connotation of the shortest path in the transportation of earthquake disaster EL, and applies the theory of vehicle flow fluctuation to study the calculation method of road travel time under earthquake disaster. Considering the time variation of travel time and reliability of various sections of the transportation network under an earthquake disaster environment and combined with the decision weight of decision makers, the analysis and calculation model of transportation route selection for earthquake disaster EL is presented.

Changshi Liu (2016) studied the location-route problem (LRP) model and optimization algorithm in a post-earthquake EL system. Considering emergency facilities, transport capacity constraints, demand point location and terrain leads to the randomness of emergency vehicle's travel time, requirements on the uncertainty of demand of ES and distribution of time urgency, with ES always arriving in the shortest time with the minimum total distribution costs as the goal, to build a multi-objective fuzzy chance-constrained programming based LRP optimization model, and according to the characteristics of the model to design a hybrid immune genetic algorithm to solve.

Nariman Nikoo, et al., (2018) proposed the emergency transportation network design problem to determine the optimal network to perform emergency response trips with high priority in the aftermath of earthquakes. The problem has three objective functions designated to identify the optimal routes for emergency vehicles considering the length, the travel time and the number of paths as performance metrics of network vulnerability.

5.4 ESDM

There are many applicable conditions and methods for the ESDM, and different ESD methods can be adopted for different dispatching needs.

There are numerous methods of one - to - many or many - to - many ESD. *Cheng Miao (2007)* studied the optimization of transportation in EL under public emergencies. This paper analyzes the difference between vehicle scheduling problem and vehicle routing problem of relief materials transportation, and concludes that the constraint conditions of this problem include the transportation of multiple materials, each material may have multiple supply and demand points, the supply and demand points of materials, the location of supply and demand will change, the vehicle can appear at any point in the supply network, and the number is limited. And it changes over time. In order to describe this complex problem, a multi-mode hierarchical network was designed to formalize the behavior of materials from source to destination and vehicle recovery. Based on the network flow model, a mixed integer programming model of relief goods transportation and vehicle scheduling was established. A pull transportation scheduling algorithm was designed based on Lagrange relaxation method to solve the approximate optimal solution of the model. *Dongqing Ma and Wei Wang (2014)* established the emergency material scheduling model of single distribution center and multi-disaster warehouse. They put forward the requirement of bidirectional distribution, which significantly improved the efficiency of ESD. *Chongchong Qu et al. (2018)* proposed the scheduling and transportation route selection of emergency relief materials from a single supply point to multiple different demand points and disaster relief points, as well as how to allocate and select a multi-supply point scheduling scheme. According to the time point and cycle of each material dispatching management decision, the management and dispatching of emergency relief materials can be divided into dynamic and static types. This paper contributes to the challenge of resource allocation by studying resource shortage and surplus. The goal of this study was to design a dynamic optimization model to support disaster relief allocation and resource allocation involving resources from multiple organizations *(Oscar Rodriguez-espindola et al., 2018)*. *Yingtao Che (2007)* mentioned in his research that two situations of closed route and open route were formed for vehicles from a single emergency rescue center to multiple demand points according to different emergency situations, a vehicle route optimization model with time constraints for emergency material scheduling was established, C-W saving algorithm was improved, and the model and algorithm were verified by examples.

Many scholars have proposed a variety of efficient and feasible research methods for ESDM. By using the dynamic rolling emergency resource allocation model and data mining algorithm service code, *Hong Xie (2017)* realized the high efficiency of dispatching ES and reduced the total emergency cost and dispatching cost. Taking earthquake disaster as an example, *Yuling Dong and Xiaofang Liu (2021)* applied the travel agent theory to the assignment problem and obtained a relatively optimal material scheduling scheme.

More efficient algorithms are needed for multi-objective models with complex constraints to solve the optimal solutions. *Tirado G. et al. (2014)* used the dictionary method to manage the delivery of disaster relief materials, using a two-phase flow model. At the first level, the difference between the aid planned to be delivered and the aid actually delivered is minimized; Time, cost, and highest unmet requirements are addressed in the second phase. In addition, given the need to repair subsequent allocations, *F. Liberatore et al. (2014)* propose a distribution-recovery model for disasters, which aims to maximize the total demand achieved, minimize the maximum distance between reliability, safety, and requirement satisfaction and their ideal values, and minimize the sum of attribute distances. Meanwhile, *Shalei Zhang et al. (2014)* combined stochastic demand, distribution network reliability and Bayesian update of disaster scenario information. This model minimizes total time, unmet requirements, and costs. *Burkart C. et al. (2016)* proposed a multi-objective location-routing model with the goal of minimizing unmet service demand and the cost of open routing for DC and relief supplies. *Ke Xu et al. (2018)* set up a multi-objective optimization model with the balance constraints of disaster relief supply and transportation with the goal of minimizing the sum of construction, maintenance and transportation costs of protected areas, so as to minimize the overall risk and difficulty of disaster management. *Li Zhang et al. (2022)* proposed a multi-objective emergency medical supplies scheduling model and adopted strategies such as dynamic inertia weight and particle perturbation term to solve the model, which effectively solved the problems of ES distribution and vehicle routing scheme generation under resource shortage. *Lin Zhang et al. (2022)* selected the severe rainstorm disaster in Henan, China in 2021 as a typical case, built a multi-objective intelligent scheduling model for ES, and calculated the phased scheduling scheme of ES from the rescue point to each disaster point.

Some scholars proposed carrying out ESD in stages or levels. *Douglas Alem et al. (2016)*, *Ali Akbar Hasani (2017)*, *Hui Hu et al. (2022)* and other scholars proposed to establish a stochastic network traffic planning model through a two-stage study to improve the efficiency of ESD. *Feihu Hu et al. (2016)* and *Hui Hu et al. (2019)* stratified the road network, proposed a two-level EMS model of multi-commodity and multi-vehicle with time minimization as the goal, and adopted a genetic algorithm and hierarchical solving method to obtain an optimization scheme. *Vahdanil (2018)* proposed a two-stage, multi-objective, multi-period mixed integer mathematical model. In the first stage, the capacity decision of distribution center and warehouse was considered. Phase two: Programming transportation routes and distribution of supplies to affected areas to minimize total cost and travel time.

There are also different solutions to the problem of inadequate or uncertain ES. *Shu-Shun Liu et al.(2021)* proposed a resource-constrained project scheduling problem (RCPSP) model. A road network rush repair scheduling model based on constraint programming (CP) search algorithm is proposed. *Wanbo Zheng et al. (2022)* established a supply scheduling model by using the impulse demand fluctuation function and the demand prediction formula to minimize the cumulative sum of unmet material demands at different emergency demand points and obtain the optimal emergency supply scheduling scheme. *Mengran Wan et al. (2023)* proposed a multi-period dynamic emergency material distribution model under uncertain demand conditions by considering the degree of disaster and demand in different disaster areas, so as to minimize the unmet demand, material distribution cost and the risk of material distribution route selection.

5.5 Summary

Through the analysis of the above literature, it is shown that ESD under the condition of emergency has always been the focus of research on EL in various countries. At present, all kinds of EL resources in China are still being integrated and perfected, especially there is still a certain gap between Guangxi and developed provinces in EL management. The above literature results do not know much about the ESD of TCD in Guangxi and lack of a scientific and reasonable dispatching model. The influence scope of TCD in Guangxi is big. Provincial, municipal, and county governments at all levels have built ES reserves warehouses that coexist with different kinds, and the number of ES, transportation lines, and distance between all levels of ES reserves warehouses are different, various municipal cities and counties are generally only responsible for the jurisdiction within the scope of the ES planning and dispatching. Because of these effect factors of ESD for TCD in Guangxi, so it is necessary to establish a highly efficient and low-cost awareness model of ESD for TCD in Guangxi. It provides a reference for Guangxi government emergency management departments at all levels to formulate emergency rescue plans for TCD.

6. Major problems in existing studies

6.1 Statistics of the main content of references

By synthesizing the main references of the above five aspects, the main contents of the main references in each field are distributed as shown in Table 2-8.

Table 8 The main contents of the main references in each field

NO	References	TCD		EL	ESR		LMESRC	ESD	
		TC	OND		LD	ESR		VRP	ESD
1	*M. Desrochers et al. , 1990*							√	
2	*Gilbert Laporte, 1992*							√	
3	*Ajay K. Rathi et al., 1992*			√				√	
4	*Biqi Liang, et al., 1995*	√		√					
5	*Luisa Equi et al., 1997*							√	
6	*Philippe Badeau et al., 1997*								

NO	References	TCD		EL	ESR		LMESRC	ESD	
		TC	OND		LD	ESR		VRP	ESD
7	*Patricio Rodríguez et al., 1998*							√	
8	*Huaming Duan, et al., 2000*	√	√						
9	*Yuanchang Zheng, 2000*	√	√						
10	*Zhixue Liu, 2002*			√					
11	*Xuejiu Li, 2004*		√				√		
12	*Linet Özdamar, et al. 2004*		√	√					√
13	*Lan Xue, Kaibin Zhong, 2005*		√	√	√				
14	*S. P. Meyn, R. L. Tweedie, 2005*								
15	*Zhongyuan Niu, 2006*				√				
16	*Bo Wang. (2006)*		√	√			√		
17	*Xiaojuan HE, et al., 2007*	√	√						
18	*Huiwen Zhou, et al., 2007*	√							
19	*Fei Meng, et al., 2007*	√							
20	*Cheng Miao, 2007*		√	√			√		√
21	*Xing Wang, 2007*		√	√	√		√		√
22	*Fangfang Zhao, Yankui Jin (2007)*			√			√		
23	*Jing Li, et al. (2007)*	√		√					
24	*Tao Jiang, Jinfu Zhu (2007)*						√		
25	*Yi Wen and Shiwei He (2007)*			√			√	√	
26	*Guohua HE., 2008*				√				
27	*Lei Wang, Xiaobo Zhao (2008)*			√			√		
28	*Fei Liu (2009)*			√			√		
29	*Qi Cheng, 2010*		√	√					
30	*Richard Oloruntoba, 2010*	√		√					
31	*Ping Xia, 2010*		√	√		√			√
32	*Shaoren Wang, 2010*		√	√					√
33	*Jiuh-Biing Sheu,2010*		√	√	√				
34	*Xiaoyan Liu, 2010*		√	√					
35	*Zongci Zhao, Ying Jiang, 2010*	√							
36	*Carmen G. Rawls, Mark A. Turnquist (2010)*		√			√	√		
37	*Jingmin Wang, et al., 2011*			√					
38	*Fei Zhao, et al., 2011*	√							
39	*Junbo LI, Lina Sun, 2011*				√				
40	*Jianming Cai, 2012*		√	√		√	√		√

NO	References	TCD		EL	ESR		LMESRC	ESD	
		TC	OND		LD	ESR		VRP	ESD
41	*Y.A. Rozanov 2012*								
42	*Abbas Afshar, Ali Haghani. (2012)*		√	√		√	√		√
43	*Jie Yin et al. (2013)*			√		√			
44	*Guoyou Yue, Zuochang Zhang (2013)*						√		
45	*S.H.M. Fakhruddin, et al., 2014*		√	√					
46	*Shihong He, 2014*			√					
47	*Yun Yu, et al., 2014*	√							
48	*Tirado G., et al., 2014*			√					√
49	*Lei Huo, 2014*				√		√		
50	*Liberatore, et al., 2014*			√					√
51	*Shalei Zhang, et al., 2014*			√				√	
52	*Dongqing Ma, Wei Wang (2014)*		√			√			√
53	*F. Liberatore et al. (2014)*		√			√			√
54	*Jiuh-Biing Sheu, Cheng Pan. (2014)*		√	√			√		
55	*Stefan Rath, Walter J. Gutjahr (2014)*			√			√		
56	*Rodrigo A. Garrido, et al., 2015*		√	√					√
57	*Jing Li, Liyan Qi, 2015*	√		√					
58	*Yandong Yang, 2015*				√				
59	*Yang Peng et al. (2015)*		√	√		√			√
60	*Changshi Liu, 2016*		√	√					√
61	*Changfa Zhou, et al., 2016*	√	√				√		
62	*Liangjie Wang., 2016*				√		√		
63	*Burkart C. et al. (2016)*		√					√	
64	*Douglas Alem et al. (2016)*		√						√
65	*Feihu Hu et al. (2016)*			√					√
66	*Flávio E.A. Horita et al., 2017*		√	√					
67	*Zhikai Jiang，Xiaohua Chen., 2017*				√				
68	*Zhuo Huang, et al., 2017*	√							
69	*Weigang Zeng, et al., 2017*	√	√						
70	*Yanxuan Chen, 2017*	√							
71	*Gagniuc Paul A, 2017*						√		

NO	References	TCD		EL	ESR		LMESRC	ESD	
		TC	OND		LD	ESR		VRP	ESD
72	*Zheng YANG, et al., 2017*				√				
73	*Bo Lu,et al., 2017*				√				
74	*Ali Akbar Hasani (2017)*		√			√			√
75	*Hong Xie (2017)*		√			√			√
76	*Y. Zhang, et al., 2018*		√	√					
77	*Nariman Nikoo, et al., 2018*		√	√					√
78	*Oscar Rodríguez-espíndola[1] et al., 2018*		√	√					√
79	*Oscar Rodríguez-espíndola[2] et al., 2018*		√	√					
80	*Yan Liang, et al., 2018*				√		√		
81	*Xiaoping Wang, Fei Yan., 2018*				√				
82	*Xiaoping Wang, et al., 2018*				√				
83	*Yasmine Rashed, et al., 2018*				√				
84	*Changyuan Wang et al. (2018）*	√		√					
85	*Chongchong Qu et al. (2018)*		√	√		√			√
86	*Ke Xu et al. (2018)*		√	√					√
87	*Rok Hribar, et al., 2019*				√				
88	*Hui Hu et al. (2019)*			√					√
89	*Wenjing Cong, 2020*	√			√		√		
90	*Xia Zheng, Liang Ma (2020)*		√			√		√	
91	*Lunhui Xu, et al. 2020*		√				√	√	√
92	*Shen Xu, 2020*		√				√	√	√
93	*Shuhua Niu, 2020*		√	√	√	√			
94	*Lunhui Xu et al. (2020)*			√			√		√
95	*Wuyang Yu (2021)*			√			√		
96	*Shu-Shun Liu, et al. 2021*		√					√	√
97	*Weihong Ni, et al. 2021*		√		√		√	√	
98	*Wenpeng Jiang, Yunlou Qian. (2021)*			√			√		
99	*Yuling Dong, Xiaofang Liu (2021)*			√					√
100	*Li Zhang, et al. 2022*		√					√	√
101	*Qingwen Li, et al. 2022*		√	√				√	
102	*Wanbo Zheng, et al. 2022*		√		√			√	√
103	*Xu W. et al. 2022*		√		√		√	√	

NO	References	TCD		EL	ESR		LMESRC	ESD	
		TC	OND		LD	ESR		VRP	ESD
104	*Yajie Wang, 2022*		√		√	√	√		
105	*Chansiri Singhtaun, Harit Piyapornthana (2022)*		√					√	
106	*Hui Hu et al. (2022)*			√					√
107	*Lin Zhang et al. (2022)*		√	√		√			√
108	*Mengran Wan et al. (2023)*			√					√
	Total	*18*	*50*	*53*	*23*	*15*	*29*	*18*	*33*

Notes: In the table, under the TCD project, special areas are divided into Tropical cyclones (TC) and other natural disasters (OND). ES requirements prediction method is divided into two types, Logistics demand forecast method (LD) and Emergency supplies requirements (ESR). LMESRC is the location model of the emergency supplies reserve center. ESD is divided into tow types, VRP and ESD.

6.2 Major problems in existing studies

Based on the above summary of previous research, the scholars have carried out relevant research on theories and models such as natural Disaster and management, EL and emergency management, requirements prediction of ES, location of ESRC, ESD, etc. But such studies mainly have the following problems: some scholars are more a qualitative discussion on the theoretical level, safeguard mechanism, and the characteristics of EL organization form, in quantitative research, are relatively few. There are still some problems, such as slow response and lack of scientific basis in the decision of unexpected events. In terms of research methods, there are more macroscopic, qualitative, and descriptive studies and less quantitative, microscopic and operational studies. Research methods are too simple, and most studies only stay on the necessity and importance of the argument. Although some ES management decision-making model is established, most of these models are based on certain information, based on the model are too simple, and not combined with emergency relief practical problems. In the material mix, for example, only consider the short circuit between the supplier and the demand of network problems, not considering the material priority to allocate the influence of not fully considering the uncertainty factors in the environment and decision-making, reduce the real promotion and application value.

The research on-demand analysis of disaster relief ES is not thorough enough. The demand analysis of materials mainly refers to the scientific prediction of ES requirements after the occurrence of emergencies and the classification of ES requirements according to its priority. The forecast and grading of ES requirements are the precondition and basis for the decision of disaster relief ES. From the current research status, there is no decision basis and evaluation criteria for disaster relief emergency, and the unclear demand has become a major obstacle and bottleneck for the in-depth study of disaster relief emergency decision theory. Must, therefore, the demand analysis into the emergency relief materials in the study of decision making, by using modern scientific forecasting methods and models, put forward suitable for requirements prediction of ES and classification method, established the corresponding ES requirements forecast and classification model, realize the requirements prediction of ES and classification model.

There are few researches on the LMESRC. The construction of the ES reserve system is a key link to carrying out an emergency rescue. So far, the ownership of ES reserve repositories of governments at all levels in Guangxi has been clarified. A small number of counties, cities, and districts have not had their own ES reserve repositories. There are unreasonable phenomena in the construction of some existing ES reserves. All these problems can be optimized by establishing the LMESRC, determining the most reasonable construction address of ESRC or reservoir, and improving the ES reserve system of Guangxi.

The research on ESD and decision-making is not thorough enough. The existing problems of material dispatching and transportation under an emergency can be divided into two types: one is to transform the material dispatching problem under an emergency into the problem of solving the shortest circuit of the network. The research results of this problem are relatively large, and most of the research are focused on the problems of ES distribution vehicle transportation scheduling, vehicle transportation route selection and so on. Another kind of research result is to transform the problem of ES transportation into the problem of selecting the ES supply point. That is to say, for multiple ES supply points and under the constraint of supply and demand of material quantity, the problem of combination optimization of ES supply points is considered. However, there is little research on the distribution decision before material transportation. Disaster EL distribution strategy is an important part of EL system rapid response mechanisms for real-time, quickly making supplies allocation, maximizing the efficient use of existing resources is of great significance. Therefore, we need to expand the research train of thought further, enrich and perfect the ES allocation decision-making theory and optimization technology, implement limited resources optimal configuration in the shortest possible time, and improve the level of disaster relief decisions.

In the existing research literature, there are only a few studies about RPMES, LMESRC, and ESDM, and the related model for simulation together and emergency decision support to carry out systematic and comprehensive research results. Therefore, this topic will carry out in-depth and systematic research in this aspect, providing support for improving the emergency decision-making of various government emergency departments.

In the existing research literature, there are few achievements in modeling EL for TCD in Guangxi. It includes RPMES, LMESRC and ESDM. There are few achievements in systematic and comprehensive research on EL decision support. Therefore, this topic will carry out in-depth and systematic research in this aspect so as to provide support for improving the emergency decision-making ability of emergency management departments at all levels of government in Guangxi.

CHAPTER III

METHODOLOGY

Theories and methods involved in this topic include EL management theory, natural disaster theory, requirements prediction method of ES, location method of ESRC, ESD method, etc. These theories and methods reflect the combination of theory and practice of qualitative and quantitative problem-solving ideas, which can help better understand and solve the problem of scientific decision-making in the face of TCD in Guangxi. In order to understand and master these theories and methods, detailed analysis and modeling are required through the literature review method, in-depth interview method, MLRM, CGM, GIS, LP, OMG, etc. The following is a detailed introduction to related research methods and problem-solving steps from these 5 aspects, shown in Fig. 10.

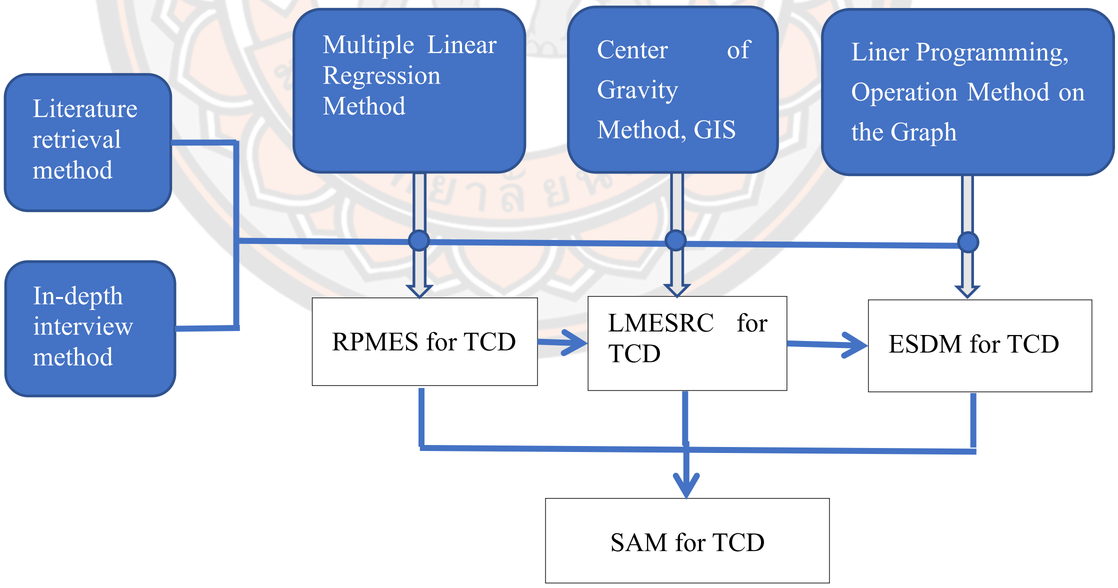

Figure 10 Relationship of methodologies and modals

1. Literature retrieval method

Searching periodical literature databases such as Scopus, Web of Science (ESCI), ISI, Google Scholar, ScienceDirect, ResearchGate, CNKI, and WANFANG DATA, papers related to EL, TCD, Requirements prediction of ES, location of ESRC, and ESD were found. Download and read papers published by other scholars related to these topics, and master the latest research achievements in the research field related to this paper, especially the research methods adopted by previous scholars to solve these related problems. The relevant models are established, the appropriate conclusions are drawn, and novel ideas are put forward. On this basis, in view of the specific situation of TCD in Guangxi, the paper puts forward solutions to the problems related to the Requirements prediction of ES, location of ESRC, ESD for TCD in Guangxi.

2. In-depth interview method

In order to obtain detailed data on TCD in Guangxi, the address of the ES reserve, and the quantity of ES stored by governments at all levels in Guangxi, the author visited the Emergency Management Department of Guangxi, Disaster Reduction Center of Guangxi, Emergency Management Bureau of Qinzhou and other units for many times. Through interviews with the staff, I learned about the disaster relief policies of the Guangxi government, the ownership of ES reserves of governments at all levels, ES storage and procurement strategies, and ESD plans. Data on TC that have entered Guangxi and caused serious losses since 2014 were collected through interviews, including specific data on various disasters caused by these TC to the whole Guangxi region, prefecture-level cities and counties (county-level cities and districts), and data of ES reserves of governments at all levels, etc. In addition, data on TC that have caused serious damage in Guangxi since 2005 were collected through the website of China Typhoon Network and the website of the China Meteorological Administration. The data obtained through the in-depth interview method provide data support for the subsequent establishment of RPMES, LMESRC, and ESDM.

3. RPMES for TCD

3.1 Prediction

3.1.1 The concept and steps of prediction

Prediction is to use scientific methods and means to estimate the development trend and future state of a certain thing and make qualitative or quantitative evaluations according to the movement and change the law of a certain thing. It is to discuss and study the result that will happen to a thing at present. It is a science of studying the future (*Youwei Zhang, 1991, Mingxi Sun, et al., 1993*). Prediction is such a process: from the past and the present known according to the situation of research on something, the known factors and the relationship between some factors can determine the future, to seek the law of development of things, the use of certain methods and techniques to explore or simulate the unknowable, does not appear or complex intermediate process, deducing the future development trend, provide the basis for the current planning, making decisions.

As a process, prediction typically consists of the following seven steps.

(1) Determine the prediction target. Define your goals and objectives. Start by figuring out what to predict and what goals or requirements to achieve. The forecast objectives, period, and quantity units must be specified in writing.

(2) Collect relevant data and analyze influencing factors. Collect data according to the specific requirements of the prediction target, analyze, process and sort out the collected data, judge the true degree and availability of data, remove those unreal and useless data, and exclude the influence of occasional events so as to have a thorough understanding of the past activities of the predicted objects.

(3) Choose the prediction method. According to the target requirements and the analysis and judgment of the data, choosing a reasonable prediction plan, the quantitative prediction can establish a mathematical model, and the qualitative prediction can select a hypothetical logical thinking model to choose the prediction method.

(4) Prediction. According to the selected scheme and the established mathematical model, input data for prediction.

(5) Analysis and prediction results. Make a careful analysis and evaluation of the prediction results, and judge whether it is reasonable. If not, another plan should be selected, and the prediction should be made again.

(6) Revised forecast results. It is necessary to revise the forecast results according to the relevant data and various past and present factors to make the forecast results more reflective of the actual situation.

(7) Output the predicted results. Output the revised final forecast.

Qualitative and quantitative forecasting methods also complement each other in the process of comprehensive forecasting. Quantitative prediction can be used under more detailed historical data, and qualitative prediction can be used under incomplete historical data or the significant influence of uncertain factors. For some complex objects, the results of various prediction methods can be comprehensively analyzed to provide more objective and practical prediction results.

3.1.2 Prediction method

The prediction methods can be divided into qualitative methods and quantitative methods.

Qualitative prediction takes experts as the object to obtain information. Experts from all aspects are organized to comprehensively analyze past and present problems using professional knowledge and experience and find rules from them. Then, predictors make subjective speculations on the future development trend and prospects based on practical experience and subjective judgment. Its advantage is that it can make relatively correct judgments and speculation without statistical and original data and is easy to operate. The disadvantage is that the prediction error depends on the selection of experts, and the general accuracy is not very high. Common qualitative forecasting methods include the market research method, expert forecasting method, subjective probability method and cross-influence method (*Mingxi Sun, et al., 1993*).

Quantitative prediction is the use of statistical methods and mathematical models, statistical analysis of historical data in the past, and quantitative indicators to measure the phenomenon of things and future system development. Quantitative prediction model classification methods are many, such as regression analysis (unary linear regression, multiple linear regression, and nonlinear regression method), time series analysis method (moving average, exponential smoothing, seasonal index method, the trend prediction method), production and marketing balance method (input-output method), gray prediction method and system dynamics method, et al. In the requirements prediction of ES, to obtain more accurate forecasting results, it is often necessary to use a variety of forecasting methods. Then the analysis and comparison results, and finally put forward the comprehensive analysis results for decision makers' reference. Different prediction methods have different results and accuracy for the same problem. Different forecasting methods often provide different useful information.

3.2 The prediction model of multiple regression analysis

3.2.1 Regression prediction

Take the requirements of ES as the object for prediction, using small sample size and data. At present, the prediction of the requirements for disaster relief supplies is still dominated by expert experience judgment. In addition, the non-routine and uncertain characteristics of the requirements for disaster relief supplies make it more difficult to predict the requirements for disaster relief supplies. In this paper, MLRM is selected for the study of RPMES.

The regression prediction method calculates the predicted object's future state, quantity, and performance by analyzing the changing trend of the phenomena related to the predicted object from the causal relationship among various phenomena. According to the change rule of historical data, the regression equation between independent variables and dependent variables was found to determine the model parameters and the prediction was made accordingly. The model parameters were estimated with sample data, and the error test was conducted on the model.

The main advantages of the regression analysis method are that the technology is relatively mature and the prediction process is simple. At the same time, the influencing factors of the predicted objects are decomposed to examine the changes of various factors, so as to estimate the quantitative state of the predicted objects in the future. But the traditional regression analysis method has the following defects.

(1) High-quality requirements for historical data. The correlation analysis of system factors and establishing a regression prediction model need sufficient data. Without sufficient historical data, the regression model cannot be

established effectively.

(2) System structure requires stability. The quantitative relationship between factors is determined by the structure of the system. When the environment of the system structure changes, the prediction accuracy of the regression model established based on historical data will be affected.

(3) The regression model is difficult to build. There are many influencing factors, and the influence of random factors on the system is often difficult to be described by definite functions, which requires a strong mathematical modeling level.

3.2.2 The prediction model of multiple regression analysis

Regression analysis focuses on finding approximate functional relationships between variables. In regression analysis, dependent variables are always random variables, while for independent variables, the situation is more complex. In most practical problems, the factors affecting dependent variables are not one but many. Although there is no strict and deterministic functional relationship between independent variables and dependent variables, we can try to find the mathematical expression that best represents the relationship between them. We call this kind of problem multivariate regression analysis.

Let's say a problem has dependent variables y and independent variables $x_1, x_2, \dots, x_m$, Establish a multiple regression model between dependent variable y and respective variable $x_j (j = 1,2, \dots, m)$.

$$\text{y} = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_m x_m + e \qquad (3\text{-}1)$$

Where, b_0 is the regression constant, $b_k (k = 1,2, \dots, n)$ is the regression parameter, and e is the random error. e can be understood as the error of various complex random factors represented by linear $x_1, x_2, \dots, x_m$ in y, The above equation is called the regression equation. By substituting the n time observation data k into the equation (3-1), the mathematical model of multiple linear variables can be obtained as follows.

$$\begin{cases} y_1 = b_0 + b_1x_{11} + b_2x_{12} + \cdots + b_mx_{1m} + e_1 \\ y_2 = b_0 + b_1x_{21} + b_2x_{22} + \cdots + b_mx_{2m} + e_2 \\ \quad \ldots \\ y_n = b_0 + b_1x_{n1} + b_2x_{n2} + \cdots + b_mx_{nm} + e_n \end{cases} \tag{3-2}$$

And suppose $(e_1, e_2, \ldots, e_n)$ are independent of each other and subject to the same normal distribution $N(0, \sigma^2)$.

In practical problem studies, it is not possible to determine the linear relationship between the random variable y and the variables $x_1, x_2, \ldots, x_m$. Before the estimation of regression parameters, multiple linear regression equations are used to fit the relationship between random variables y and variables $x_1, x_2, \ldots, x_m$. This relationship is only based on assumptions made by some qualitative analysis. Therefore, after solving the linear regression equation, it is necessary to test the significance of the regression equation. Generally, two statistical methods are used to test the regression equation: the F test of the significance of the regression equation and the t test of the significance of the regression coefficient.

Assuming that the estimated values of $b_0, b_1, b_2, \ldots, b_m$ are $a_0, a_1, a_2, \ldots, a_m$, then the observed values of y can be expressed as:

$$y_i = b_0 + b_1x_{i1} + b_2x_{i2} + \cdots + b_mx_{im} + e_i \ (i = 1,2, \ldots, n) \tag{3-3}$$

Here, e_i is an estimate of ε_i, which is still called the residual. Let $\hat{y}_i$ be the estimated value of y_i, namely:

$$\hat{y}_i = a_0 + a_1x_{i1} + a_2x_{i2} + \cdots + a_mx_{im} + \varepsilon_i \ (i = 1,2, \ldots, n) \tag{3-4}$$

Similar to linear regression with one variable, the least square estimation is conducted for b_i, and a_i is selected to minimize the sum of squared residuals $Q = \sum(y_i - \hat{y}_i)^2$. Then a_i should satisfy the equations: $\frac{\delta Q}{\delta a_i} = 0, (i =$

1,2, … , m), namely:

$$\begin{cases} \sum_{i=1}^{n}(y_i - a_0 + a_1 x_{i1} + a_2 x_{i2} + \cdots + a_m x_{im}) = 0 \\ \sum_{i=1}^{n}(y_i - a_0 + a_1 x_{i1} + a_2 x_{i2} + \cdots + a_m x_{im}) x_{1i} = 0 \\ \cdots \\ \sum_{i=1}^{n}(y_i - a_0 + a_1 x_{i1} + a_2 x_{i2} + \cdots + a_m x_{im}) x_{mi} = 0 \end{cases} \quad (3\text{-}5)$$

Set $\bar{x}_j = \frac{1}{n}\sum x_{ij}$, $\bar{y} = \frac{1}{n} y_i$, (i, j = 1,2, … , m)， then the regression equation can be solved simply by the above equation:

$$\hat{y}_i = a_0 + a_1 x_{i1} + a_2 x_{i2} + \cdots + a_m x_{im} \ (i = 1,2, \ldots, n) \quad (3\text{-}6)$$

3.2.3 Significance test of the regression equation

To test whether the multiple linear regression equation is significant is actually to test whether there is a close linear relationship between y and some independent variables in the regression equation. The commonly used F distribution test, whose test hypothesis is:

$$H_0: a_0 = a_1 = \cdots = a_m = 0 \quad (3\text{-}7)$$

When H_0 is assumed to be rejected, the regression equation is said to be significant, and it is believed that y has a close linear correlation with some variables $x_1, x_2, \ldots, x_m$ (not all of them) in the regression equation. When H_0 is accepted, it is said that the regression equation is not significant, and it is considered that y has no close linear relationship with the variables in the regression equation. Remember to:

$$S_R = \sum_i (\hat{y}_i - \bar{y})^2$$

$$S_e = \sum_i (y_i - \hat{y}_i)^2$$

$$S_{yy} = \sum_i (y_i - \bar{y})^2$$

Moreover, S_{yy} is the sum of squares of total deviation, S_R is the sum of regression squares, and S_e is the sum of residual squares, and the equation $S_{yy} = S_R + S_e$ holds. I can point out without proof that when hypothesis (3-7) is true,

$$S_R/\sigma^2 \;\dot{}\; x^2(m)$$
$$S_e/\sigma^2 \;\dot{}\; x^2(n-m-1)$$
$$S_{yy}/\sigma^2 \;\dot{}\; x^2(n-m)$$

And S_R and S_e are independent. So statistics $F = \frac{S_R/m}{S_e/(n-m-1)} \;\dot{}\; F(m, n-m-1)$ follows the $F(m, n-m-1)$ distribution with the first degree of freedom m and the second degree of freedom $(n-m-1)$.

3.2.4 Regression coefficient significance test

In the multivariate regression model, it is not only satisfied with the significant conclusion of linear regression equation. Because the regression equation is significant, it does not mean that the influence of each independent variable x_i on y is important. We need to eliminate those unnecessary variables from the regression equation and establish a simpler and more effective regression equation. Therefore, it is necessary to test the proposed variable $x_i (i = 1,2,\ldots,m)$ one by one, which is equivalent to testing the following hypothesis H_0.

Suppose $H_0: a_j = 0$;

If $C = (C_{ij})_{m\times m}$ is the inverse matrix of the matrix $(S_{ij})_{m\times m}$, then, when the hypothesis is true, the statistic T obeys the t-distribution with degrees of freedom $(n-m-1)$.

$$T = \frac{{a_j}^2/C_{ij}}{S_e/(n-m-1)}$$

For a given significance level α, the t-distribution critical value t_α with degrees of freedom $(n-m-1)$ can be obtained by looking up the table. If $t_j >$

t_α, the hypothesis is rejected, and x_j is considered important and should be retained in the regression equation; if $t_j \leq t_\alpha$, the variable x_j can be removed from the regression equation. In general, a variable can be removed at most after a significance test for all variables, and the removed variable is the one with the smallest T value among all non-significant variables. Then the regression equation is established and tested until the regression equation and various variables are significant.

3.3 RPMES for TCD based on MLRM

3.3.1 Selection of model parameters

As a kind of natural disaster, TC is different from other natural disasters in that it has a high incidence, high frequency of occurrence, many secondary disasters, and a wide range of impacts, causing huge casualties and losses to people's lives and property. In the EL of TCD relief, the index of ES requirements and distribution can be found. Under normal circumstances, there is a direct relationship between the amount of ES needs and the number of people to be relocated. This paper selects the emergency relocation and resettlement population as the dependent variable y, and the following typical influencing factors are selected as the independent variables. Specific independent variable factors include the maximum wind speed when the typhoon entered Guangxi, the length of time it caused the disaster in Guangxi, the number of collapsed houses, and the direct economic loss. These four factors are the main factors affecting the number of emergency resettled populations.

3.3.2 Assumptions

(1) It is assumed that the requirements for ES mainly consider the requirements for ES of the population in need of emergency relocation and resettlement, and other disaster-stricken populations are subsidized mainly through cash and do not need to provide ES.

(2) The greater the maximum wind speed when the typhoon enters Guangxi, the more affected people, the more people in need of emergency relocation and resettlement, the more ES are needed, and vice versa.

(3) The longer the disaster impact time in Guangxi, the more affected the people in need of emergency relocation and resettlement, the more ES are needed, and vice versa.

(4) The more collapsed houses, the more affected people, the more people in need of emergency relocation and resettlement, the more ES are needed, and vice versa.

(5) The greater the direct economic losses, the more affected people, the more people in need of emergency relocation and resettlement, the more ES are needed, and vice versa.

(6) There is an obvious linear relationship between the dependent and independent variables.

3.3.3 Modeling

Therefore, the following multiple linear regression equation can be constructed:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$

The meanings of parameters in the equation are as follows:

y — emergency relocation and resettlement population

b_0 — regression constant

b_i — regression parameter (i=1, 2, 3, 4)

x_1 — the maximum wind speed when the typhoon entered Guangxi

x_2 — the length of time it caused disaster in Guangxi

x_3 — the number of collapsed houses

x_4 — the direct economic loss

3.3.4 The idea of establishing prediction model

The idea of establishing the RPMES for TCD is shown in Fig. 3-2.

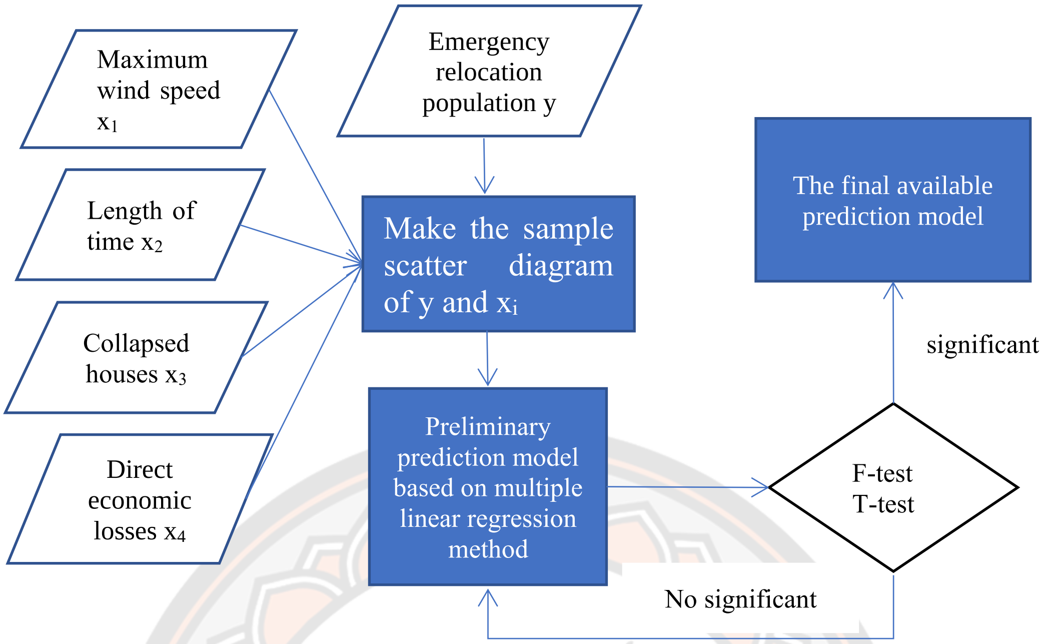

Figure 11 The idea of establishing prediction model

4. LMESRC for TCD

4.1 Location Model of the CGM

Logistics center location decisions can be divided into single-facility and multi-facility locations from the number of facilities. This paper takes a single facility location model as the research object. The single facility location model refers to the model method to seek the best location for a new logistics facility in a particular area, and the commonly used method is the location model of the CGM. The CGM mainly considers the distance between existing facilities and the amount of goods to be transported. It is often used for the location of logistics centers or distribution warehouses. The volume of commodity transportation is the main factor affecting the cost of commodity transportation. The logistics center should be as close as possible to the network with a larger volume of goods so that the larger volume of goods can be transported through a relatively short distance to find the location of the center of gravity of the actual volume of goods in the region.

The center of gravity of a region can be simplified by a proposed logistics facility point (warehouse, distribution center) to supply to n the customer, the customer location coordinates can be set as (x_i, y_i), the demand of the goods is w_i, and the freight rate is B_i, where $i = 1,2,3,\ldots,n$. In order to obtain the coordinates (x, y) of the best facility point address to minimize the shipping cost (C), the CGM model is established.

Generally speaking, the coordinates of the customer's location can usually be measured from the map or field measurement. The demand for goods and freight can also be obtained through the actual survey so that the minimum cost of delivery and transportation can be calculated.

$$\min C = \sum_{i=1}^{n} B_i w_i d_i$$

Where is the distance d_i between the customer point i and the logistics center to be selected.

According to the principle of least square method, to minimize the cost C, there are:

$$\frac{\partial C}{\partial x} = 0, \quad \frac{\partial C}{\partial y} = 0$$

Assume that the coordinates of location selection of the optimal logistics center can be obtained iteratively k ($k = 1,2,3,\ldots,m$) times. So as to obtain the iterative Eq.:

$$x^k = \frac{\sum B_i w_i x_i / d_i^k}{\sum B_i w_i / d_i^k} \qquad y^k = \frac{\sum B_i w_i y_i / d_i^k}{\sum B_i w_i / d_i^k} \tag{3-1}$$

$$d_i^k = \sqrt{(x-x_i)^2 + (y-y_i^k)^2} \tag{3-2}$$

Can be obtained x, y by iterative method.

(1) Let $d_i^0 = 1$ be substituted into Eq. (3-1), an initial solution can be obtained as (x^0, y^0).

(2) (x^0, y^0) is substituted into Eq. (3-2) to find out d_j^1.

(3) d_j^1 is substituted into the Eq. (3-1) to find the value of (x^1, y^1), and so on until (x^k, y^k) is close enough to the value of (x^{k+1}, y^{k+1}). Then (x^{k+1}, y^{k+1}) is the optimal solution of location selection, which is the optimal solution selected by the logistics center.

4.2 Advantages Of GIS Location Selection

In GIS (Geographic Information System), origin and demand are spatial entities that can be expressed according to the available points of their physical characteristics. Meanwhile, the basic information and the whole planned area can be expressed through spatial data, corresponding to location feature data, attribute feature data, and topological feature data, respectively. The location feature data records the geographical data of each place of origin and demand. Attribute feature data records the attributes of spatial entities (such as single and two-way roads, road length, etc.). The Topological feature data records the road topological data related to each place of origin and demand. These spatial data are stored in GIS spatial databases and can be updated in real-time. The use of these basic spatial data has the following benefits for the location of logistics centers. Firstly, since data can express the location of the origin and demand without using the grid to obtain the relative position between them, it is convenient to use and can be more accurate for calculation. Secondly, because the spatial entities within the site selection area have also been digitized (including roads and various logistics bases), the road situation with each origin and demand can be easily obtained, which is more in line with the actual objective conditions. Unlike the classical gravity center method, the distance between two points is directly expressed in a straight line without considering the actual road situation. Lastly, GIS data can be updated in real-time to better adapt to changes in the actual situation.

4.3 LMESRC Based On GIS

4.3.1 Assumptions

(1) It is assumed that there are a total of disaster-affected places in the area to be located, and an ESRC needs to be determined to supply ES to this disaster-affected place. The optimal location coordinates of the ESRC can be obtained using the single facility location model of the ESRC based on GIS.

(2) Road data in disaster areas can be obtained, and roads in disaster areas are unimpeded.

(3) The shortage of ES in all disaster areas will be provided by the planned provincial ESRC, which has enough ES for use.

(4) The 14 prefecture-level city ES reserve repositories serve as the places where ES needed by prefecture-level cities are received.

(5) The coordinates and line distance obtained by GIS system are available.

(6) Assume that all roads cost the same per unit of transport.

4.3.2 Modeling

Generally, the modeling is carried out in the following 6 steps:

(1) First, the data of the disaster-affected areas and their related roads within the site selection area is realized.

(2) Determine the coordinate values of each disaster-affected place (x_i , y_i), and determine the ES requirements v_i and transportation rate r_i of each disaster-affected point in which $i = 1,2,3,\ldots,n$.

(3) Distance d_i^k is not considered (let d_i^0 =1), where $k = 0,1,2,3,\ldots,m$, k represents the number of iterations, and the CGM is used to solve the initial site selection point:

$$x^0 = \frac{\sum v_i r_i x_i}{\sum v_i r_i} \qquad y^0 = \frac{\sum v_i r_i y_i}{\sum v_i r_i} \tag{3-3}$$

(4) Match the initial site selection point (x^0, y^0) to the GIS plan area, and use GIS to find the shortest path between the initial site selection point

(x^0, y^0) and each demand point (x_i, y_i) (considering the least time and shortest distance). The shortest path length is denoted.

(5) d_i^1 will be substituted into the following Eq. (3-4) to solve the revised coordinate value of (x^1, y^1) Eq. (3-4) is as follows:

$$x^k = \frac{\sum v_i r_i x_i / d_i^k}{\sum v_i r_i / d_i^k} \qquad y^k = \frac{\sum v_i r_i y_i / d_i^k}{\sum v_i r_i / d_i^k} \tag{3-4}$$

(6) Replace the last obtained coordinate value with the newly obtained coordinate value, and repeat steps (4) and (5) until the coordinate value of (x^k, y^k) no longer changes or there are small changes in the continuous iteration process, so it is no longer meaningful to continue the calculation. At this time, the coordinate value obtained is the best and most in line with the actual location of the logistics center.

5. ESDM for TCD

5.1 Transportation problem

Transport problems in logistics can be described in the following mathematical language:

There is a material that needs to be shipped from m places of production ($A_1, A_2, \dots, A_m$) to n places of sale ($B_1, B_2, \dots, B_n$), where the production of A_i from each producing area is a_i (i = $1, 2, \dots,$ m), the sales volume of B_j from each sale place is b_j (j= $1, 2, \dots,$ n). The known cost of transporting a unit of material from A_i to any place of sale B_j is C_{ij} (i = $1, 2, \dots,$ m, j = $1, 2, \dots,$ n). How can the total cost be minimized of material transfer?

The production, sales, and unit freight table of this problem is shown in Table 9

Table 9 production, sales and unit freight

Place of sale / place of production	B_1	B_2	…	B_n	output
A_1	C_{11}	C_{12}	…	C_{1n}	a_1
A_2	C_{21}	C_{22}	…	C_{2n}	a_2
…	…	…	…	…	…
A_m	C_{m1}	C_{m2}	…	C_{mn}	a_m
sales volume	b_1	b_2	…	b_n	$\sum a_i$ / $\sum b_i$

This is the issue of the transfer of goods from multiple production sites to multiple sales sites. If the total production of the problem is equal to the total volume of sales, there are

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

Then the problem is said to be a balance of production and marketing transport problem. Otherwise, it is called an unbalanced transportation problem.

If x_{ij} is used to represent the amount of goods transferred from the point of origin A_i to the collection point B_j, the mathematical model for solving the transport problem is as follows:

$$x_{ij} \ (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

$$\sum_{i=1}^{n} x_{ij} = a_i \ (i = 1, 2, \dots, m)$$

$$\sum_{j=1}^{m} x_{ij} = b_j \ (i = 1, 2, \dots, n)$$

$$x_{ij} \geq 0 \ (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

$$\min Z \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$$

When $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$, the total output of the material transfer problem is equal to its total sales volume; such a transportation problem is called the balance of production and marketing transportation problem.

When $\sum_{i=1}^{m} a_i \neq \sum_{j=1}^{n} b_j$, that is, when the total output of the material transfer problem is not equal to its total sales volume, such a transportation problem is called an unbalanced of production and marketing transportation problem.

In fact, the problem of transportation only considers the balance of production and sales because when the production and sales are unbalanced, we can increase the virtual place of production and sale and convert it into the problem of balanced transportation of production and sale.

5.2 LP Model for ESD

5.2.1 Assumptions

(1) The ESD for TCD in Guangxi is a transshipment problem of ES involving multi-supply nodes, multi-transfer nodes, and multi-demand nodes of the province, municipality, and county at three levels.

(2) This problem is also a special subproblem of the transportation problem that requires timely ES delivery to victims at minimum cost.

(3) The ES provided by the provincial, prefecture-level city, and county-level ES reserves are equal to the needs of county-level disaster areas and the balance between supply and demand.

(4) The ES stored in the ES reserve of prefecture-level cities and counties shall be used for disaster relief as a matter of priority, and the ES needed by the disaster victims shall not be kept. The shortfall is provided by the provincial ESRC.

(5) Assume that all roads cost the same per unit of transport.

(6) Assume that the selected transport route is smooth and the selected transport route is the shortest distance and the shortest time line.

5.2.2 Modeling

The LP model to solve this problem can be expressed as:

$$\min f = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$$

The constraints are as follows:

For provincial ESRC: $\sum_{j=1}^{n} x_{ij} = s_i$

For municipal ES storage warehouse: $\sum_{all-out} x_{ij} - \sum_{all-in} x_{ij} - M_{0i} = 0$

For county level ES storage warehouse: $\sum_{i=1}^{m} x_{ij} + D_{0j} = d_j$

For the amount of ES originally stored in each municipal ES reserve warehouse: $M_{0i} \geq 0 (i = 1,2,..., m)$

For the amount of ES originally stored in each county level ES reserve warehouse: $D_{0j} \geq 0 (j = 1,2,..., n)$

For transfers of ES between all nodes: $x_{ij} \geq 0(i = 1,2,..., m; j = 1,2,..., n)$

Among them,

x_{ij} - represents the transferred volume from node i to node j.

c_{ij} - represents the unit freight rate from node i to node j.

s_i - represents the total supply of ES provided by the provincial ESRC.

M_{0i} - represents the amount of ES originally stored in the municipal ES reserve warehouse.

D_{0j} - represents the amount of ES originally stored in the county level ES reserve warehouse.

d_j - represents the total demand of ES needed by the county level ES reserve warehouse.

5.3 ESDM based on OMG

To solve the problem of ESD, LP, production-marketing balance, mileage saving, shortest path, and OMG can be adopted. This paper uses the OMG to solve the problem of ESD based on the principle of LP, and the scheme obtained is optimal. The OMG plans and calculates ESD's transportation network diagram to minimize the tons•kilometers of ES running and reduce the cost and time. The traffic network diagram can be distinguished into two types: the traffic network diagram without circles and the traffic network diagram with circles.

5.3.1 OMG Without Circle

The non-circular OMG adopts the principle of "nearby transportation". If there is no convection and roundabout transport phenomenon in the scheme, it is the optimal scheme. The situation of ES transportation of the operation method is illustrated in Fig. 12. The supply point of ES is represented by "○", the quantity of ES supplied is recorded in addition to "○" (unit: ton), the ES requirements is represented by "×", the quantity of ES received is recorded next to "×" (unit: ton), and the distance between the two points is marked on the route (unit: km). The total ES is equal to the total ES requirements.

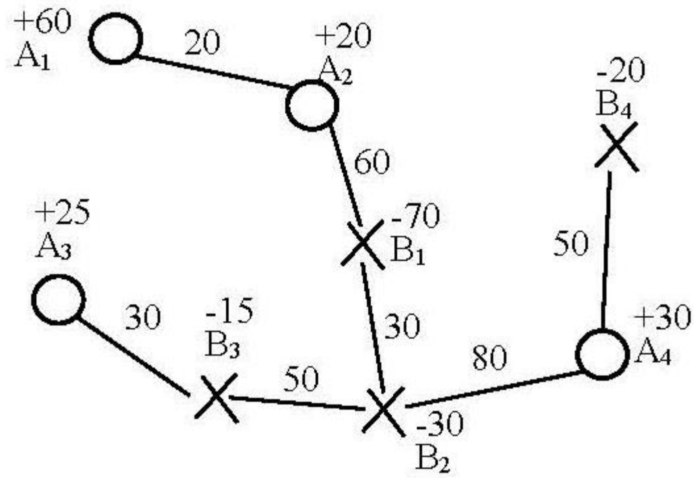

Figure 12 Traffic network diagram of OMG without circles

According to the OMG, the ES should first meet the ES requirements of the neighboring demand point and then meet the other demand points. From the A_1-A_2-B_1-B_2 branch line, the Supply of A_1 and A_2 is 80 tons, and the demand for B_1 is 70 tons. Therefore, 70 tons are transferred from A_1 and A_2 to B_1, and the remaining 10 tons are transferred to the next nearest demand point, B_2.

Looking at the A_3-B_3-B_2 branch line, A_3 is transferred to B_3, the nearest demand point, totaling 15 tons, and the remaining 10 tons are shipped to B_2.

Finally, look at the branch line B_4-A_4-B_2. At this time, only two demand points, B_4 and B_2, have not met the demand. 20 tons of A_4 should be transferred to B_4 and 10 tons to B_2.

Fig. 13 shows the flow diagram of the final ES transportation plan. Where "→" represents the flow direction of ES, and the number on "→" represents the number of ES transported.

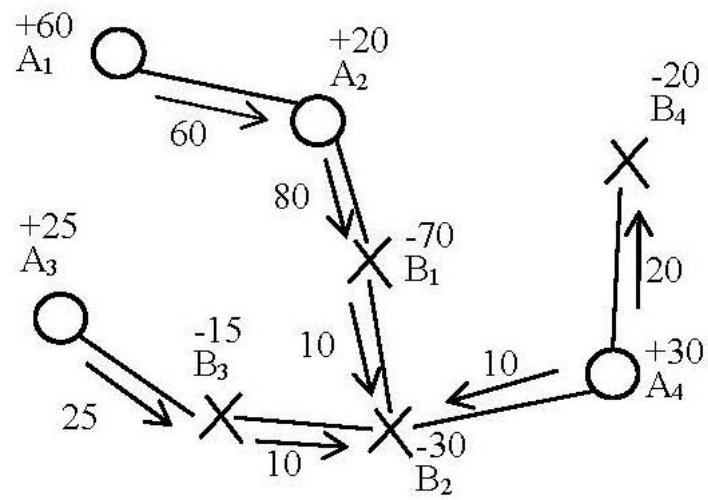

Figure 13 Flow diagram of ES transfer scheme of the OMG without circles

According to the ESD situation in Fig. 3-4, the optimal ESD scheme of the OMG without circles is obtained, as shown in Table 10.

Table 10 The optimal ES transfer scheme of the OMG without circles

	B_1	B_2	B_3	B_4	Supply (ton)
A_1	60				60
A_2	10	10			20
A_3		10	15		25
A_4		10		20	30
Demand (ton)	70	30	15	20	135

The total tons•km S_1 dispatching of its transportation scheme is:

S_1=60*120+10*60+10*（60+30）+10*（30+50）

+10*80+15*30+20*50=11750（tons•km）

5.3.2 OMG With Circle

The traffic network diagram with a circle needs to be transformed into a traffic network diagram without a circle. The method is to sum the flow lines of the inner and outer circles of the feasible scheme, respectively, and judge whether they are more than half of the total circumference of the whole circle. The scheme is optimal if the total length of the flow line of the outer ring exceeds half of the circumference of the whole ring. The specific adjustment method is to choose the circle flow line in the smallest adjustment, in more than one-half of the full circle minister of the inner (or outer) circle. The above method is applied until the sum of the flow lines of empty vehicles in the inner and outer circles is less than half of the circumference, and then the transportation scheme obtained is the optimal scheme. According to the OMG of ES transportation in the circle in Fig. 3-5, the total supply of ES is equal to the total ES requirements.

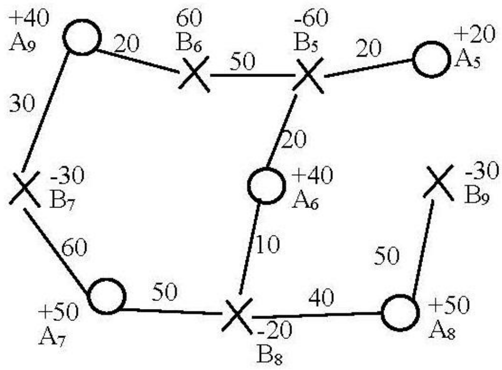

Figure 14 Traffic network diagram of ES transfer with circle

The circled ES transportation diagram is changed into an uncircled diagram. Assuming that the route between A_7 and B_7 is not feasible, the initial transportation scheme is obtained according to the principle of "nearby transportation," as shown in Fig. 15.

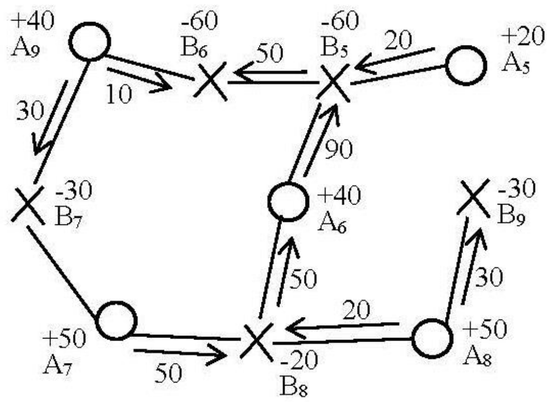

Figure 15 Flow diagram of initial ES transportation scheme with circle

Test the initial scheme:

Circumference：

C_1=60+50+10+20+50+20+30=240（km）

Half of the circumference：

C_1/2=240/2=120（km）

The inner circuit length：

C_{inner1}=20（km）

The outer circuit length：

C_{outer1}=50+10+20+50+30=160（km）

From this, we can see that $C_{inner1} < C_1/2$, $C_{outer1} > C_1/2$, so it's not optimal. After adjusting the initial scheme according to the adjustment method described above, the final transport scheme, as shown in Fig. 3-7, can be obtained.

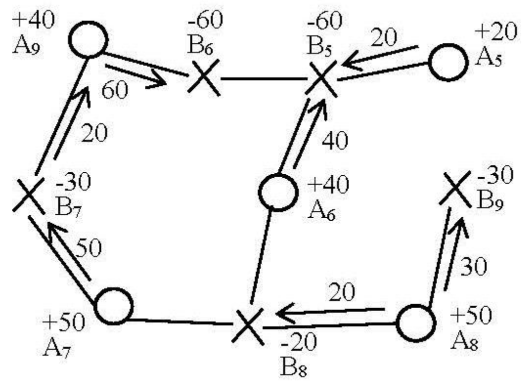

Figure 16 The flow diagram of the ES transfer scheme with a circle after adjustment

To test:

C_{inner2}=60+30+20=110（km）

C_{outer2}=20（km）

So, $C_{inner2} < C_1/2$, $C_{outer2} < C_1/2$, so the adjusted scheme is the optimal scheme.

The optimal ES distribution scheme of the OMG with circles is shown in Table 11.

Table 11 Optimal scheme of ES distribution of the OMG without circles

	B5	B6	B7	B8	B9	Supplyton）
A5	20					20
A6	40					40
A7		20	30			50
A8				20	30	50
A9		40				40
Demand（ton）	60	60	30	20	30	200

The minimum tons•km S_2 is:

S_2=20*20+40*20+20*(50+10+20+50)+30*60+20*40+30*50+40*20=8700(tons•km)

The resulting minimum tons•km is multiplied by the road freight rate to get the minimum transport cost.

CHAPTER IV

RESULTS

1. Data collation of TCD in Guangxi

The data used in this paper are from the basic data and information of TCD in Guangxi since 2005 provided by China Tropical Cyclone Statistical Yearbook (2005-2019), China Weather Typhoon Network, China Meteorological Science Data Sharing Service Network (China Meteorological Data Network), Guangxi Water Resources Bulletin and China Disaster Network. In addition, I personally visited the Emergency Management Department of Guangxi and other units to obtain detailed loss data of severe TCD suffered by Guangxi since 2014 (the data reflected the whole region, prefecture-level cities, disaster-stricken counties (county-level cities, districts) and other multi-tiered jurisdictions).

1.1 Statistics of severe TCD suffered by Guangxi from 2005 to 2022

Since 2005, Guangxi has been hit by TC twice a year on average, causing huge losses to its people and society. The specific disaster statistics are shown in Table 12.

Table 12 Statistics of severe TCD suffered by Guangxi since 2005

No.	TC NO.	TC Name	Affected population (10,000)	emergency relocation and resettlement population (10,000)	Collapsed house (room)	Affected area of crops (thousands of hectares)	Direct economic loss (100 million yuan)	Maximum central wind speed extremum during Guangxi (m/s)	Duration of impact on Guangxi (hours)	Typhoon entering Guangxi (East 1, Southeast 2, South 3)
1	0518	Damrey	101.0	12.7	403	49.5	1.6	20	17	3
2	0604	Bilis	635.6	49.9	25600	262.63	22.5	10	44	1
3	0605	Kaemi	53.4	5.033	6770	3.544	0.3859	10	52	1
4	0606	Prapiroon	570.6	38.7	16000	256.8	20.3	23	38	2
5	0703	Toraji	179.3	11.458	1763	98.7	3.01	23	17	3
6	0709	Sepat		0.1644	407	2.021	0.15462	6	36	1
7	0714	Francisco	11.9	3.8	239	0	3.23	12	48	3
8	0715	Lekima	9.2	3.2	147	42	0.132	6	24	3
9	0806	Fengshen	7.3	0.2	470	9.1	0.45	6	51	3
10	0809	Kammuri	179.2	5.8	2480	226.7	5.49	18	22	3
11	0812	Nuri	18.8	1.5	220	6.1	0.297	6	8	1
12	0814	Hagupit	665	105.3	19300	656.6	69.7	30	48	2
13	0906	Molave	50.75	0.22	700	11.69	0.89	18	6	1
14	0915	Koppu	21.82	1.12	400	7.11	0.27	23	16	2
15	1003	Chanthu	177.42	10.46	4880	72.38	3.9	30	24	2
16	1011	Fanapi	7.8	0.13	360	4.6	0.17	20	40	3

No.	TC NO.	TC Name	Affected population (10,000)	emergency relocation and resettlement population (10,000)	Collapsed house (room)	Affected area of crops (thousands of hectares)	Direct economic loss (100 million yuan)	Maximum central wind speed extremum during Guangxi (m/s)	Duration of impact on Guangxi (hours)	Typhoon entering Guangxi (East 1, Southeast 2, South 3)
17	1104	Haima	13.5	0.5	1000	0.8	0.1	8	22	1
18	1117	Nesat	379.8	16.3	8000	427.5	34.6	8	36	3
19	1119	Nalgae	11.2	0.2	1000	6.7	1.5	8	16	3
20	1208	Vicente	75.5	2.9	4000	35.6	1.9	20	42	2
21	1213	Kai-Tak	277.6	15.3	5000	281.5	22.8	30	48	2
22	1223	Son-Tinh	45.3	4.3	1000	22.5	2.6	30	60	3
23	1306	Rumbia	47.3	0.5	1000	14.1	1.0	26	18	2
24	1309	Jebi	8.8	0.3	1000	17.4	1.3	15	10	3
25	1311	Utor	161.1	13.1	17000	60.9	21.7	25	108	2
26	1312	Trami	28.2	0.7	2000	16.5	0.9	10	24	1
27	1319	Usagi	4.5	0.3	0	4.3	0.9	10	54	1
28	1330	Haiyan	196	4.9	4000	340.1	14.4	28	28	3
29	1409	Rammasun	433.0361	32.0261	10167	777.3	138.9863	50	33	3
30	1415	Kalmaegi	333.0261	15.1265	3258	273.5	31.0844	42	24	3
31	1522	Mujigae	275.6582	13.5448	2518	16.06	17.9591	42	54	2
32	1603	Mirinae	0.2	0	0	0.1	0.01	10	24	3
33	1604	Nida	20.9	0.5	700	8	1.4	10	39	1
34	1608	Dianmu	1.6810	0.0476	47	33	0.0997	8	20	3
35	1621	Sarika	35.6649	2.4627	221	24.1	2.3284	20	26	3
36	1713	Hato	33.8512	1.0455	320	19	2.4670	23	48	1
37	1714	Pakhar	2.6983	0.0270	54	1.2	0.2609	22	20	1
38	1720	Khanun	0.7632	0.0084	24	0.086	0.0241	8	8	3
39	1809	Son-Tinh	0.3329	0	0	0.052	0.0051	11.4	26	3
40	1822	Mangkhut	147.9397	13.7910	1451	106.870	8.5052	38	24	2
41	1907	Wipha	21.979	0.3522	154	24.769	2.3498	23	52	3
42	1911	Bailu	7.4788	0.3223	352	1.729	1.0399	6	19	1
43	2002	Nuri	2.8697	0.1204	1	0.2	0.7632	8	24	2
44	2003	Sinlaku	3.0592	0.0308	4	0.117	0.0370	10	48	3
45	2007	Higos	8.8854	0.1036	46	2.389	0.3222	25	16	1
46	2107	Cempaka	1.3826	0.0020	1	0.536	0.1544	15	18	1
47	2117	Lionrock	17.9978	0.0212	46	16.785	0.8362	10	24	3
48	2118	Kompasu	1.3476	0	10	0.478	0.399	15	30	3
49	2203	Chaba	80.2348	2.5790	321	30.083	8.8678	20	34	2
50	2207	Mulan	4.5495	0.0032	25	0.587	0.09677	20	22	3
51	2209	Ma-on	2.869	0.1059	11	3.906	0.6285	25	8	3

Data source: (1) China Tropical Cyclone Statistical Yearbook (2005-2019). (2) TC disaster statistics from the Emergency Management Department of Guangxi.

1.2 Typical characteristics of severe TCD suffered by Guangxi from 2005 to 2022

In the 18 years from 2005 to 2022, Guangxi suffered 51 severe TCDs. These TCDs have typical characteristics in terms of the distribution year, the direction of entering Guangxi, the number of affected people, and the emergency resettlement of displaced people.

1.2.1 Uneven annual distribution of TCD

The yearly distribution of severe TCD suffered by Guangxi since 2005 can be summarized from the statistical data in Table 4-1, as shown in Table 13 As can be seen from the annual distribution of Table 4-2, the annual distribution of TCDs that caused serious losses to Guangxi in the past 18 years is uneven, with an average of nearly 3 severe TCDs affecting Guangxi every year, and the maximum number of TCD reaching 6 in 2013. Fig. 17 shows the annual distribution comparison of TCD.

Table 13 Annual distribution of severe TCD in Guangxi since 2005

Year	Number of TCD
2005	1
2006	3
2007	4
2008	4
2009	2
2010	2
2011	3
2012	3
2013	6
2014	2
2015	1
2016	3
2017	3
2018	2
2019	2
2020	3
2021	3
2022	3

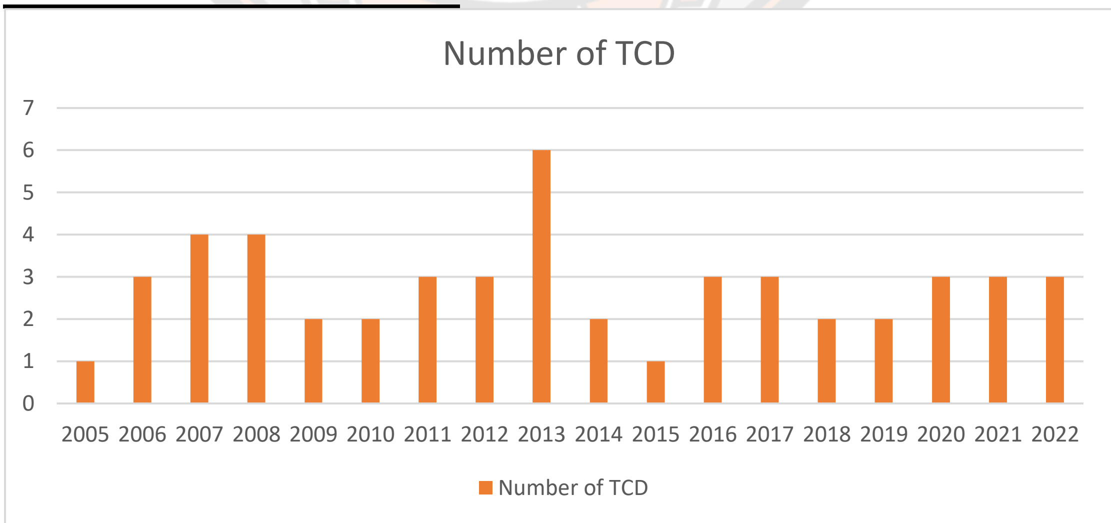

Figure 17 Annual distribution comparison of severe TCD in Guangxi since 2005

1.2.2 The TCD enters Guangxi in different directions

According to the statistical data in Table 12 the direction of severe TCD in Guangxi since 2005 can be summarized, as shown in Table 14. As can be seen from the annual distribution of Table 14, the number of TCD that caused serious losses to Guangxi in the past 18 years varies greatly in the three directions, and nearly half of the severe TCD come from the southern coastal areas of Guangxi. Fig. 18 shows the proportional distribution diagram of specific TCD entering Guangxi.

Table 14 Distribution of severe TCD in Guangxi since 2005

The typhoon entered the direction of Guangxi	East	South-east	South
Quantity	14	12	25

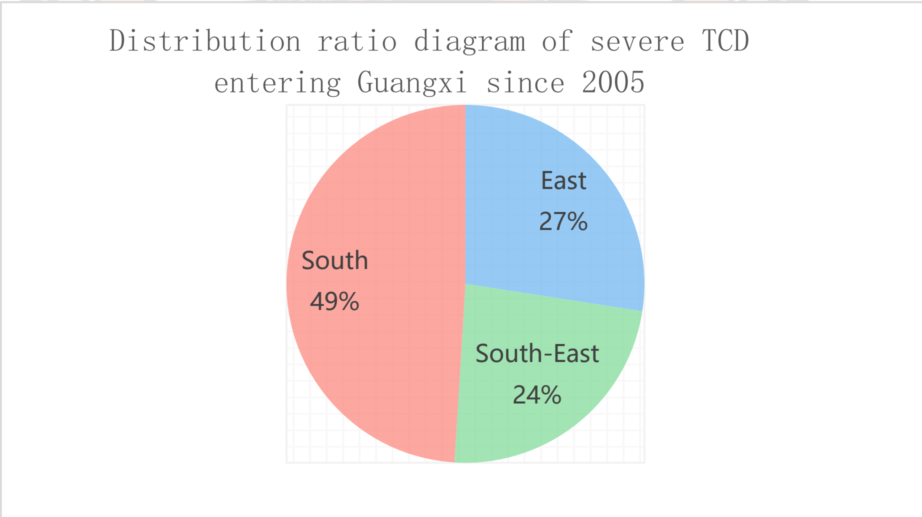

Figure 18 Distribution ratio diagram of severe TCD entering Guangxi since 2005

1.2.3 TCD has caused serious losses to the economy and society of Guangxi

According to the statistical data in Table 12, the severe TCD suffered by Guangxi since 2005 are summarized and compared in terms of the number of affected population, the number of emergency resettlement and relocation population, the number of collapsed houses, the affected area of crops and direct economic losses. For details, see Fig. 19, Fig. 20, Fig. 21, Fig. 22, and Fig. 23.

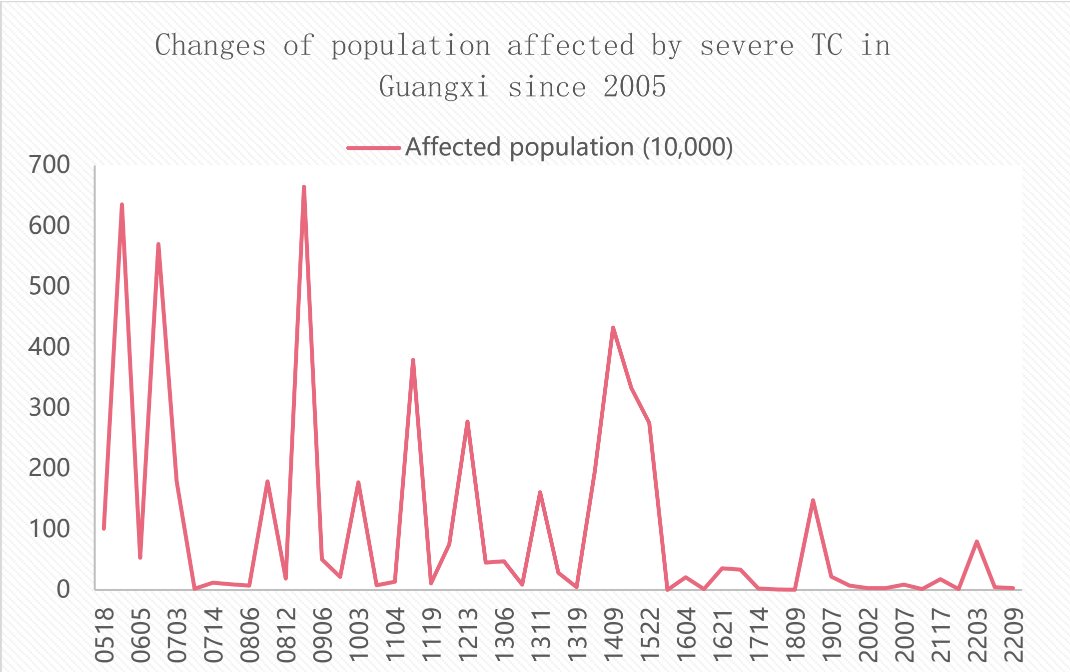

Figure 19 Changes in population affected by severe TC in Guangxi since 2005

As can be seen from Fig. 19, the number of people affected by severe TC in Guangxi since 2005 has varied greatly. The most serious ones are No. 0814 Typhoon "Hagupit", No. 0604 Typhoon "Bilis," No. 0606 Typhoon "Pipian" and No. 1409 Typhoon "Rammasun". The largest disaster was No. 0814 Typhoon "Hagupit," which affected 6.65 million people.

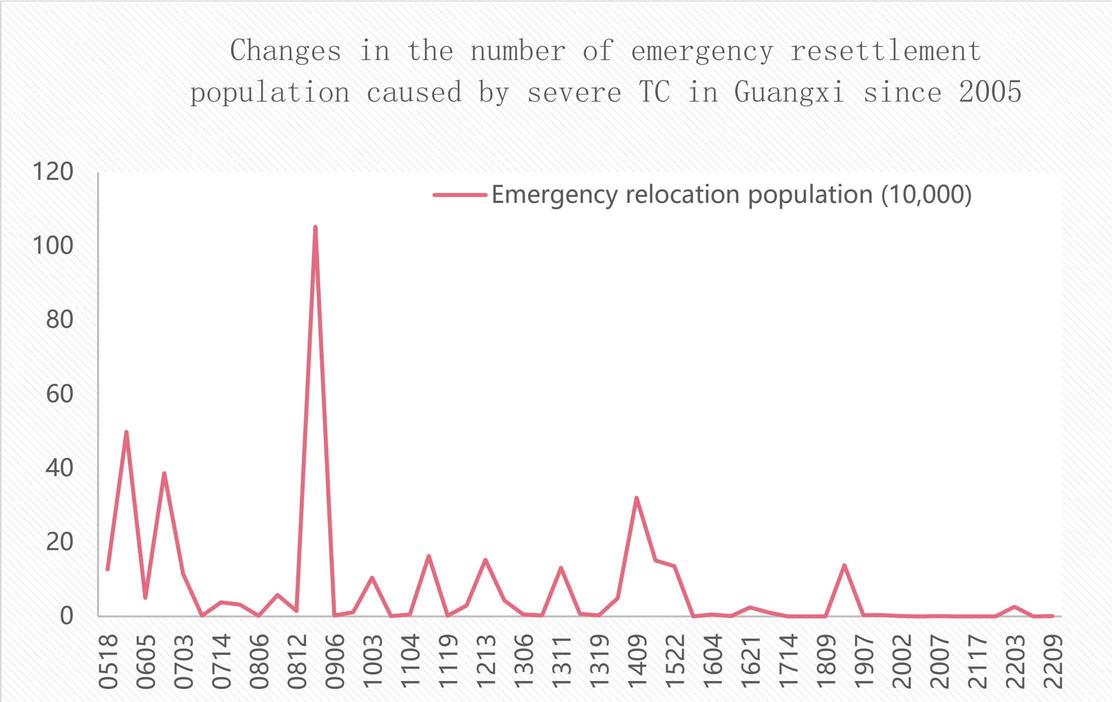

Figure 20 Changes in the number of emergency resettlement population caused by severe TC in Guangxi since 2005

As can be seen from Fig. 20, the severe TCD in Guangxi since 2005 resulted in a significant difference in the number of emergency resettlement population. The most serious was No. 0814 Typhoon “Hagupit”, which caused 1.053 million people to be relocated, causing heavy losses to the people of Guangxi.

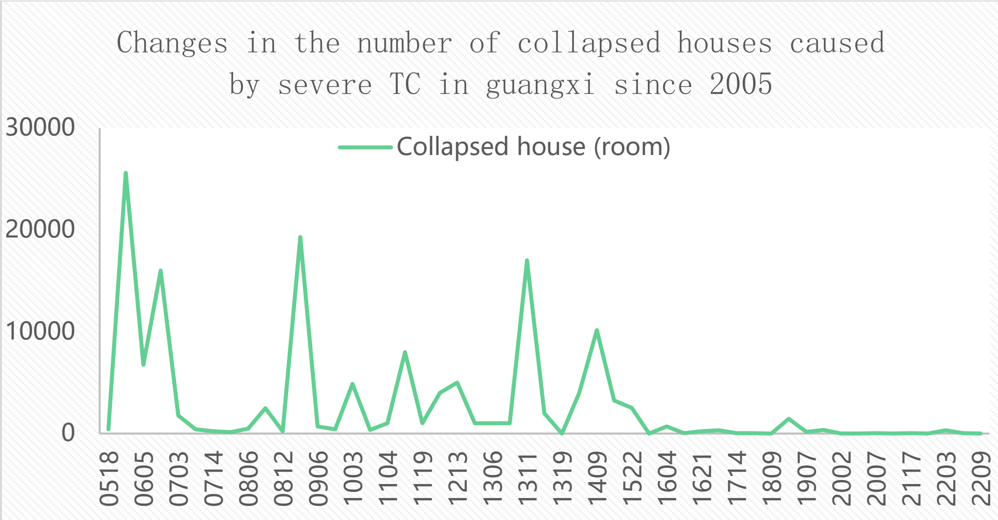

Figure 21Changes in the number of collapsed houses caused by severe TC in Guangxi since 2005

As can be seen from Fig. 21, the number of collapsed houses in Guangxi caused by severe TCD since 2005 has changed greatly, and the overall trend is gradually decreasing. In particular, the number of collapsed houses in Guangxi suffered from severe TCD after 2015 has been very small. This also reflects that the housing quality and living standards of Guangxi people have been greatly improved, and the number of dilapidated houses has been greatly reduced. The poverty alleviation and relief work carried out by the state has brought huge benefits to a large number of poor rural households.

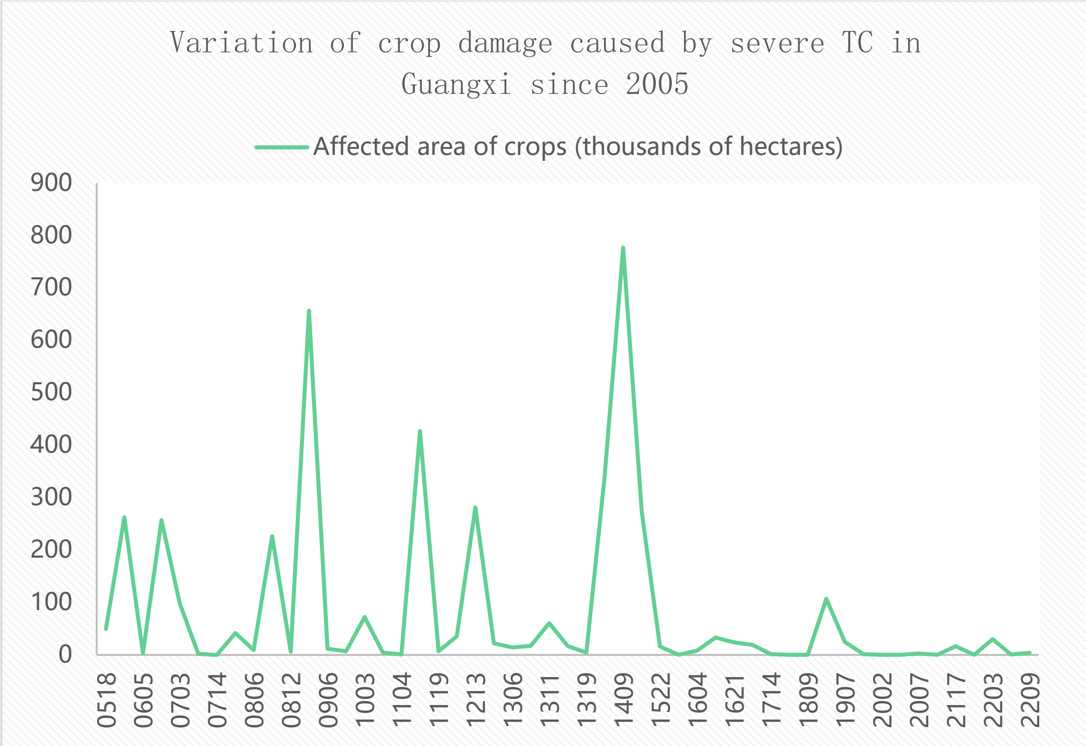

Figure 22 Variation of crop damage caused by severe TC in Guangxi since 2005

As can be seen from Fig. 22, the areas of crops affected by severe TC in Guangxi since 2005 vary greatly. The most serious one was No. 1409 Typhoon "Rammasun", which affected 777.3 thousand hectares of crops. A large number of grain crops failed to harvest or reduced production, causing serious economic losses to farmers.

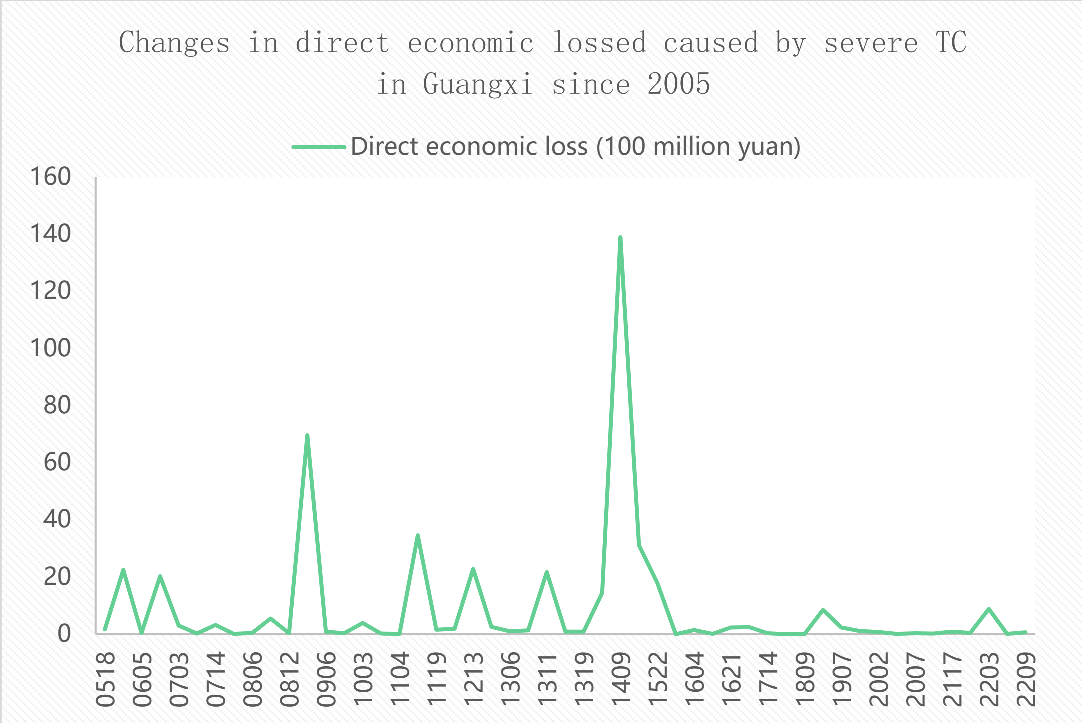

Figure 23 Changes in direct economic losses caused by severe TC in Guangxi since 2005

As can be seen from Fig. 23, the direct economic losses caused by severe TC in Guangxi since 2005 are related to huge. The most serious is No. 1409 Typhoon “Rammasun” caused a total of 13,898.63 million yuan of direct economic losses.

2. Developing a RPMES for TCD in Guangxi

2.1 Information and major disasters of severe TC in Guangxi

Stockpiling, procurement and distribution of relief materials based on the number of people displaced in emergency situations as a result of each disaster. According to the measures for natural disaster relief in Guangxi issued by the Emergency Management Department of Guangxi, the Requirements prediction of ES for TCD in Guangxi mainly refers to the number of urgently relocated people. Therefore, this paper selects the data of 51 severe TCD suffered by Guangxi from 2005 to 2022 as the basis for collecting the data on the emergency relocation and resettlement population caused by these 51 severe TCDs. In addition, the maximum wind speed of 51 typhoons when they entered Guangxi, the duration of disaster impact in Guangxi, the number of collapsed houses, direct economic losses and other factors related to the emergency relocation and resettlement of population were analyzed, and the multiple regression method was used to construct the RPMES for TCD in Guangxi. Detailed TCD information and major disaster data are shown in Table 15.

Table 15 Information and major disasters of severe TC in Guangxi since 2005

No.	TC No.	emergency relocation and resettlement population (10,000)	Maximum central wind speed extremum during Guangxi (m/s)	Duration of impact on Guangxi (hours)	Collapsed house (room)	Affected area of crops (thousands of hectares)
1	0518	12.7	20	17	403	1.6
2	0604	49.9	10	48	25600	22.5
3	0605	5.033	10	56	6770	0.3859
4	0606	38.7	25	38	16000	20.3
5	0703	11.458	23	17	1763	3.01
6	0709	0.1644	10	60	407	0.15462
7	0714	3.8	20	101	239	3.23
8	0715	3.2	10	48	147	0.132
9	0806	0.2	25	78	470	0.45
10	0809	5.8	18	26	2480	5.49
11	0812	1.5	25	54	220	0.297
12	0814	105.3	30	24	19300	69.7
13	0906	0.22	18	6	700	0.89
14	0915	1.12	23	12	400	0.27
15	1003	10.46	30	24	4880	3.9
16	1011	0.13	20	40	360	0.17
17	1104	0.5	8	22	1000	0.1
18	1117	16.3	8	36	8000	34.6
19	1119	0.2	8	16	1000	1.5
20	1208	2.9	13	38	4000	1.9

No.	TC No.	emergency relocation and resettlement population (10,000)	Maximum central wind speed extremum during Guangxi (m/s)	Duration of impact on Guangxi (hours)	Collapsed house (room)	Affected area of crops (thousands of hectares)
21	1213	15.3	30	48	5000	22.8
22	1223	4.3	30	60	1000	2.6
23	1306	0.5	26	18	1000	1
24	1309	0.3	15	10	1000	1.3
25	1311	13.1	25	108	17000	21.7
26	1312	0.7	10	24	2000	0.9
27	1319	0.3	10	54	0	0.9
28	1330	4.9	28	28	4000	14.4
29	1409	32.0261	50	33	10167	138.9863
30	1415	15.1265	42	24	3258	31.0844
31	1522	13.5448	42	54	2518	17.9591
32	1603	0	10	24	0	0.01
33	1604	0.5	10	39	700	1.4
34	1608	0.0476	8	20	47	0.0997
35	1621	2.4627	20	26	221	2.3284
36	1713	1.0455	23	48	320	2.467
37	1714	0.027	22	20	54	0.2609
38	1720	0.0084	8	8	24	0.0241
39	1809	0	11	26	0	0.0051
40	1822	13.791	38	24	1451	8.5052
41	1907	0.3522	23	52	154	2.3498
42	1911	0.3223	6	19	352	1.0399
43	2002	0.1204	8	24	1	0.7632
44	2003	0.0308	10	48	4	0.037
45	2007	0.1036	25	16	46	0.3222
46	2107	0.002	15	18	1	0.1544
47	2117	0.0212	10	24	46	0.8362
48	2118	0	15	30	10	0.399
49	2203	2.579	20	34	321	8.8678
50	2207	0.0032	20	22	25	0.09677
51	2209	0.1059	25	8	11	0.6285

2.2 Developing RPMES for TCD in Guangxi

This paper uses MLRM to develop RPMES for TCD in Guangxi. The emergency relocation and resettlement population in Table 4-4 was selected as the dependent variable, and four factors; including the maximum wind speed when the typhoon entered Guangxi, the length of disaster impact in Guangxi, the number of collapsed houses and direct economic losses, were selected as independent variables. Matlab mapping and calculation were used to construct the multiple linear regression prediction model.

2.2.1 Make the sample scatter diagram of dependent variable Y and their variables

The purpose of the scatter chart is to observe whether there is a good linear relationship between the dependent variable y, the emergency relocation and resettlement population, and the four independent variables, the maximum wind speed x1 when the typhoon enters Guangxi, the length of time x2 when it causes disaster in Guangxi, the number of collapsed houses x3, and the direct economic loss x4, so as to select an appropriate mathematical model form. Fig. 4-8 shows the scatter plot between the dependent variable emergency relocation and resettlement population y and the independent variable maximum wind speed x1 when the typhoon entered Guangxi. Fig. 4-9 shows the scatter plot between y, the dependent variable, and x2, the time length of disaster impact caused by the independent variable in Guangxi. Fig. 4-10 shows the scatter plot between y, the dependent variable, and x3, the number of collapsed houses. Fig. 4-11 shows the scatter plot between the dependent variable emergency relocation and resettlement population y and the independent variable direct economic loss x4.

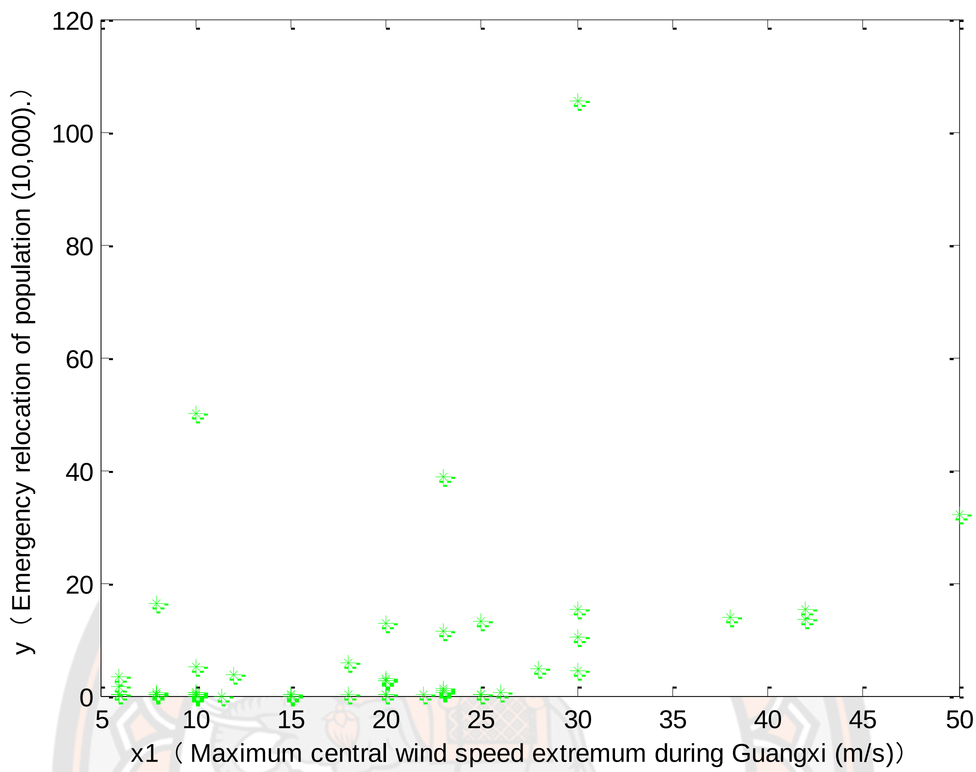

Figure 24 Sample scatter plots of dependent variable emergency relocation and resettlement population y and independent variable maximum wind speed x1 when the typhoon entered Guangxi

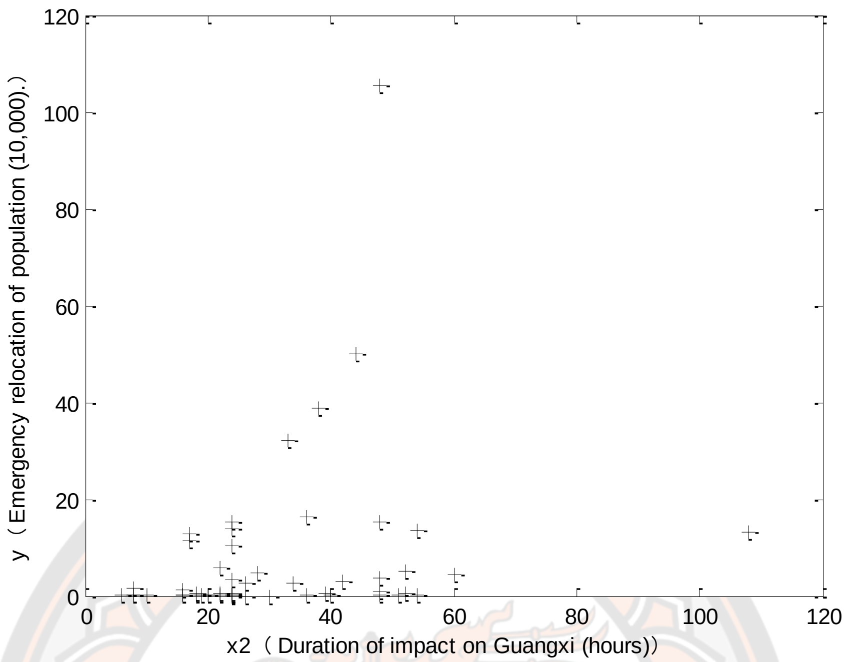

Figure 25 Sample scatter plots of dependent variable emergency relocation and resettlement population y and the time length x2 of disaster impact in Guangxi

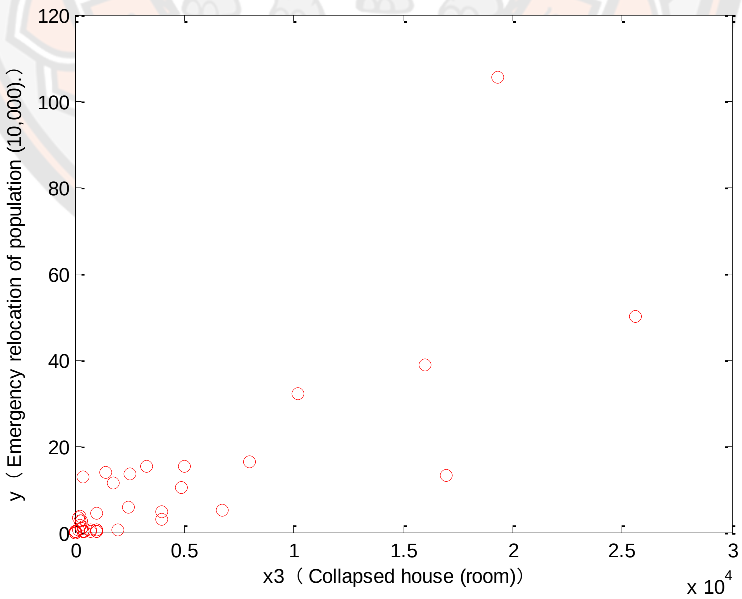

Figure 26 Sample scatter plots of dependent variable emergency relocation and resettlement population y and independent variable number of collapsed houses x3

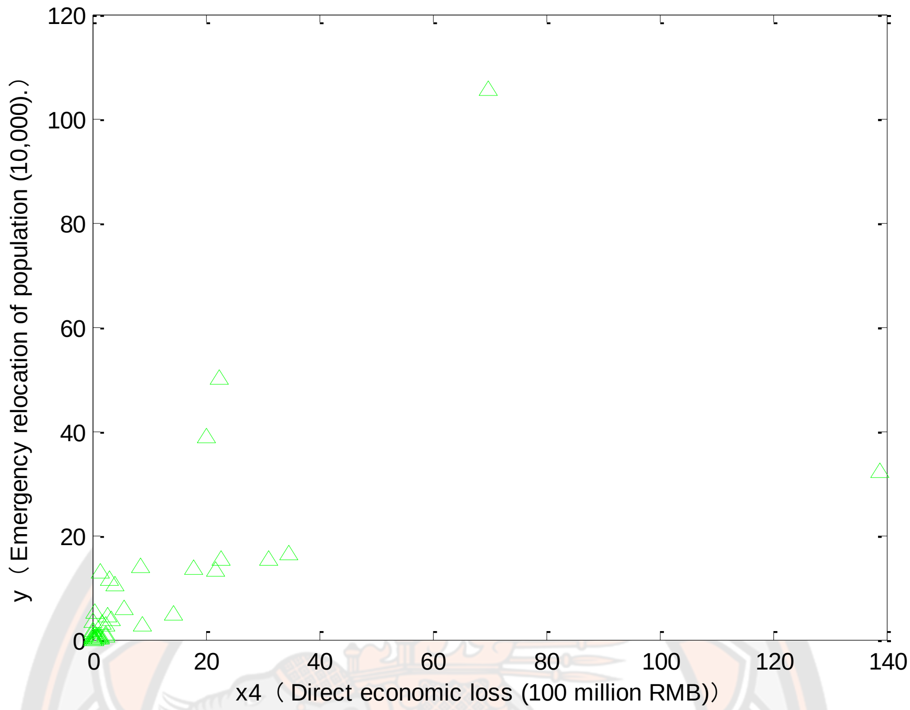

Figure 27 Sample scatter plots of dependent variable emergency relocation and resettlement population y and independent variable direct economic loss x4

2.2.2 Developing and optimizing RPMES for TCD in Guangxi based on MLRM

As can be seen from the scatter plot of the dependent variable y and the 4 independent variables, there is a certain linear relationship between the dependent variable y and the 4 independent variables. The multiple linear regression function regress can be directly used to calculate the initial calculation results, as shown in Table 16, and the residual figure of the initial calculation is shown in Fig. 28

Table 16 Initial calculation results of RPMES for TCD in Guangxi based on MLRM

Regression coefficient	The estimate of the regression system	Confidence interval for the regression coefficient
b0	1.4683	[-5.5654, 8.5019]
b1	0.1302	[-0.1770, 0.4375]
b2	-0.1388	[-0.3048, 0.0273]
b3	0.0023	[0.0017, 0.0030]
b4	0.1702	[0.0001, 0.3402]

Notes: R^2=0.7353, F=31.9475, p< 0.0001, s^2= 85.9095

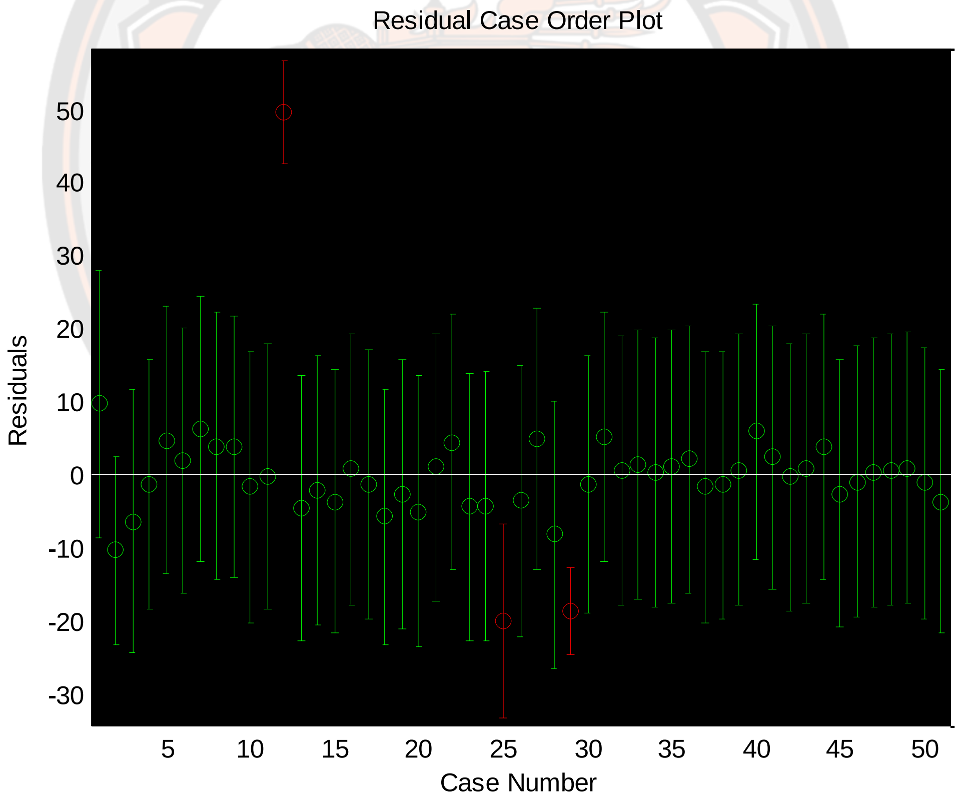

Figure 28 Residuals for initial calculation

It can be seen in Fig. 28 that points 12, 25, and 29 are outliers. Therefore, the above three points are deleted and optimized, and the coefficients, confidence intervals, and statistics of the regression model after improvement are shown in Table 17. The residual figure after improvement is shown in Fig. 29.

Table 17 Improved calculation results of RPMES for TCD in Guangxi based on MLRM

Regression coefficient	The estimate of the regression system	Confidence interval for the regression coefficient
b0	-1.4502	[-4.1251, 1.2247]
b1	0.1556	[0.0453, 0.2658]
b2	-0.0256	[-0.0926, 0.0413]
b3	0.0018	[0.0015, 0.0021]
b4	0.1777	[0.0160, 0.3394]

Notes: R^2=0.9032, F=100.3109, p< 0.0001, s^2= 9.9897

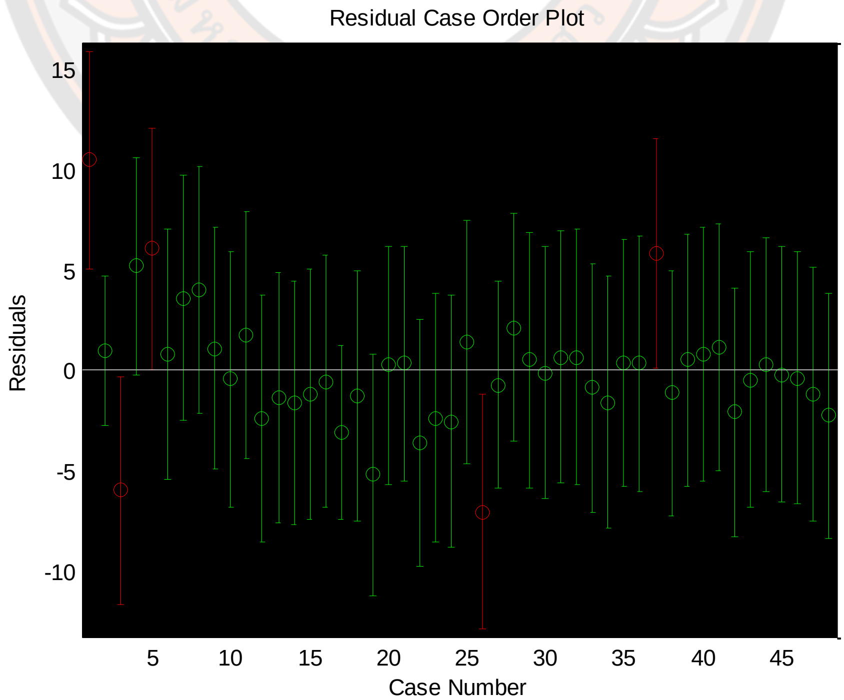

Figure 29 Residual calculation after improvement

It can be seen from Fig. 29 that points 1, 3, 5, 26 and 37 are outliers. Therefore, the above 5 points are deleted to optimize them, and the coefficients, confidence intervals and statistics of the optimized regression model are shown in Table 18.

Table 18 Optimized calculation results of RPMES for TCD in Guangxi based on MLRM

Regression coefficient	The estimate of the regression system	Confidence interval for the regression coefficient
b0	-2.0356	[-3.6593, -0.4118]
b1	0.0947	[0.0240, 0.1655]
b2	0.0170	[-0.0251, 0.0591]
b3	0.0018	[0.0017, 0.0020]
b4	0.1907	[0.0909, 0.2906]

Notes: R^2=0.9684, F=290.8963, p< 0.0001, s^2= 3.5355

In summary, the optimized regression equation can be written as follows:

$$y = -2.0356 + 0.0947x_1 + 0.0170x_2 + 0.0018x_3 + 0.1907x_4$$

Judgment of the model based on the results:

Evaluation of correlation coefficient R: According to the calculation results R^2=0.9684, and can calculated the absolute value of R is 0.9841, which is much optimized compared with the initial calculated value of 0.8575 in Table 4-5, indicating a strong linear correlation between the dependent variable y of emergency relocation and resettlement and the four independent variables.

F test: the above calculation result F = 290.8963 > $F_{1-0.05}(4,38)$=2.6190, indicating that there is a significant linear correlation between the dependent variable y and the four independent variables.

p-value test: the above calculation results p < 0.0001, which obviously satisfies p < α=0.05, indicating that there is a significant linear correlation between the dependent variable y and the four independent variables.

The inferred results of the above three statistical methods are consistent, indicating a significant linear correlation between the dependent variable y and the four independent variables, and the obtained linear regression model can be used. After optimization, the residual variance s^2 = 3.5355, compared with the initially calculated residual variance s^2 = 85.9095, the accuracy is much improved, indicating that the optimized regression equation model has higher accuracy.

2.2.3 Application of TCD RPMES

In the future, when TCD comes, governments at all levels can obtain the four independent variable parameter values in RPMES, and then substitute the obtained four independent variable data into RPMES, so as to predict the number of emergency resettlement population caused by TCD. Then, according to the predicted number of emergency relocation and resettlement population multiplied by the per capita standard of emergency supplies formulated by governments at all levels, the required demand for emergency supplies can be obtained. Governments at all levels shall collect and purchase emergency materials according to the calculated demand for emergency materials. This can greatly improve the effectiveness of governments at all levels to deal with TCD relief.

3. Developing an LMESRC for TCD in Guangxi

3.1 TCD data statistics and ES requirements analysis of prefecture-level cities in Guangxi over the past years

Based on the investigation of the Emergency Management Department of Guangxi, data on 16 severe TCD suffered by Guangxi from 2014 to 2021 were collected. And the number of people in need of emergency relocation and resettlement in 14 prefecture-level cities in Guangxi was selected as the calculation basis of ES requirements. In order to simplify the identification, the 14 prefecture-level cities in Guangxi and their corresponding prefecture-level city ES reserves are represented by letters A ~ N, as shown in Table 19. The detailed data of TCD in each prefecture-level city during 2014-2021 are shown in Table 20.

Table 19 Numbers of 14 prefecture-level cities in Guangxi and ES storage warehouses of each prefecture

No.	Prefecture-level city	Prefecture-level City ES Reserve
A	Nanning	Nanning Food and Strategic Reserves Bureau
B	Beihai	Beihai Food and Strategic Reserves Bureau
C	Qinzhou	Qinzhou Grain and Strategic Reserves Bureau
D	Fangchenggang	Fangchenggang Food and Strategic Reserves Bureau
E	Yulin	Yulin Food and Strategic Reserves Bureau
F	Chongzuo	Chongzuo Grain and Strategic Reserves Bureau
G	Wuzhou	Wuzhou Grain and Strategic Reserves Bureau
H	Hezhou	Hezhou Grain and Strategic Reserves Bureau
I	Liuzhou	Liuzhou Disaster Preparedness Center
J	Guilin	Guilin Grain and Strategic Reserves Bureau
K	Laibin	Laibin Food and Strategic Reserves Bureau
L	Guigang	Guigang Food and Strategic Reserves Bureau
M	Baise	Baise Food and Strategic Reserves Bureau
N	Hechi	Hechi Food and Strategic Reserves Bureau

Data source: Statistics from the Emergency Management Department of Guangxi.

Table 20 Previous severe TCD suffered by 14 prefecture-level cities in Guangxi from 2014 to 2021

No.	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1409	2980	88017	90650	85654	15076	31333	5039	0	0	0	20	0	1420	72
1415	3064	28200	67070	29703	10483	11186	0	0	0	0	4	150	1405	0
1522	95	20879	25304	0	53469	0	2892	3425	0	14381	1877	13126	0	0
1608	0	57	0	419	0	0	0	0	0	0	0	0	0	0
1621	52	9056	6544	8970	0	5	0	0	0	0	0	0	0	0
1713	1315	0	2305	1736	0	143	2765	0	0	0	0	2162	0	0
1714	97	0	0	0	0	0	119	0	0	0	0	0	54	0
1720	75	9	0	0	0	0	0	0	0	0	0	0	0	0
1822	23978	17353	19683	5027	47842	8859	4895	6	0	3544	2082	4641	0	0
1907	0	1035	0	1285	0	1202	0	0	0	0	0	0	0	0
1911	15	0	0	0	3159	0	0	17	0	0	32	0	0	0
2002	0	0	0	1204	0	0	0	0	0	0	0	0	0	0
2003	0	13	0	200	0	0	0	0	0	0	0	0	0	95
2007	0	0	0	0	0	0	313	0	0	0	17	28	225	453
2107	15	5	0	0	0	0	0	0	0	0	0	0	0	0
2117	0	39	0	39	0	51	0	0	0	0	0	0	72	11
Total（person）	31686	164663	211556	134237	130029	52779	16023	3448	0	17925	4032	20107	3176	631

Data source: Statistics from the Emergency Management Department of Guangxi.

According to a circular on natural disaster relief subsidies issued by the Guangxi government, the maximum time for the autonomous region's financial assistance to people in need of emergency relocation and resettlement should not exceed 10 days. ES shall be arranged according to the maximum rescue time of 10 days. All kinds of ES (including food, drinking water, tents, etc.) needed for emergency transfer and resettlement of the people shall be converted into 1kg per person per day. See Table 20 for the amount and proportion of various ES needed by prefecture-level cities' emergency relocation and resettlement population. Other disaster losses can be saved through cash subsidies.

Table 21 Proportion of ES requirements affected by TC in prefecture-level cities of Guangxi from 2014 to 2021

City No.	Number of population relocated and resettled in emergency (persons)	Demand for ES (tons)	Proportion of demand for disaster and ES (%)	Accumulated proportion of demand for disaster and ES (%)
C	211556	2115.56	26.77	26.77
B	164663	1646.63	20.84	47.61
D	134237	1342.37	16.99	64.59
E	130029	1300.29	16.45	81.04
F	52779	527.79	6.68	87.72
A	31686	316.86	4.01	91.73
L	20107	201.07	2.54	94.28
J	17925	179.25	2.27	96.54
G	16023	160.23	2.03	98.57
K	4032	40.32	0.51	99.08
H	3448	34.48	0.44	99.52
M	3176	31.76	0.40	99.92
N	631	6.31	0.08	100.00
I	0	0	0.00	100.00
Total	790292	7902.92	100.00	100.00

Table 21 shows the 16 severe TCD that hit Guangxi in recent 8 years. The prefecture-level cities that have suffered severe damage are Qinzhou (C), Beihai (B), and Fangchenggang (D) on the south coast of Guangxi and Yulin (E) on the southeast of Guangxi. Chongzuo (F) and Nanning (A) are the second most seriously damaged areas. In the above six prefecture-level cities in Guangxi Beibu Gulf Economic Zone, the proportion of the population and ES needing emergency relocation exceeds 91%. Other prefecture-level cities in western, northern, central, and northeastern Guangxi were relatively lightly affected, especially Liuzhou (I) in central and northern Guangxi, which was least affected by TC in the past eight years and did not require emergency relocation and resettlement of population.

3.2 Location coordinates of prefecture-level cities in Guangxi

Through the investigation of the Emergency Management Department of Guangxi, information on disaster relief material reserve repositories of prefecture-level cities in Guangxi was obtained. The latitude and longitude coordinates of the addresses of the ES reserve repositories of 14 prefecture-level cities in Guangxi (generally located in the same place as the Food and Strategic Reserves Bureau) were queried by using Baidu Map and Tiandi Map (National Geographic Information Public Service Platform). Detailed data are shown in Table 22.

Table 22 Longitude and latitude coordinates of the addresses of 14 prefecture-level cities in Guangxi

ES reserve warehouse No.	Address of ES reserve warehouse	Longitude coordinate (x)	Latitude coordinate (y)
A	No.62, Xinyang Road, Xixiang Tang District, Nanning	108.30	22.82
B	No.76, New Road, Dijiao Middle Street, Beihai	109.08	21.48
C	140 meters north of the intersection of Qinzhou Bay Avenue and Xihuan North Road, Qinbei District, Qinzhou	108.63	21.99
D	Dongxing Avenue SLATE field, Gangkou District, Fangchenggang	108.37	21.66
E	449 Renmin East Road, Yuzhou District, Yulin	110.16	22.64
F	3 Xinmin Road, Jiangzhou District, Chongzuo	107.35	22.41
G	No. 2 Tongyuan, Dongzheng Road, Wanxiu District, Wuzhou	111.30	23.49
H	266 Pingan West Road, Palbu District, Hezhou	111.56	24.40

ES reserve warehouse No.	Address of ES reserve warehouse	Longitude coordinate (x)	Latitude coordinate (y)
I	1 Hangsi Road, Liannan District, Liuzhou	109.39	24.27
J	Hongmou Avenue, Lingui District, Guilin	110.18	25.24
K	82 Zhenghe Road North, Xingbin District, Laibin	109.22	23.75
L	12 Gangcheng Road, Gangbei District, Guigang	109.59	23.10
M	15 Xinxing Road, Youjiang District, Baise	106.61	23.90
N	71 Jiangnan East Road, Jinchengjiang District, Hechi	108.08	24.69

Data source: (1) Statistics from the Emergency Management Department of Guangxi.
(2) Baidu Map and Tiandi Map (National Geographic Information Public Service Platform).

3.3 Developing an LMESRC in prefecture-level cities of Guangxi

According to the standard of China's road freight rate of 0.35 yuan/ton • km, it is assumed that the road freight rate between all nodes is 0.35 yuan/ton • km. The initial model obtained by matching the data in Table 4-11 to the map of Guangxi is shown in Fig. 30

Figure 30 Initial location model of TCD ESRC in 14 prefecture-level cities of Guangxi

Data source: Baidu Map and Tiandi Map (National Geographic Information Public Service Platform).

Data can be put in Table 4-10 and Table 4-11 to generate the Eq. (3-3) get S^0 coordinates the (x^0, y^0) of (108.95, 22.16) (Tiandi Map find these coordinates located in Qinzhou Lingshan county near the home town of Luwu Yannian). Baidu map is used to query the distance d_i^1 of the shortest line between the initial coordinate S^0 (x^0, y^0) and the Emergency Management Bureau of 14 prefecture-level cities in Guangxi, and the distance data is shown in Table 23.

Table 23 Distance d_i^1 from the initial site selection point (x^0, y^0) to the Emergency Management Bureau of 14 prefecture-level cities in Guangxi

ES reserve warehouse No.	Longitude coordinate (x)	Latitude coordinate (y)	d_i^1
A	108.30	22.82	143.2
B	109.08	21.48	152.9
C	108.63	21.99	57.1
D	108.37	21.66	119.4
E	110.16	22.64	211.5
F	107.35	22.41	219.1
G	111.30	23.49	409.0
H	111.56	24.40	500.9
I	109.39	24.27	276.2
J	110.18	25.24	416.6
K	109.22	23.75	209.6
L	109.59	23.10	191.9
M	106.61	23.90	359.4
N	108.08	24.69	374.8

Substitute d_i^1 that obtained from Table 4-12 into Eq. (3-4), and the coordinates of S^1 (x^1, y^1) are (108.77, 22.01) (Tiandi Map find these coordinates are located at the Tongtian Candle near Naqing Primary School, Qinbei District, Qinzhou). Baidu map was used to query the distance of the shortest route between the first iteration coordinate S^1 (x^1, y^1) and the ES reserve repositories of 14 prefecture-level cities in Guangxi (usually the grain and reserve bureau of each city). After successive iterations, d_i^2 that obtained from Table 4-13 is substituted into Eq. (3-4), and the coordinates of S^2 (x^2, y^2) are (108.70, 21.98) (according to the map of Tiandi Map, this coordinate is located in Ma Taoxu near Qinzhou East Railway Station, Qinbei District, Qinzhou). Baidu Map is used to query the distance d_i^3 of the shortest route between the second iteration coordinate S^2 (x^2, y^2) and the 14 prefecture-level city ES reserve repositories in Guangxi (usually the food and reserve bureau of each city). And d_i^3 that obtained from Table 4-13 is substituted into Eq. (3-4). The coordinates of S^3 (x^3, y^3) are (108.68, 21.97) (according to Tiandi Map, this coordinate is located near Evergrande Luzhou Community beside Qinzhou East Railway Station, Qinnan District, Qinzhou). Baidu Map is used to query the distance of the shortest route d_i^4 between the third iteration coordinate S^3 (x^3, y^3) and the ES reserve repositories of 14 prefecture-level cities in Guangxi (usually the food and reserve bureau of each city). And substitute d_i^4 that obtained from Table 4-13 into Eq. (3-4). The coordinates of S^4 (x^4, y^4) are (108.65, 21.98) (Tiandi Map find this coordinates are located near Tiecheng Yipin, next to Qinzhou East Railway Station, Qinnan District, Qinzhou). The Baidu Map is used to query the distance of the shortest route between the fourth iteration coordinate S^4 (x^4, y^4) and the ES reserve of 14 prefecture-level cities in Guangxi (usually the grain and reserve of each city). And d_i^5 that obtained from Table 4-13 is substituted into Eq. (3-4). The coordinates of S^5 (x^5, y^5) are (108.64, 21.98) (according to Tiandi Map, this coordinate is located near Liuwu Village beside Qinzhou East Railway Station, Qinnan District, Qinzhou). The coordinates and distances of the four iterations are shown in Table 24.

Table 24 The distance between the coordinates of four iterations and the ESRC of 14 prefecture-level cities in Guangxi

ES reserve warehouse No.	Longitude coordinate (x)	Latitude coordinate (y)	(x^1, y^1) S¹（108.77, 22.01） d_i^2	(x^2, y^2) S²（108.70, 21.98） d_i^3	(x^3, y^3) S³（108.68, 21.97） d_i^4	(x^4, y^4) S⁴（108.65, 21.98） d_i^5
A	108.30	22.82	159.6	139.7	129.1	127.2
B	109.08	21.48	126.9	119.2	117.5	120.8
C	108.63	21.99	24.1	17.5	8.4	5.6
D	108.37	21.66	93.4	73.4	62.9	60.4
E	110.16	22.64	241.3	238.5	238.0	244.5
F	107.35	22.41	194.6	181.2	173.8	171.3
G	111.30	23.49	440.7	431.1	430.6	435.4
H	111.56	24.40	532.5	529.7	529.2	534.0
I	109.39	24.27	306.1	303.3	302.8	307.6
J	110.18	25.24	447.1	444.3	443.8	448.5
K	109.22	23.75	240.1	236.7	236.2	240.1
L	109.59	23.10	221.7	218.6	218.4	223.3
M	106.61	23.90	376.6	341.3	346.1	343.6
N	108.08	24.69	388.7	353.6	358.1	355.6

After 4 iterations, it is found that the relatively best location coordinates $S^2(x^2, y^2)$, $S^3(x^3, y^3)$, $S^4(x^4, y^4)$ and $S^5(x^5, y^5)$ of Guangxi TCD ESRC are all located near Qinzhou East Railway Station, Qinnan District, Qinzhou (also near ES Reserve C). The obtained coordinates are relatively close, and the distance between them and Qinzhou East Railway Station is within 3km. Therefore, it can be determined that the most suitable location for Guangxi TCD ESRC is within 3km of Qinzhou East Railway Station.

The coordinates of the initial site selection point and the coordinate data obtained from the four iterations in Table 2 are matched to the map of Guangxi to obtain the best location of the Guangxi TCD ESRC, as shown in Fig. 4-15.

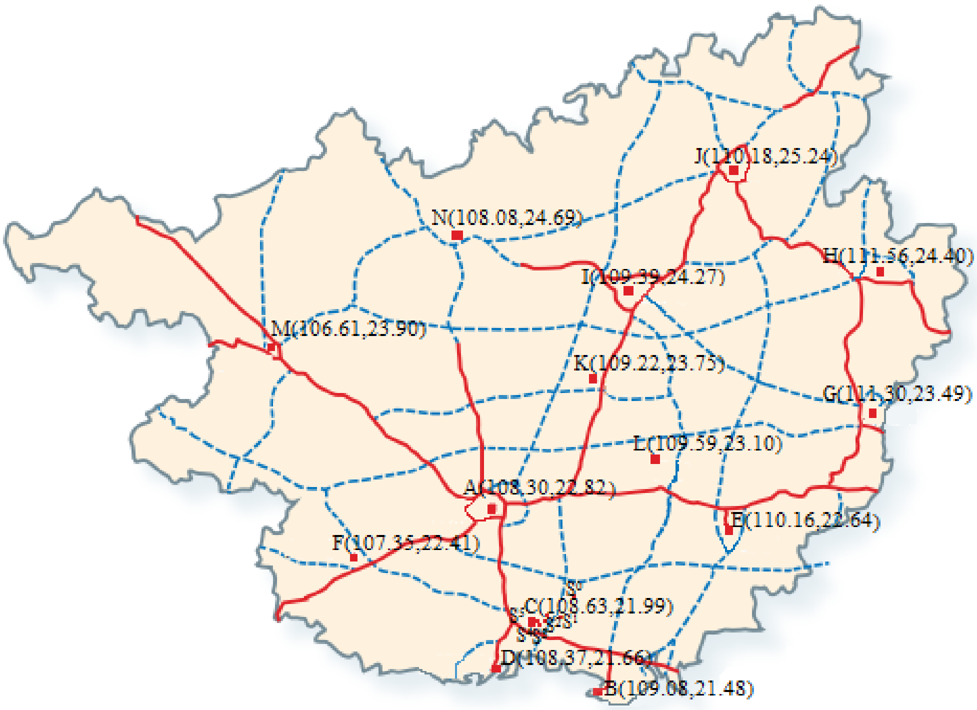

Figure 31 Optimal scheme of location selection model for TCD ESRC in 14 prefecture-level cities of Guangxi

Data source: Baidu Map and Tiandi Map (National Geographic Information Public Service Platform).

4. Developing an ESDM for TCD in Guangxi

4.1 Developing an ESDM for TCD in Guangxi based on the LP method

Each TC will have different impacts on different cities in Guangxi, and the severity of the disaster varies from region to region. However, the methods and models for ESD are the same. Super typhoon No. 1409 "Rammasun" was selected as an example to develop an ESDM for TCD based on the LP method.

4.1.1 The disaster situation in the main disaster areas, the demand and reserve of ES

According to the statistical yearbook 2014 for TC data, super typhoon No. 1409 "Rammasun" has caused a serious loss to Guangxi. The main disaster area ranging from Beihai, Qinzhou, Fangchenggang, Yulin, Nanning, Chongzuo, Wuzhou and other seven cities as 47 units at the county level, within the scope of the jurisdiction of the affected population of 4.33 million people, 10 deaths, emergency relocation and resettlement population of 320000 people, the affected area of 777300 hectares of crops, crop lost area of 40400 hectares, 10000 houses collapsed, the direct economic loss of 13.9 billion RMB yuan.

According to the survey statistics data of the affected population caused by super typhoon No. 1409 "Rammasun" from the Emergency Management Department of Guangxi, selecting the need for emergency relocation and resettlement population of more than 1000 units at the county level as the research object. A total of 24 units at the county level are in need of urgent to relocate a population of more than 1000 people. And the 24 units at the county level belong to Nanning, Qinzhou, Beihai, Fangchenggang, Chongzuo, Yulin, and Wuzhou. The rest of the affected less the number of units at the county level are not counted. The specific node number of each provincial, prefecture-level, and county-level unit and the number of people affected at each node are shown in Table 4-14.

According to the notice on adjusting the subsidy standard for natural disaster relief issued by the Department of Civil Affairs and The Department of Finance of Guangxi, the subsidy standard for people in need of emergency living assistance shall be no more than 400 RMB yuan per person, and the longest period of assistance shall not exceed 10 days. The actual subsidy shall be calculated as 10 days. Each person receiving transitional assistance will receive a subsidy of 25 RMB yuan per day for a period not exceeding 3 months, and the actual subsidy will be calculated on the basis of 90 days in 3 months. All kinds of ES, such as food, drinking water, and the peripherals, convert 1 kg per person per day, according to the standard to calculate all kinds of ES requirements quantity, for the convenience of calculation, results are rounded. ES around the demand quantity as shown in Table 4-14, other aid, according to the standard of relief in the form of cash to the affected people.

Table 25 Disasters, demand and reserve ES caused by "Rammasun" in Guangxi

Number of disaster units	Name of disaster units	Affected population (person)	Emergency resettlement of population (person)	Population in need of emergency assistance (person)	Population in need of transitional assistance (person)	Total demand of ES (ton)	Quantity of ES in reserve (ton)
1	Guangxi	3351465	314190	192430	27450	4395	3514
2	Nanning city	34041	1805	1499	186	32	20
11	LiangQing district	34041	1805	1499	186	32	0
3	Qinzhou city	1252020	90650	35088	4386	745	100
12	Qinbei district	392000	24243	9756	619	153	24
13	Qinnan district	389583	47843	15110	1891	321	20
14	Lingshan county	399600	11316	6650	103	76	8
15	Pubei county	70837	7248	3572	1773	195	12
4	Beihai city	530391	88017	71330	5536	1212	160
16	Haicheng district	135000	12850	11830	672	179	40
17	Yinhai district	94500	23000	18000	652	239	26
18	Tieshanggang district	90000	16000	11000	412	147	20
19	Hepu county	210891	36167	30500	3800	647	35
5	Fangchengang city	614584	85654	74995	12905	1911	120
20	Dongxing city	26000	5800	1355	355	46	10
21	Shangshi county	106000	18487	40000	8961	1206	25
22	Gangkou district	156084	30557	21830	1763	377	30
23	Fangchen district	326500	30810	11810	1826	282	20
6	Chongzhuo city	693314	30658	3982	2447	260	50
24	Longzhou county	61555	9175	690	270	31	10
25	Pingxiang city	43165	1640	732	2134	199	20
26	Ningming county	231670	14587	977	0	10	2
27	Fusui county	231430	2401	0	43	4	1
28	Jiangzhou district	125494	2855	1583	0	16	5
7	Yulin city	198697	13146	3992	1264	154	40
29	Fuming district	26516	2657	326	0	3	1
30	Luchuan county	15000	1520	312	0	3	1
31	Bobai county	136641	6891	3004	1264	144	35
32	Yuzhou district	20540	2078	350	0	4	2
8	Wuzhou city	28418	4260	1544	726	81	20
33	CenXi city	16789	1713	782	341	39	10
34	Cangwu county	11629	2547	762	385	42	14

Data source: Statistics from the Emergency Management Department of Guangxi.

4.1.2 The distance between ES storage warehouses at all levels and the unit price of transportation

The ESD in Guangxi adopts the three-level management mode of provincial level, prefecture level city and county. There is one disaster preparedness center in Guangxi at the provincial level, one main ES reserve warehouse in each prefecture level city, and one ES reserve warehouse in each county level unit. See Table 4-14 for the amount of ES stored in the ES reserve warehouses at all levels. Through traffic and Baidu map query to Guangxi provincial ESRC of the Guangxi disaster preparedness center with the affected the distance between prefecture and county units, and each affected under the jurisdiction of the prefecture level and the distance between the county units, and in accordance with the highway cargo tariff of the People's Republic of China highway freight unit price is 0.35 RMB yuan/ton•km, multiplied by the distance between the around with highway freight unit price between freight unit price, for the convenience of calculating all freight unit price is rounded. The specific calculation results are shown in Table 26.

Table 26 Freight unit price between ES storage warehouses.

Number of disaster units	1	2	3	4	5	6	7	8
2	4							
3	41							
4	78							
5	47							
6	44							
7	96							
8	132							
11	3	3						
12	41		1					
13	46		5					
14	44		36					
15	58		53					
16	77			1				
17	77			1				
18	81			13				
19	68			10				

Number of disaster units	1	2	3	4	5	6	7	8
20	61				16			
21	33				37			
22	49				3			
23	46				4			
24	63					22		
25	69					28		
26	57					17		
27	24					26		
28	42					2		
29	99						3	
30	118						15	
31	106						16	
32	96						1	
33	125							29
34	126							5

Data source: Baidu Map and Tiandi Map (National Geographic Information Public Service Platform).

4.1.3 Developing an ESDM

The ESDM usually adopts the level-by-level centralized dispatching model or the unified dispatching model of the provincial emergency management center.

4.1.3.1 Level-by-level centralized dispatching model

According to the statistics on disaster relief and relief caused by super typhoon No.1409 "Rammasun" to all cities and counties in Guangxi, the provincial, municipal and county management system is usually adopted for the storage and distribution of ES in Guangxi. The Emergency Management Bureau at the county level is the management organ of the grassroots government, responsible for the implementation of disaster relief work within the county. The specific principles of ES are as follows. First, the Emergency Management Department at the county level shall provide the relief supplies needed by the victims according to the situation of the ES reserve warehouse at the county level, and the insufficient part shall be reported to the Emergency Management Department of the prefecture government. Then, the prefecture government shall make statistics on the insufficient demand for ES in each county under its jurisdiction. The prefecture ES reserve warehouse shall try to meet the shortage according to the supplies reserve. The insufficient part shall be reported to the Emergency Management Department of the provincial government. Finally, emergency management department at the provincial level statistics of various cities declare the shortage of the ES requirements, warehouse according to the materials by provincial ES reserves situation as far as possible to meet. Skimpy shares that Emergency Management Department at the provincial level shall be responsible for the centralized purchasing of all kinds of ES issued by the number of cities to declare ES.

The above analysis shows the Network diagram of the level-by-level centralized dispatching model for ES in Guangxi in Fig. 4-16.

According to Fig. 4-16 with the transshipment model of intermediate nodes, x_{ij} means from point i to point j ES carrying quantity. Such as x_{13} represents the dispatching quantity from the provincial level node 1 Disaster Preparedness Center of Guangxi to the prefecture level node 3 Qinzhou ES storage warehouse. And x_{419} represents the dispatching quantity from the prefecture level node 4 Beihai ES storage warehouse to the county level node 19 Hepu county ES storage warehouse. And the number on the line represents the freight unit price between the two nodes. And the number 3514 on the top of node 1 represents the total supply quantity of provincial level Disaster Preparedness Center. And the number on the top of nodes 2 to 8 represents the reserves in each prefecture level warehouse. And the first number on the right of node 11 to 34 represents the demand quantity of each county level warehouse, and the second number on the right of nodes 11 to 34 represents the reserves in each county level warehouse.

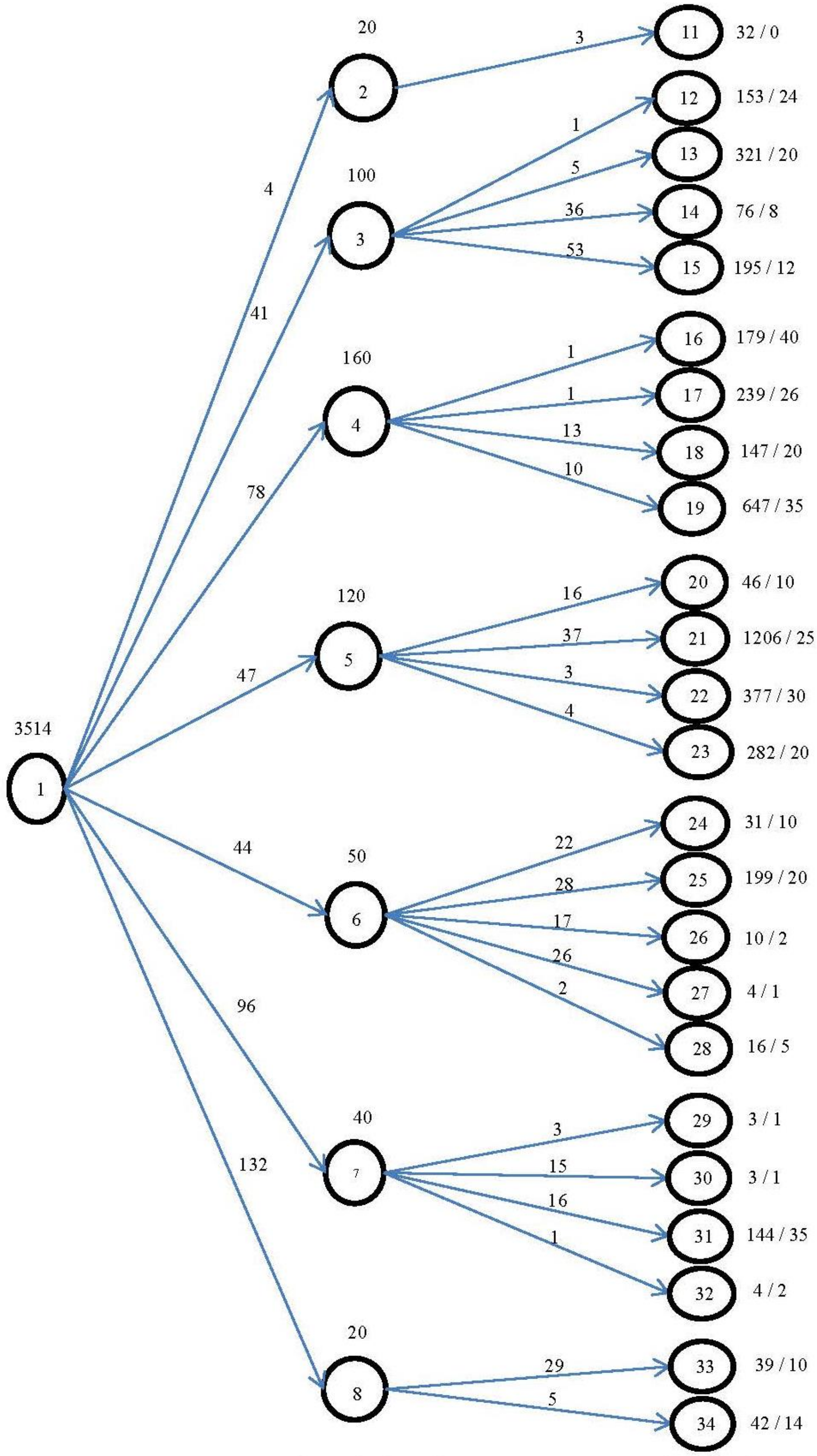

Figure 32 Network diagram of level-by-level centralized ESDM in Guangxi

The LP model to solve the level-by-level centralized ESDM in Guangxi as follows. The objective function of the minimum dispatching cost under this dispatching model is:

$$\begin{aligned}\min f_1 = & 4x_{12} + 41x_{13} + 78x_{14} + 47x_{15} + 44x_{16} + 96x_{17} + 132x_{18} + 3x_{211} + x_{312} + 5x_{313} \\ & + 36x_{314} + 53x_{315} + x_{416} + x_{417} + 13x_{418} + 10x_{419} + 16x_{520} + 37x_{521} + 3x_{522} + 4x_{523} \\ & + 22x_{624} + 28x_{625} + 17x_{626} + 26x_{627} + 2x_{628} + 3x_{729} + 15x_{730} + 16x_{731} + x_{732} \\ & + 29x_{833} + 5x_{834}\end{aligned}$$

Constraint：

$$\begin{aligned}& x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} \le 3514, \\ & x_{211} - x_{12} - 20 = 0, \\ & x_{312} + x_{313} + x_{314} + x_{315} - x_{13} - 100 = 0, \\ & x_{416} + x_{417} + x_{418} + x_{419} - x_{14} - 160 = 0, \\ & x_{520} + x_{521} + x_{522} + x_{235} - x_{15} - 120 = 0, \\ & x_{624} + x_{625} + x_{626} + x_{627} + x_{628} - x_{16} - 50 = 0, \\ & x_{729} + x_{730} + x_{731} + x_{732} - x_{17} - 40 = 0, \\ & x_{833} + x_{834} - x_{18} - 20 = 0,\end{aligned}$$

$$\begin{aligned}& x_{211} + 0 = 32, \\ & x_{312} + 24 = 153, \\ & x_{313} + 20 = 321, \\ & x_{314} + 8 = 76, \\ & x_{315} + 12 = 195, \\ & x_{416} + 40 = 179, \\ & x_{417} + 26 = 239, \\ & x_{418} + 20 = 147, \\ & x_{419} + 35 = 647, \\ & x_{520} + 10 = 46, \\ & x_{521} + 25 = 1206, \\ & x_{522} + 30 = 377, \\ & x_{523} + 20 = 282,\end{aligned}$$

$$x_{624}+10=31,$$
$$x_{625}+20=199,$$
$$x_{626}+2=10,$$
$$x_{627}+1=4,$$
$$x_{628}+5=16,$$
$$x_{729}+1=3,$$
$$x_{730}+1=3,$$
$$x_{731}+35=144,$$
$$x_{732}+2=4,$$
$$x_{833}+10=39,$$
$$x_{834}+14=42,$$
$$x_{ij}\geq 0(i=1,2,3,4,5,6,7,8;\ j=2,3,4,5,6,7,8,11,12,13,\cdots\cdots,34)$$

The calculated results are as follows:

$$x_{12}=12, x_{13}=581, x_{14}=931, x_{15}=1706, x_{16}=172, x_{17}=75, x_{18}=37,$$
$$x_{211}=32, x_{312}=129, x_{313}=301, x_{314}=68, x_{315}=183, x_{416}=139,$$
$$x_{417}=213, x_{418}=127, x_{419}=612, x_{520}=36, x_{521}=1181, x_{522}=347,$$
$$x_{523}=262, x_{624}=21, x_{625}=179, x_{626}=8, x_{627}=3, x_{628}=11, x_{729}=2,$$
$$x_{730}=2, x_{731}=109, x_{732}=2, x_{833}=29, x_{834}=28.$$

The dispatching quantity between the above nodes is substituted into the objective function to obtain the minimum dispatching cost of 272,651 RMB yuan.

4.1.2.2 Unified dispatching model of the provincial emergency management center

According to the comparison of data in Table 4-15, the freight rates of units directly supplying ES to the emergency storage warehouse at the county level of disaster areas by the provincial disaster preparedness center are lower than the unit price of the level-by-level dispatching model, which is transferred from the provincial level to the prefecture level city and then to the county level. Therefore, it is cheaper and more time efficient to change the level-by-level centralized dispatching model into the provincial disaster preparedness center to supply the ES directly to the county level emergency stores. ES stored in prefecture level cities shall also be transferred directly to ES storage warehouse at the county level within their jurisdiction. The network diagram of the unified dispatching model of provincial emergency management center for ES in Guangxi is shown in Fig. 33.

According to Fig. 4-17 with the transshipment model, the biggest difference between this model and the level-by-level dispatching model is that the provincial disaster preparedness center directly sends the ES to the disaster county level units instead of passing through the prefecture level warehouse, which greatly improves the rescue efficiency and reduces the transport cost. In this model, x_{ij} means from point i to point j ES carrying quantity. Such as x_{112} represents the dispatching quantity from the provincial level node 1 Disaster Preparedness Center to the county level node 12 Qinbei district ES storage warehouse. And x_{419} represents the dispatching quantity from the prefecture level node 4 Beihai ES storage warehouse to the county level node 19 Hepu county ES storage warehouse. And the number on the line represents the freight unit price between the two nodes. And the number 3514 on the top of node 1 represents the total supply quantity of provincial level Disaster Preparedness Center. And the number on the top of node 2 to 8 represents the reserves in each prefecture level warehouse. And the first number on the right of node 11 to 34 represents the demand quantity of each county level warehouse, and the second number on the right of node 11 to 34 represents the reserves in each county level warehouse.

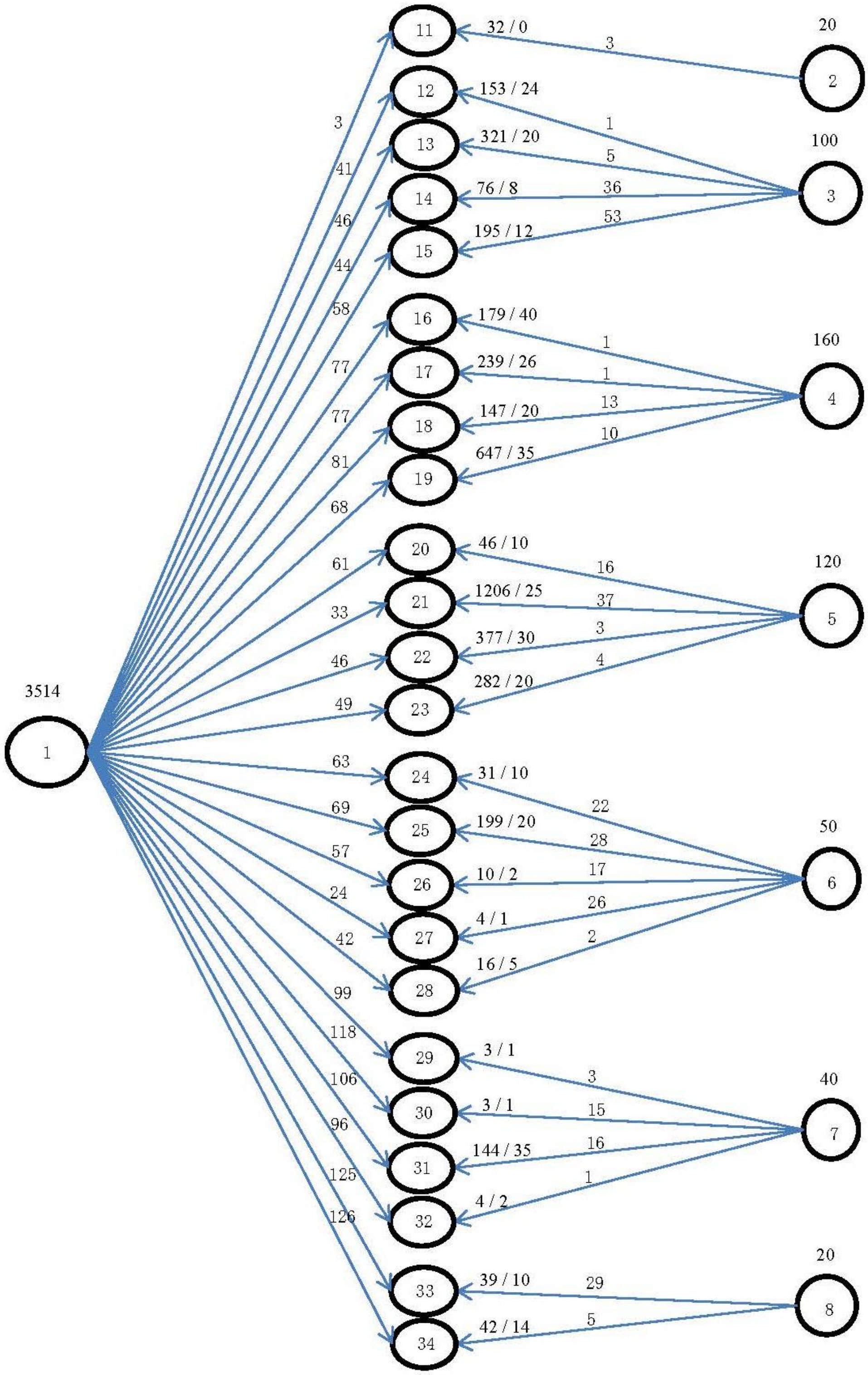

Figure 33 Network diagram of unified dispatching model of provincial emergency management center for ES in Guangxi

In the same way, the LP model to solve unified dispatching model of provincial emergency management center for ES in Guangxi as follows. The objective function of the minimum dispatching cost under this dispatching model is:

$$\begin{aligned}\min f_2 = & 3x_{111} + 41x_{112} + 46x_{113} + 44x_{114} + 58x_{115} + 77x_{116} + 77x_{117} + 81x_{118} \\ & + 68x_{119} + 61x_{120} + 33x_{121} + 49x_{122} + 46x_{123} + 63x_{124} + 69x_{125} + 57x_{126} + 24x_{127} \\ & + 42x_{128} + 99x_{129} + 118x_{130} + 106x_{131} + 96x_{132} + 125x_{133} + 126x_{134} + 3x_{211} + x_{312} \\ & + 5x_{313} + 36x_{314} + 53x_{315} + x_{416} + x_{417} + 13x_{418} + 10x_{419} + 16x_{520} + 37x_{521} + 3x_{522} \\ & + 4x_{523} + 22x_{624} + 28x_{625} + 17x_{626} + 26x_{627} + 2x_{628} + 3x_{729} + 15x_{730} + 16x_{731} + x_{732} \\ & + 29x_{833} + 5x_{834}\end{aligned}$$

Constraint：

$$\begin{aligned}& x_{111} + x_{112} + x_{113} + x_{114} + x_{115} + x_{116} + x_{117} + x_{118} + x_{119} + x_{120} + x_{121} + x_{122} \\ & + x_{123} + x_{124} + x_{125} + x_{126} + x_{127} + x_{128} + x_{129} + x_{130} + x_{131} + x_{132} + x_{133} + x_{134} = 3514, \\ & x_{211} = 20, \\ & x_{312} + x_{313} + x_{314} + x_{315} = 100, \\ & x_{416} + x_{417} + x_{418} + x_{419} = 160, \\ & x_{520} + x_{521} + x_{522} + x_{235} = 120, \\ & x_{624} + x_{625} + x_{626} + x_{627} + x_{628} = 50, \\ & x_{729} + x_{730} + x_{731} + x_{732} = 40, \\ & x_{833} + x_{834} = 20,\end{aligned}$$

$$\begin{aligned}& x_{111} + x_{211} + 0 = 32, \\ & x_{112} + x_{312} + 24 = 153, \\ & x_{113} + x_{313} + 20 = 321, \\ & x_{114} + x_{314} + 8 = 76, \\ & x_{115} + x_{315} + 12 = 195, \\ & x_{116} + x_{416} + 40 = 179, \\ & x_{117} + x_{417} + 26 = 239, \\ & x_{118} + x_{418} + 20 = 147, \\ & x_{119} + x_{419} + 35 = 647, \\ & x_{120} + x_{520} + 10 = 46, \\ & x_{121} + x_{521} + 25 = 1206, \\ & x_{122} + x_{522} + 30 = 377, \\ & x_{123} + x_{523} + 20 = 282,\end{aligned}$$

$$x_{124}+x_{624}+10=31,$$
$$x_{125}+x_{625}+20=199,$$
$$x_{126}+x_{626}+2=10,$$
$$x_{127}+x_{627}+1=4,$$
$$x_{128}+x_{628}+5=16,$$
$$x_{129}+x_{729}+1=3,$$
$$x_{130}+x_{730}+1=3,$$
$$x_{131}+x_{731}+35=144,$$
$$x_{132}+x_{732}+2=4,$$
$$x_{133}+x_{833}+10=39,$$
$$x_{134}+x_{834}+14=42,$$
$$x_{ij}\geq 0(i=1,2,3,4,5,6,7,8;\ j=11,12,13,\cdots\cdots,34)$$

The calculated results are as follows:

$$x_{111}=12, x_{112}=129, x_{113}=201, x_{114}=68, x_{115}=183, x_{116}=0, x_{117}=192,$$
$$x_{118}=127, x_{119}=612, x_{120}=36, x_{121}=1181, x_{122}=227, x_{123}=262, x_{124}=0,$$
$$x_{125}=150, x_{126}=8, x_{127}=3, x_{128}=11, x_{129}=0, x_{130}=0, x_{131}=75, x_{132}=0,$$
$$x_{133}=29, x_{134}=8, x_{211}=20, x_{312}=0, x_{313}=100, x_{314}=0, x_{315}=0,$$
$$x_{416}=139, x_{417}=21, x_{418}=0, x_{419}=0, x_{520}=0, x_{521}=0, x_{522}=120, x_{523}=0,$$
$$x_{624}=21, x_{625}=29, x_{626}=0, x_{627}=0, x_{628}=0, x_{729}=2, x_{730}=2, x_{731}=34,$$
$$x_{732}=2, x_{833}=0, x_{834}=20.$$

The dispatching quantity between the above nodes is substituted into the objective function to obtain the minimum dispatching cost of 186,167 RMB yuan.

4.2 Developing an ESDM for TCD in Guangxi Beibu Gulf Economic Zone (GBGEZ) based on OMG

4.2.1 Disaster Situation And ES Requirements

According to the population data survey of 6 prefecture-level cities in GBGEZ affected by Typhoon "Mangkhut," 25 counties (districts and county-level cities) in these 6 prefecture-level cities where more than 500 people need to be urgently relocated and resettled. The remaining disaster victims in other counties (districts or county-level cities) where no more than 500 people need to be urgently relocated are counted into neighboring counties. A total of 122,742 people need to be urgently relocated and resettled in 6 prefecture-level cities. The detailed disaster data of each city and county are shown in Table 27.

The maximum time for the autonomous region's financial assistance to people in need of emergency relocation and resettlement should not exceed 10 days, according to the circular on natural disasters by the Guangxi government. All ES shall be converted into 1kg per person per day. Table 4-16 shows the number of ES needed by cities and counties for emergency relocation and resettlement. Other disaster losses can be saved through cash subsidies.

According to the survey data of Guangxi's ES reserve pool, A_1 Guangxi Disaster preparedness Center is the provincial ES reserve and supply place, A_2-A_7 of the six prefecture-level city Emergency Management Bureau of GBGEZ is the prefecture-level city ES reserve and supply place. The Emergency Management Bureau of 25 counties in need of emergency relocation and resettlement of more than 500 people under the jurisdiction of 6 prefecture-level cities B_1-B_{25} receive places for relief materials. The 25 counties' need to supplement ES (991 tons) is equal to the ES needed by the counties for emergency population relocation (1227.42 tons) minus the ES reserves of (236.42 tons). ES of prefecture-level cities (255 tons) can only be given priority to those under their jurisdiction for disaster relief. Insufficient ES are supplied by the provincial ESRC (736 tons). See Table 4-16 for information on the disaster situation of each city and county, the amount of ES reserves, and the supply of supplementary ES.

Table 27 Disaster situation and ES requirements of 6 prefecture-level cities in GBGEZ caused by Typhoon "Mangkhut"

No.	Name of the disaster area	Affected population (persons)	Emergency transfer and resettlement Population (persons)	Emergency transfer and resettlement population ES requirements (tons)	ES reserve (tons)	Supplementary ES (tons)
A_2	Nanning City	322606	23978	239.78	50	119
B_1	Qingxiu district	1078	678	6.78	4.78	2
B_2	Xixiangtang District	9174	9144	91.44	20.44	71
B_3	Liangqing district	5581	842	8.42	5.42	3
B_4	Yongning district	5078	735	7.35	4.35	3

No.	Name of the disaster area	Affected population (persons)	Emergency transfer and resettlement Population (persons)	Emergency transfer and resettlement population ES requirements (tons)	ES reserve (tons)	Supplementary ES (tons)
B_5	Wuming district	8594	3201	32.01	10.01	22
B_6	Long 'an County	9889	929	9.29	4.29	5
B_7	Binyang County	60315	3573	35.73	10.73	25
B_8	Hengzhou City	222897	4876	48.76	10.76	38
A_3	Beihai City	20360	17353	173.53	40	97
B_9	Haicheng district	7402	4670	46.7	10.70	36
B_{10}	Yinhai district	6449	6449	64.49	10.49	54
B_{11}	Tieshan port area	895	895	8.95	4.95	4
B_{12}	Hepu County	5614	5339	53.39	10.39	43
A_4	Qinzhou City	25827	19683	196.83	45	112
B_{13}	Qinnan district	4154	4154	41.54	10.54	31
B_{14}	Qinbei district	4540	3229	32.29	8.29	24
B_{15}	Lingshan County	6997	4699	46.99	10.99	36
B_{16}	Pubei County	10136	7601	76.01	10.01	66
A_5	Fangchenggang City	11910	5027	50.27	20	17
B_{17}	Defense district	7175	3308	33.08	8.08	25
B_{18}	Shangsi County	4735	1719	17.19	5.19	12
A_6	Yulin City	225677	47842	478.42	80	333
B_{19}	Fumian district	61859	1206	12.06	5.06	7
B_{20}	Rongxian County	60272	6050	60.5	10.50	50
B_{21}	Luchuan county	15630	4672	46.72	10.72	36
B_{22}	Bobai County	37571	26130	261.3	20.30	241
B_{23}	Xingye county	25356	3761	37.61	8.61	29
B_{24}	Beiliu city	24989	6023	60.23	10.23	50
A_7	Chongzuo City	20746	8859	88.59	20	58
B_{25}	Fusui County	20746	8859	88.59	10.59	78
	Total of 6 cities	627126	122742	1227.42	491.42	736
A_1	Guangxi	1479397	137910			736

Data source: Statistics from the Emergency Management Department of Guangxi.

4.2.2 Distance between the places where ES are supplied and the places where they are received

The distance between the provincial ESRC of Guangxi (A_1) and the ES reserve repositories of disaster-stricken prefecture-level cities (A_2-A_7) and the ES reserve repositories of counties (districts and county-level cities) (B_1-B_{25}) can be queried through the transportation map of Guangxi and Baidu map (unit: km). The transport routes selected for ES are the shortest to ensure the rapid delivery of ES to the disaster area. The distances between the places where ES are supplied and the places where they are received are shown in Table 28

Table 28 Distances between the places where supplied and received

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
A_2	12						
A3	224						
A4	116						
A5	135						
A6	274						
A7	125						
B_1	14	3					
B_2	25	15					
B_3	8	9					
B_4	21	18					
B_5	68	60					
B_6	115	105					
B_7	91	98					
B_8	129	119					
B_9	220						
B_{10}	220						
B_{11}	231						
			6				
B_{12}	194						
			8				
B_{13}	131						
				5			

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
B_{14}	117						
B_{15}	127						
				03			
B_{16}	167						
				52			
B_{17}	130				11		
B_{18}	94				105		
B_{19}	283						
B_{20}	255						
						0	
B_{21}	336						
						2	
B_{22}	302						
						6	
B_{23}	184					36	
B_{24}	231					21	
B_{25}	68						75

Data source: Baidu Map and Tiandi Map (National Geographic Information Public Service Platform)

4.2.3 Developing a traditional provincial → prefecture-level city → county step-by-step ESDM based on OMG

4.2.3.1 Dispatching model assumptions

Based on the disastrous impact of Typhoon "Mangkhut" on 6 prefecture-level cities and counties (districts and county-level cities) in GBGEZ, as well as the management system of Guangxi's ES reserve at the provincial, prefecture-level city and county (district and county-level city) levels, ES shall be dispatched step by step according to the traditional province → prefecture-level city → county. The following assumptions are set up to better dispatch ES in the ES reserve of governments at all levels.

(1) The six prefecture-level cities are respectively responsible for the relief and resettlement of the disaster victims in the disaster-stricken counties (districts and county-level cities) within their respective jurisdictions. That is to say,

all ES stored in the emergency reserves of the prefecture-level cities can only be supplied to the disaster-stricken counties (districts and county-level cities) within their respective jurisdictions as a matter of priority.

(2) The ES needed by disaster-stricken counties (districts and county-level cities) that cannot be met by the prefecture-level cities shall be first centrally transferred to the prefecture-level city ES reserve warehouse and then supplied by the prefecture-level city ES reserve warehouse to the counties.

(3) The provincial ESRC must have enough ES to supply the insufficient ES needs of the cities and counties. However, the equilibrium of supply and demand is crucial to avoid wasting over supplies.

4.2.3.2 Developing a provincial → prefecture-level → county-level ESDM

Combined with the data in Table 4-16 and Table 28, according to the actual locations of the six prefecture-level cities and their subordinate counties (districts and county-level cities) in GBGEZ, the OMG is adopted to obtain the transport network diagram of three-level dispatch from province to the prefecture-level city to county (districts and county-level cities), as shown in Fig. 34.

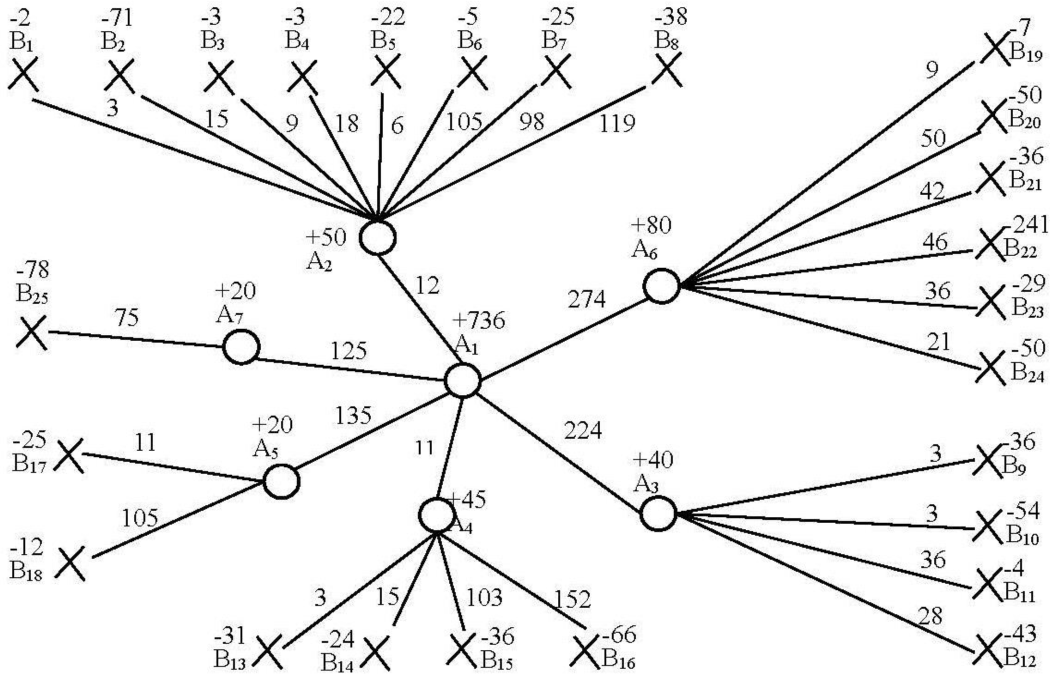

Figure 34 Traffic network diagram of provincial → prefecture-level → county-level ESDM

The above traffic network diagram of the provincial → prefecture-level → county-level ESDM shows a traffic network diagram that does not contain circles. The OMG without circles can be used to solve the lowest-cost transportation scheme. The lowest-cost transportation scheme obtained is shown in Fig. 35.

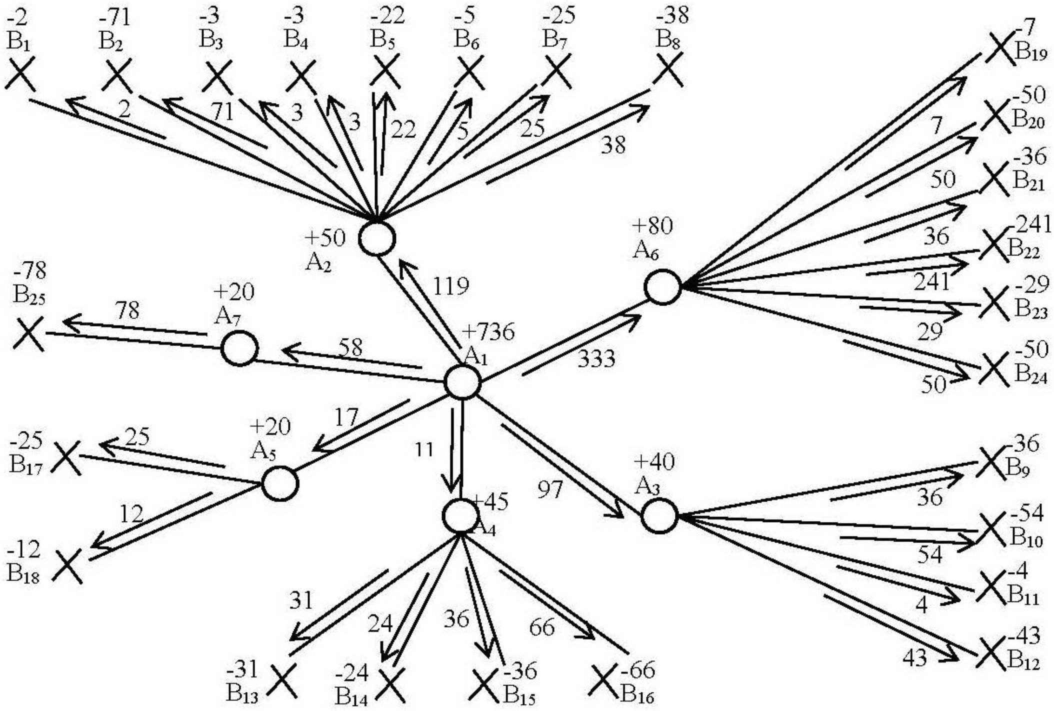

Figure 35 Flow chart of ESD scheme at provincial → prefecture-level city → county level

According to the flow diagram of the provincial → prefecture-level city → county-level ESD scheme obtained using the OMG in Fig. 35, there is no convection and roundabout phenomenon in this scheme which means this scheme is the optimal dispatching scheme. The optimal dispatching scheme, A_1-A_7, is the supply place of ES. Meanwhile, A_2-A_7 ES reserve prefecture-level cities serve as the intermediate transfer station. It also receives ES from A_1 provincial ESRC; the B_1-B_{25} of ES requirements area receives ES from higher prefecture-level cities. The optimal provincial → prefecture-level city → county-level ESD scheme is shown in Table 29.

Table 29 Optimal plan of ESD by province, prefecture-level city and county

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	Demand (ton)
A_2	119							119
A_3	97							97
A_4	112							112
A_5	17							17
A_6	333							333
A_7	58							58
B_1		2						2
B_2		71						71
B_3		3						3
B_4		3						3
B_5		22						22
B_6		5						5
B_7		25						25
B_8		38						38
B_9			36					36
B_{10}			54					54
B_{11}			4					4
B_{12}			43					43
B_{13}				31				31
B_{14}				24				24
B_{15}				36				36
B_{16}				66				66
B_{17}					25			25
B_{18}					12			12
B_{19}						7		7
B_{20}						50		50
B_{21}						36		36
B_{22}						241		241
B_{23}						29		29
B_{24}						50		50
B_{25}							78	78
Supply (ton)	736	169	137	157	37	413	78	1727

As seen from Table 4-18, the total supply equals the total demand, which is 1727 tons, reaching a balance between supply and demand. Table 4-18 shows the 736 tons of ES from the provincial ESRC. A_1 was first transferred to A_2-A_7 and then from A_2-A_7 of the prefecture-level city to B_1-B_{25} of the county. The supply and demand of the 736 tons of supplies in Table 4.5-5 were calculated twice. The total amount of ES transferred from A_1-A_7 is 1727-736 = 991 tons, and the total amount of ES needed to be replenished from B_1-B_{25} counties (districts and county-level cities) is also 991 tons. If the total number of tons•kilometers transferred in the optimal plan for the province → prefecture-level city → county step-by-step ESD is S_3, S_3 is equal to the actual transport volume transferred in the optimal plan for the province → prefecture-level city → county step-by-step ESD in Table 4-18 multiplied by the distance between the corresponding supply place and the receiving place in Table 4-17. Substitute the corresponding data in Table 4-18 and Table 4-17 to obtain:

$$S_3 = 187{,}439 \text{ (tons•km)}.$$

4.2.4 Developing a provincial → county direct supply ESDM Based On OMG

4.2.4.1 Problems existing in the traditional provincial → prefecture-level city → county-level ESDM

The disastrous impact of Typhoon "Mangkhut" on 6 prefecture-level cities and counties (districts and county-level cities) in GBGEZ can be seen from the traditional provincial → prefecture-level city → county (districts and county-level cities) level-by-level dispatching traffic network diagram. Part of the ES needed by disaster-stricken counties are first shipped from the provincial ESRC to the prefecture-level city ES reserve warehouse and then transferred from the prefecture-level city to the county ES reserve warehouse. There is a circuitous problem in this traditional ES transfer route, which increases the transportation cost. From this situation, this paper puts forward an improved scheme that can dispatch ES directly from the provincial ESRC to the ES reserve of the disaster-stricken county (district or county-level city).

4.2.4.2 Assumptions of the improved provincial → county direct supply ESDM

In order to improve ESD in the ES reserve of governments at all levels, the following assumptions are established.

(1) The six prefecture-level cities are responsible for the victims' relief and resettlement. Under their respective jurisdictions, the ES stored in the emergency reserves of the prefecture-level cities can only be supplied to the disaster-stricken counties on a priority basis.

(2) The ES needed by the affected counties can be directly supplied to the affected counties by the provincial ESRC without first transferring them to the ES reserve repositories of prefecture-level cities. Then they are transferred from the prefecture-level city emergency warehouse to the disaster-stricken county's warehouse.

(3) The provincial ESRC should have enough ES to supply the needed by cities and counties. The amount of supply and demand must be in equilibrium to avoid oversupply.

4.2.4.3 Developing a provincial → county direct supply ESDM

The traditional transportation network diagram of ESD at the provincial → prefecture-level city → county (district or county-level city) level was improved, and two approaches of prefecture-level city → county (district or county-level city) supply ES and province → county (district or county-level city) supply ES directly were obtained. Fig. 36 shows the traffic network diagram improved by the OMG.

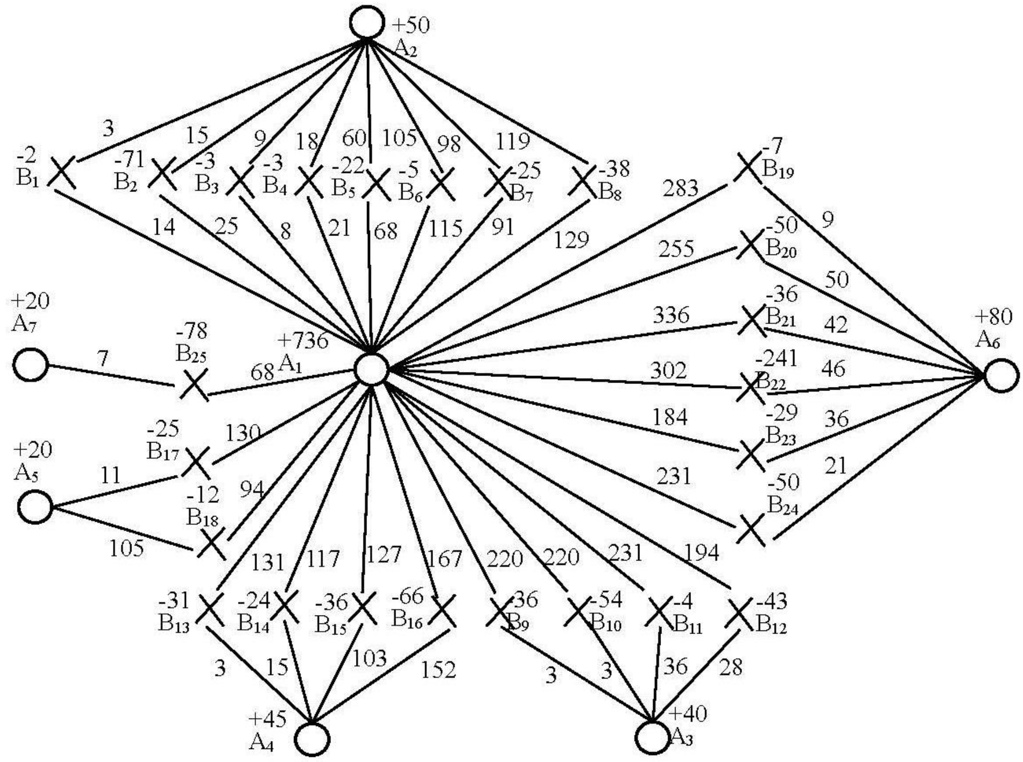

Figure 36 Traffic network diagram of provincial → county direct supply ESDM

The traffic network diagram contains many circles, as reflected in Fig. 36. The ES stored in the ES reserve of each prefecture-level city can only be preferentially dispatched to the county (district or county-level city) under its jurisdiction. When the ES stored in each prefecture-level city are distributed but cannot meet the needs of the county needs, they must be dispatched from the provincial ESRC. Therefore, a relatively independent circle is formed between each prefecture-level city emergency reserve pool, its subordinate counties, and the provincial ESRC. Each relatively independent circle is a small circle composed of four nodes connected to each other.

It is required that the optimal dispatching scheme of the provincial → county direct supply ESDM can be completed by using the OMG with a circle. For example, the large circle formed by A_1, A_4, B_{13}, B_{14}, B_{15}, and B_{16} is selected, and then the small circle formed by A_1, A_4, B_{13}, and B_{14} is selected from the large circle. Assuming that the $A_1 \rightarrow B_{13}$ line is blocked, the "nearby transfer" principle is adopted. All 31 tons of ES needed by B_{13} will be supplied by A_4 (according to the principle of transferring ES in the right direction, this line belongs to the inner circle, with a length of 3km), and the remaining 14 tons of ES in A_4 will be supplied to B_{14} (this line belongs to the outer circle, with a length of 15km).

At this time, 45 tons of ES stored in A_4 of the prefecture-level city have been distributed. Of the 24 tons of ES needed by B_{14}, only 14 tons can be obtained from A_4, and the insufficient 10 tons can only be supplied by A_1, the provincial ESRC (this line belongs to the inner circle, with a length of 117km). At this time, ES needed by B_{13} and B_{14} in the small circle formed by A_1, A_4, B_{13}, and B_{14} have been met. The transport scheme of this small circle is tested as follows:

Circumference: C_2=3+131+117+15=266 (km)

Half of the circumference: $C_2/2$=266/2=133 (km)

The inner ring length: C_{inner3}=3+117=120 (km)

Outer ring length: $C_{outer\ 3}$=15 (km)

$C_{inner3} < C_2/2$, $C_{outer3} < C_2/2$, so this transportation plan is optimal..

At this time, 45 tons of ES stored in A_4 of the prefecture-level city in the big circle have been distributed, and A1 of the provincial ESRC can only supply the ES needed by B15 and B16. A_1 shall supply 36 tons of ES to B_{15}, and A_1 shall supply 66 tons of ES to B_{16}. At this time, B_{13}, B_{14}, B_{15} and B_{16} in the big circle formed by A_1, A_4, B_{13}, B_{14}, B_{15} and B_{16} have all received the needed ES, and the total number of tons and kilometers of this transportation plan is the smallest. Other prefecture-level cities and their subordinate counties (districts and county-level cities) can refer to this scheme to solve the optimal transportation scheme, and the flow diagram of the optimal dispatching scheme of the final provincial-level → county direct supply ESDM can be obtained according to this method, as shown in Fig. 4-21.

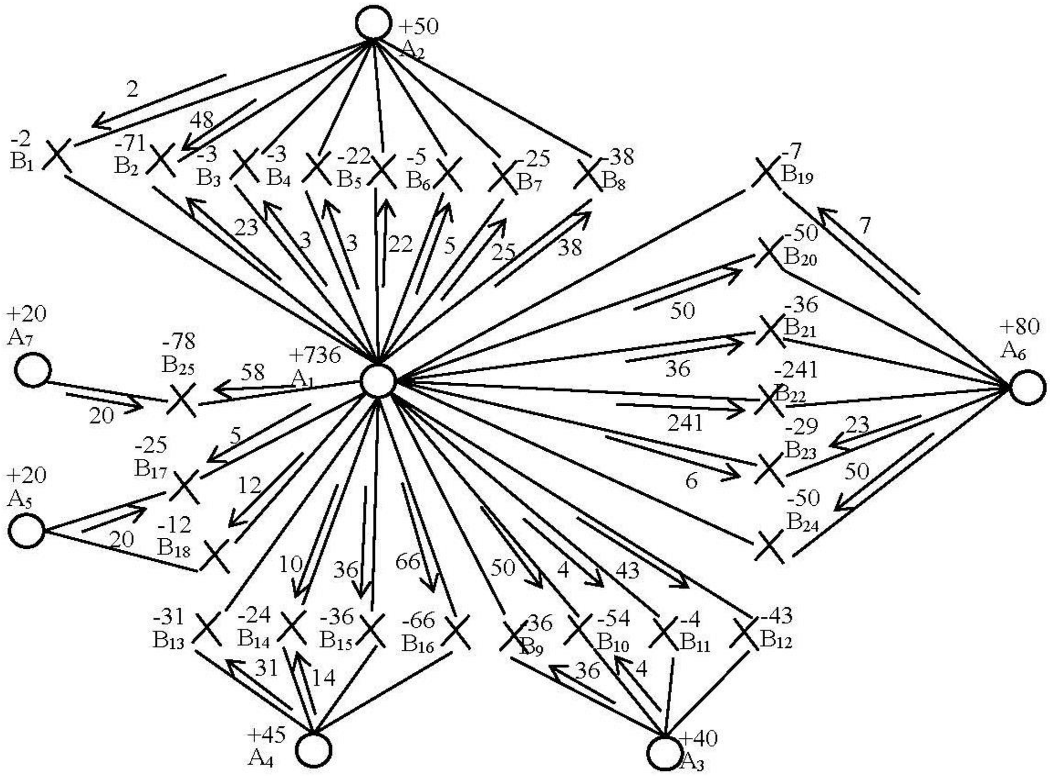

Figure 37 Flow diagram of optimal dispatching scheme of provincial → county direct supply ESDM

According to the flow diagram of the optimal dispatching plan for the provincial → county direct ES model in Fig. 37, the emergency supply places in the dispatching plan are A_1-A_7. And the ES requirements places B_1-B_{25} receive ES from A_2-A_7 of the superior prefecture-level city or A_1 of the provincial ESRC. The optimal provincial → county direct supply ESD scheme is shown in Table 4-19.

Table 30 Optimal plan of direct supply ESD from province to county

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	Demand (ton)
B_1		2						2
B_2	23	48						71
B_3	3							3
B_4	3							3
B_5	22							22
B_6	5							5
B_7	25							25
B_8	38							38
B_9			36					36
B_{10}	50		4					54
B_{11}	4							4
B_{12}	43							43
B_{13}				31				31
B_{14}	10			14				24
B_{15}	36							36
B_{16}	66							66
B_{17}	5				20			25
B_{18}	12							12
B_{19}						7		7
B_{20}	50							50
B_{21}	36							36
B_{22}	241							241
B_{23}	6					23		29
B_{24}						50		50
B_{25}	58						20	78
Supply (ton)	736	50	40	45	20	80	20	991

Table 30 shows the balance between supply and demand, which is a total of 991 tons. The total number of tons•kilometers transported in the optimal plan for direct supply of ES by province→county as S_4, then S_4 is equal to the actual transport volume in the optimal plan for direct supply of ES by province→county as shown in Table 30 multiplied by the distance between the supply place and the receiving place of ES as shown in Table 4-19. Substitute the corresponding data in Table 4-19 and Table 4-17 to obtain:

S_4=156408 (tons•km).

5. Combining the situation awareness model of EL for TCD in Guangxi

5.1 Combining the situation awareness model of EL for TCD in Guangxi

The combination of the content of the previous four sections of this chapter, the severe TCD events suffered by Guangxi during 2005-2022 are selected as the basis of data analysis of EL, and the RPMES, the LMESRC and the ESDM are developed based on the data of TCD. Finally, the function of the three models is integrated to form the overall situation awareness model of EL for TCD in Guangxi. Fig. 38 shows a specific model.

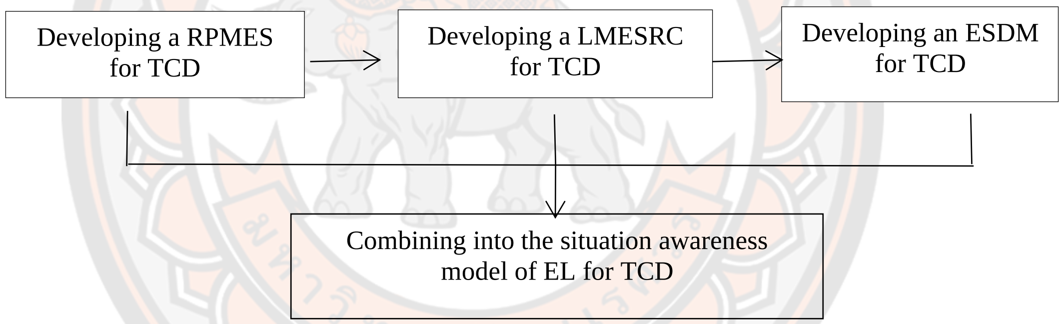

Figure 38 Combining into the situation awareness model of EL for TCD

In Fig. 38, the combined situational awareness model is not a single model but a comprehensive solution that integrates RPMES, LMESRC, and ESDM. The aim is to solve a series of urgent problems faced by emergency management departments of Guangxi governments at all levels when facing TCD. These questions include how much ES will be needed to meet the needs of the victims. How will the ES need to be collected and procured? Who will procure these ES? How to get these ES to victims quickly and cheaply? The situational awareness model of EL for TCD in Guangxi combined with this thesis can solve these problems and provide scientific and reasonable intellectual support for the emergency management departments of Guangxi governments at all levels.

5.2 The relationship of RPMES, LMESRC, and ESDM

In Fig. 38, the three basic models are closely related. First of all, when the TCD comes, the first model developed in this thesis, namely the RPMES, can accurately predict the quantity and types of ES needed in Guangxi. Secondly, the predicted requirements for all kinds of ES can just provide the requirements data for ES for the second model, the LMESRC, which becomes an important parameter of the location model. In addition, if the location of the ESRC has been determined, it can also provide a basis for the ESRC to purchase and collect the necessary ES. Finally, once the address of the ESRC is determined and the requirements for ES in each disaster area is known, it just provides data support for the third model, namely the ESDM. It is enough to select the route with the shortest distance and time to transport all kinds of ES to the disaster area. These three models can be used independently to solve TCD problems or combined into an interrelated overall model to solve multiple TCD problems.

5.3 The role and significance of situational awareness model

The situation awareness model of EL for TCD solves the core problems of requirements prediction of ES, location, and storage of ESRC, ESD, etc., which need to be solved in the face of TCD. It is an effective solution for EL in response to TCD. This model can provide a feasible reference for emergency management departments of Guangxi at all levels to formulate emergency plans for TCD.

CHAPTER V

DISCUSSION

The situation awareness model of EL for TCD in Guangxi has been established in this paper. The main research contents include three models: the RPMES for TCD in Guangxi, the LMESRC for TCD in Guangxi, and the ESDM for TCD in Guangxi. The data selected by each model are all from the statistical data of all cities and counties of Guangxi proposed by the Emergency Management Department, which has higher authority, and the model established based on these data has a high reference value. Of course, for different individual TCD, the difference is very big. In the practical application process, we can refer to these model methods to make appropriate adjustments to meet the actual needs. The following is a further discussion of these three models and their applications.

1. Discussion on the RPMES for TCD in Guangxi

In establishing the RPMES for TCD in Guangxi, this paper mainly selected four independent variables: the maximum wind speed when the TC entered Guangxi, the length of the disaster impact in Guangxi, the number of collapsed houses, and direct economic losses. The emergency relocation and resettlement population was selected as the dependent variable, and the MLRM was adopted to establish the prediction model. The data of these four independent variables and one dependent variable are derived from the statistics of 51 severe TCD suffered by Guangxi during 2005-2022. In the China Statistical Yearbook of TC from 2005 to 2022, there are no accurate statistical data on the maximum wind speed when the TC entered Guangxi and the length of time it caused disasters in Guangxi. The author found small errors by reading a large number of statistical yearbook data.

In addition, two influencing factors can be added to the selection of the independent variable index. What are the specific prefecture-level cities and counties affected by each TCD? What was the total population of the affected cities and counties that year? What was the GDP of the affected cities and counties that year? The first factor that can be considered increased has a significant linear relationship between the total population of the disaster-hit cities and counties and the number of emergencies displaced and resettled population of the dependent variable. However, this data is only available from the Emergency Management Department of Guangxi after 2014, and there are no specific statistics on TCD before 2014. The second factor that can be considered is a linear relationship between the GDP data of the year of the economic aggregate of the affected cities and counties and the number of the dependent variable emergency relocation and resettlement population. More developed areas can better resist and prevent disasters, which can effectively reduce the number of people affected by disasters and the number of people in need of emergency relocation and resettlement. The next research can consider adding these two dependent variables to re-establish the multiple regression model.

2. Discussion on LMESRC for TCD in Guangxi

This paper uses the CGM based on GIS to establish the LMESRC for TCD in Guangxi. The CGM is a suitable location for a single logistics center in a large area. The CGM does not restrict the choice of specific alternative points and has great flexibility. Its calculation method is relatively simple, and the degree of freedom is relatively large. Another disadvantage of the CGM is that the distance between two points ignores the actual road conditions and simply adopts the straight line distance, resulting in inaccuracy.

When choosing a location for a logistics center, GIS can not only accurately obtain the exact location of each origin and demand but also can be expressed by coordinates. Therefore, it is convenient to use and can be used for calculation more accurately. The matching query function of GIS can more accurately match the logistics center to the road node with convenient transportation. Moreover, since the spatial entities in the location selection area (including roads and various logistics bases) have been digitized, the road conditions and transportation conditions of each origin and demand can be easily obtained, which is more in line with the actual and objective conditions, unlike the classical algorithm. The distance between two points is directly expressed in a straight line, regardless of the actual road conditions. The CGM does not possess these two advantages but also can not achieve the CGM. Therefore, to a certain extent, GIS has greater advantages in the algorithm of logistics center location than CGM. It can be seen that compared with the gravity center method model, GIS is more in line with the actual situation in practice, and it is a more convenient and effective logistics center location method.

The location model of ESRC for TCD in Guangxi established in this thesis adopted the total requirements of ES in 14 prefecture-level cities in Guangxi as the location selection parameter. The algorithm can be further improved to refine the requirements for ES for each county (county-level city, district). The county level, as the most basic administrative unit of the government, directly commands the disaster relief work within its jurisdiction. If the requirements for ES are refined to each county (county-level city, district), the accuracy of the site selection model can be improved, and the calculation workload will be much larger.

3. Discussion on ESDM for TCD in Guangxi

This paper uses the LP method and OMG to establish the ESDM for TCD in Guangxi. Each method establishes the traditional province - prefecture-level city - county ESDM and province - county-level city direct ESDM. The four ESDMs established by the two methods have good applicability. For the ESD problem of multi-supply points to multi-demand points, the advantage of OMG is that it is simple and easy to understand. When drawing the traffic network map, the calculation is relatively simple, and there is no need to establish complex mathematical formulas. However, the LP method needs to establish complex mathematical formulas, and the calculation difficulty increases when there are many nodes.

At present, governments at all levels in Guangxi usually adopt the traditional provincial → prefecture-level city → county level-by-level ESDM when carrying out ES. The model can better define the relationship between governments at all levels, and governments at all levels can better control the rational distribution of ES within their jurisdiction. However, there will be a time delay in communicating information in this mode, and there may be unreasonable transportation conditions, such as detours in the ESD between government warehouses at all levels. As a result, it takes more time and costs to collect and dispatch ES.

The improved provincial-county direct supply ESDM is more efficient. In this mode, ES can be transferred directly between the provincial emergency management center and the county ES storage warehouse, eliminating the transport link of the prefecture-level city ES warehouse and greatly improving the efficiency of ESD. The dispatch time of ES is shortened, and the cost is reduced.

From the calculation results of different TC case data selected by the two methods, the provincial → county direct supply ESDM is better than the traditional provincial → prefecture-level city → county step-by-step supply ESDM. Under the two dispatching models established by using the LP method and the disaster data of super Typhoon No. 1409 "Rammasun", the freight saving of the provincial → county direct supply ESDM (namely the unified dispatching mode of the provincial emergency management center) is 272651-186167= 86,484 RMB yuan. The saving rate is :(86484 /272651)*100%=31.72%. The saving effect is obvious, and the unified dispatch mode of the provincial emergency management center is more feasible. The disaster data of severe Typhoon No. 1822 “Mangkhut” was selected, and the traditional provincial → prefecture-level city → county ESDM was established using the OMG. The total number of tons • km transported was 187439 tons • km. The total number of tons • km transported by the provincial → county direct supply ESDM established by the OMG is 156,408 tons • km. Compared with the traditional provincial → prefecture-level city→county ESDM, the total transportation volume of 31,031 tons • km was saved, with a saving rate of 16.56%. It can be seen from the calculation results that the provincial → county direct supply ESDM established by the OMG has lower cost, saved limited dispatching resources, and achieved better results.

CHAPTER VI

CONCLUSIONS

Through the literature retrieval method, this paper understands the academic achievements and progress in the research field of this thesis and master the basic principles and application methods of various research methods needed for this research. Through the in-depth interview method, the author mastered the authoritative and complete TCD data provided by the Emergency Management Department of Guangxi and understood the relevant measures and methods of disaster relief carried out by the emergency management departments of governments at all levels in Guangxi. The methods and data needed for the follow-up quantitative research are obtained through the above two qualitative research methods, laying a good foundation. Then, the multiple linear regression method was adopted to establish the RPMES for TCD in Guangxi. The location model of ESRC for TCD in Guangxi was established using the CGM based on GIS, and the ESDM for TCD in Guangxi using the LP method and OMG. Finally, the three established models were combined into a situation awareness model of EL for TCD in Guangxi, forming a set of EL solutions for TCD in Guangxi. This includes Requirements Prediction of ES, location of ESRC and ESD, which solved various problems encountered by governments at all levels in Guangxi in the face of TCD assistance. Complete the research content of this thesis successfully. The main conclusions are reflected in the following aspects:

(1) Emergency management departments of governments at all levels in Guangxi have completed the integration process of emergency resources, and their disaster relief capabilities have been significantly improved. Through in-depth interviews, the author learned that since the establishment of emergency management departments of governments at all levels in Guangxi four years ago, various disaster relief forces had been coordinated, emergency plans have been formed in the face of various common disasters, and emergency management departments of governments at the provincial, prefecture-level and county levels have clear coordination and division of labor. The mechanisms for the reserve and storage of ES at all levels of

government have been sorted out, and a sound working mechanism has been formed for the procurement and utilization of ES, greatly enhancing the government's ability to respond to various disasters.

(2) The RPMES for TCD in Guangxi based on MLRM is simple and practical. It can be seen from the sample scatter plot of the dependent variable and independent variable that there is a good linear correlation between the selected dependent variable and the independent variable. After three times of residual map analysis to remove impurities, finally, through F test and P test, the accuracy of RPMES for TCD in Guangxi was improved. This model can provide a simple and practical requirements prediction ability of ES for all levels of government emergency management departments in Guangxi and can also provide a reference for making ES reserve and procurement plans.

(3) The LMESRC for TCD in Guangxi developed by using the improved CGM based on GIS is very applicable. After four iterations of calculation, the longitude and latitude coordinates S^5 (108.64, 21.98) were used as a suitable site to construct the ESRC for TCD in Guangxi to ensure the fastest and lowest cost delivery of ES to the disaster areas in Guangxi. According to the map, the actual place corresponding to this coordinate is near Liuwu Village next to Qinzhou East Railway Station, Qinnan District, Qinzhou City, Guangxi. The site selection result is also consistent with the proportion of ES requirements of urban node C and surrounding cities B, D, E, F, and A in Table 4-15 is more than 91%. This model can provide intellectual support for the emergency management departments of Guangxi governments at all levels to improve the ES reserve system and quickly select suitable places for the establishment of ESRC or ES reserve warehouse.

(4) The ESDM for TCD in Guangxi was developed using the LP method and good OMG operability. At present, governments at all levels in Guangxi still adopt the traditional model of providing ES step by step from province to the prefecture-level city to county, but the cost of this model is relatively high. But the improved provincial-county direct supply ESDM greatly reduces the transportation cost. The four ESDMs developed by these two methods have good applicability. In summary, the provincial → county direct supply ESDM established by the operation method in the figure is the most suitable. The ESDM established by the OMG shows that the

provincial → county direct supply ESDM can save 16.56% of dispatching cost compared with the traditional provincial → prefecture-level city → county step-by-step supply ESDM, which has lower cost, saved limited dispatching resources and achieved better results. This model can quickly help the emergency management departments of Guangxi governments at all levels to formulate disaster ESD plans.

(5) Integrate the developed RPMES, LMESRC, and ESDM to form a fully functional situation awareness model of EL for TCD in Guangxi. This model can help the emergency management departments at all levels of Guangxi government develop perfect EL solutions for TCD.

CHAPTER VII

CONTRIBUTIONS AND RECOMMENDATIONS

1. Contributions

The main contributions of this thesis are reflected in the following four aspects:

(1) Requirements prediction of ES is the premise of ES reserve and collection. At present, there is a lack of effective methods to accurately determine the requirements of ES, and it is urgent to carry out exploration in this aspect. In this thesis, the MLRM was used to develop the RPMES for TCD in Guangxi. This model can provide a reference for Guangxi governments at all levels to make ES reserve plan and purchase decisions.

(2) Guangxi is affected by about 2 severe TCDs every year on average, and a large number of disaster victims need governments at all levels to collect enough ES for effective relief. However, there is no proper reserve center for storing and collecting ES for TCD in Guangxi, so choosing a suitable location to build the ESRC for TCD in Guangxi is urgent. The location coordinates determined by using the improved CGM based on GIS can provide a reference for the Guangxi government to select the appropriate address for the construction of ESRC for TCD in Guangxi. Prefecture-level cities or counties in Guangxi can also adopt this method to determine the best location for ES storage warehouses within their jurisdiction. The improved CGM based on GIS can also provide a reference for other provinces or cities to carry out ESRC locations.

(3) ESD is a key link to carry out TCD relief. It is an urgent problem to select a fast and low-cost ESD scheme. To solve the problem of ESD from multiple supply points to multiple demand points, the traditional provincial → prefecture-level city → county ESDM and provincial → county direct supply ESDM of TCD in Guangxi were constructed respectively by LP model and OMG. Through calculation and comparison, the developed provincial → county direct supply ESD mode can save

more transportation costs, and it is more suitable for emergency management departments of Guangxi at all levels to provide a reference for the development of ESD plans for TCD.

(4) The situational awareness model of EL integrated with the three basic models provides a set of solutions to deal with TCD for the emergency management departments of governments at all levels in Guangxi. This will provide scientific basis and technical support for emergency management departments of Guangxi governments at all levels to formulate emergency plans of requirements prediction of ES for TCD, location of ESRC for TCD, ESD for TCD, and other emergency plans.

2. Recommendations

According to the current situation of emergency management departments of governments at all levels in Guangxi and the research results of this thesis, the following recommendations are put forward:

(1) Strengthening and clarifying the overall management of emergency resources by governments at all levels. Clarify the ownership and management of ES reserves and ES of governments at all levels, properly divide the rights and responsibilities of emergency resource management of relevant departments, and formulate corresponding management systems.

(2) Emergency management departments of governments at all levels in Guangxi should strengthen their contacts with high-end think tanks such as universities and research institutes. To support think tank experts in carrying out research on basic and applied technologies related to requirements prediction of ES, ES management, ESD etc., and to provide government emergency management departments at all levels with high-end intelligence, cutting-edge research results, and research technologies.

(3) Emergency management departments of governments at all levels in Guangxi need to strengthen cooperation with large logistics enterprises and ES providers. Sign long-term cooperation agreements with selected large logistics enterprises and ES providers, and carry out emergency logistics exercises regularly in peacetime to ensure that these partners can cooperate efficiently, punctually, and effectively during emergencies.

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