Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

A study on the location of emergency supplies reserve center in Guangxi for tropical cyclone disasters

Guoyou Yue[a*] and Boonsub Panichakarn[a]

[a]*Faculty of Logistics and Digital Supply Chain, Naresuan University, Thailand*

A B S T R A C T

Article history:
Received November 10, 2022
Received in revised format December 22, 2022
Accepted March 12 2023
Available online March 12 2023

Keywords:
Location of emergency supplies reserve center
Tropical cyclone disaster
Center of gravity method
GIS

On average, Guangxi experiences 2 severe tropical cyclone disasters yearly. A large number of disaster victims need governments at all levels to raise enough emergency supplies to carry out effective relief. However, there is no proper reserve center for tropical cyclone disaster storage and collection of emergency supplies in Guangxi, so it is urgent to choose a suitable location to build the Guangxi tropical cyclone disaster emergency supplies reserve center. The data of 16 severe tropical cyclone disasters and rescues in Guangxi from 2014 to 2021 were collected. An optimal location model of the emergency supplies reserve center for tropical cyclone disasters in Guangxi was established using the improved center of gravity method based on GIS. After four iterations of calculation, the longitude and latitude coordinate S5(108.64, 21.98) were used as a suitable site to construct the Guangxi Tropical Cyclone Disaster Emergency Supplies Reserve Center to ensure the fastest and lowest cost delivery of emergency supplies 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 S5 can provide a reference for the Guangxi Zhuang Autonomous Region government to select a suitable address to construct the Guangxi Tropical Cyclone Disaster Emergency Supplies Reserve Center. The improved center of gravity location model based on GIS can also provide a reference for other provinces or cities to carry out emergency supplies reserve center locations.

1. Introduction

Every year, Guangxi suffers about two severe tropical cyclones (called typhoons in China), which cause heavy economic and social losses in Guangxi. According to the report of the Civil Affairs Department of Guangxi (Guangxi), as of 7:10 a.m. on July 20, 2014, super typhoon No. 1409 "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. A total of 10 people died from the disaster, and 320,621 people needed urgent relocations. 770,787.41 hectares of crops were affected, 10,167 houses collapsed, and direct economic losses amounted to 13,898,639,400 yuan. According to the civil affairs department of Guangxi report, the 1822 strong typhoon "Mangkhut" 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 just one death reported. However, 137,910 people needed to be urgently relocated, 106,869.98 hectares of crops were affected, and 1,451 houses collapsed. And the direct economic loss amounted to a total of 850,518,883 yuan. From 2014 to 2021, Guangxi suffered 16 severe tropical cyclones. In previous tropical cyclone disasters, the 14 prefecture-level cities in Guangxi suffered a significant impact from the disasters, among which Qinzhou, Beihai, Fangchenggang, and Yulin on the southeast coast were seriously affected. At the same time, Liuzhou, Hechi, and Baise in the central and northern regions were less affected. The focus of disaster relief is to provide timely and low-cost emergency supplies to disaster-stricken areas. The location of the emergency supplies reserve center will

* Corresponding author
E-mail address 563601374@qq.com (G. Yue)

doi: 10.5267/j.uscm.2023.3.007

directly affect the timeliness and cost of relief supplies. However, there is no special emergency supplies reserve center for tropical cyclone disasters in Guangxi, so it is urgent to choose an appropriate address to build the emergency supplies reserve center for tropical cyclone disasters in Guangxi. This paper shows 16 severe tropical cyclone disasters suffered by Guangxi from 2014 to 2021 as examples. The number of people needing emergency relocation and resettlement in 14 prefecture-level cities during previous tropical cyclone disasters was counted as the basis for calculating the demand for emergency supplies. As well as the amount of emergency supplies needed by each city was calculated. The Center of Gravity Method based on GIS improvement was used to select the most appropriate address for the emergency supplies reserve center for 14 prefecture-level cities in Guangxi as the construction address of the emergency supplies reserve center for tropical cyclone disasters.

2. Literature Review

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 emergency supplies storage or distribution centers. Specific location selection methods include the gravity center method, multi-objective programming, uncertain demand model, random demand model, etc.

Center of gravity method site selection is the most used single facility site selection method. Liu (2009) established a mathematical model with the modified center of gravity method and solved the location optimization of chain supermarket logistics distribution centers according to the characteristics and conditions of the distribution center location problem. Yue and 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 center of gravity 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. Ni and Chen (2021) ensure the rationality of the location of emergency logistics distribution center and the timely supply of emergency supplies 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 emergency logistics distribution center with the clustering and gravity center method.

The multi-objective optimization model considering time and cost minimization is popular in the location selection algorithm. Rath and Gutjahr (2014) established a multi-objective optimization model of LRP for emergency supplies transfer facilities and proposed a sub-heuristic algorithm based on analyzing optimization problems of the two-level emergency supplies distribution system after disasters. Sheu and Pan (2014) established a mixed integer linear programming model based on multiple objectives such as transportation distance minimization, operation cost minimization and transportation cost minimization. Cong (2020) conducted a systematic study on the location of emergency supplies 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 emergency supplies storage centers, Zheng and Ma (2020) built a multi-objective optimization model of location selection and routing problem for emergency supplies 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 emergency supplies 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, Xu et al. (2020) applied the immune optimization algorithm to the location problem of the emergency supplies center. They also established an integrated solution for location selection - scheduling, and distribution of the emergency supplies center and established a mathematical model of the location problem of the logistics distribution center and multi-objective material scheduling problem. Wang et al. (2022) adopted the fuzzy comprehensive evaluation method to establish a multi-objective optimization model for the location of emergency supplies reserve in the South China Sea.

There are also many achievements in the study of location selection under uncertain environments and random demand. Zhao and Jin (2007) respectively studied the location selection of RDC under an uncertain environment. Bo (2006) established an uncertain multi-attribute decision model for the application of logistics center location. Jiang and Zhu (2007) discussed the robust optimization method of the central location in the case of weight uncertainty. Considering the randomness and uncertainty of disasters, Yu (2021) established a two-stage pre-disaster positioning and storage model based on the randomness and uncertainty of disasters to hedge against such disasters. Wang and 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. Wen andi 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. Rawls and 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. Li et al. (2022) in order to effectively utilize the military and civilian reserve resources and reduce the cost of reserve, incorporated military reserve facilities into the layout plan of emergency supplies reserve and established a two-stage stochastic programming model of location - allocation optimization of emergency supplies.

There are many other ways to locate emergency storage centers. Afshar and Haghani (2012) based their emergency logistics structure proposed by the US Federal Emergency Management Agency (FEMA). This paper analyzes four factors in coping with natural disasters: facility location, emergency supplies distribution, vehicle scheduling and route selection to establish a multi-cycle integrated supply chain optimization model with mixed integer programming method and adopt CPLEX software to solve it. Jiang and 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. 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 emergency logistics distribution center has not failed, a more stable emergency logistics distribution network was found to prevent the failure risk of the distribution center. Xu et al. (2022) combined grey correlation analysis, complex networks and relative entropy to establish a community-centered multi-criteria location selection method for rescue supply facilities.

According to the above research literature on the location of emergency supplies reserve centers, methods such as the center of gravity method, multi-objective planning, uncertain demand model, and random demand model are all commonly used. The location problem of the emergency supplies reserve center 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 emergency supplies reserve center has a higher requirement on the timeliness of the rescue, and the cost is second. Few studies on the location of emergency supplies reserve centers for tropical cyclone disasters appeared in the above literature. The problem to be solved in this paper is to find an address suitable for the construction of an emergency supplies reserve center for tropical cyclone disasters 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.

3. Methodology

3.1 Location Model of the Center of Gravity Method

The location model of the center of gravity method is a suitable method to select an optimal location in a certain area to build a distribution center. The center of gravity of a region can be simplified by a proposed logistics facility point (warehouse, distribution center) to supply to n 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 center of gravity method model is established.

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.

3.2 Location Model Of Emergency Supplies Reserve Center Based On GIS

In GIS (Geographic Information System), origin and demand places are spatial entities, represented by their physical characteristics available points, and basic information about them and the whole planned area can be expressed through spatial data. The distance between the place of origin and the place of demand is the real road transportation distance, which overcomes the defect of the linear distance between them in the traditional location model of the center of gravity method. The location model of emergency supplies reserve center based on GIS is more in line with the actual situation.

It is assumed that there are a total of disaster-affected places in the area to be located, and an emergency supplies reserve center needs to be determined to supply emergency supplies to this disaster-affected place. The optimal location coordinates of the emergency supplies reserve center can be obtained using the single facility location model of the emergency supplies reserve center based on GIS. Generally, it is carried out in the following 6 steps:

(1) Firstly, 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 emergency supplies demand 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 center of gravity method 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.

4. Results

4.1 Tropical cyclone disaster data statistics and emergency supplies demand analysis of prefecture-level cities in Guangxi over the past years

Based on the investigation of the Guangxi Emergency Management Department, data on 16 severe tropical cyclone disasters 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 emergency supplies demand. In order to simplify the identification, the 14 prefecture-level cities in Guangxi and their corresponding prefecture-level city emergency supplies reserves are represented by letters A ~ N, as shown in Table 1. The detailed data of tropical cyclone disasters in each prefecture-level city during 2014-2021 are shown in Table 2.

Table 1
Numbers of 14 prefecture-level cities in Guangxi and emergency supplies storage warehouses of each prefecture

No.	Prefecture-level city	Prefecture-level City emergency supplies 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

Table 2
Previous severe tropical cyclone disasters 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

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. Emergency supplies shall be arranged according to the maximum rescue time of 10 days. All kinds of emergency supplies (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 3 for the amount and proportion of various emergency supplies needed by the emergency relocated and resettled population of prefecture-level cities. Other disaster losses can be saved through cash subsidies.

Table 3
Proportion of demand for emergency supplies affected by tropical cyclones in prefecture-level cities of Guangxi from 2014 to 2021

City No.	Number of population relocated and resettled in emergency (persons)	Demand for emergency supplies (tons)	Proportion of demand for disaster and emergency supplies (%)	Accumulated proportion of demand for disaster and emergency supplies (%)
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 3 shows the 16 severe tropical cyclone disasters that hit Guangxi in the last 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 emergency supplies 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 tropical cyclones in the past eight years and did not require emergency relocation and resettlement of population.

4.2 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 emergency supplies 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 4.

Table 4
Longitude and latitude coordinates of the addresses of 14 prefecture-level cities in Guangxi

Emergency supplies reserve warehouse No.	Address of emergency supplies 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
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

4.3 Construction Of Location Model Of Emergency Supplies Reserve Center In Prefecture-level Cities of Guangxi

According to the standard of China's road freight rate of 0.35 yuan/ton • km, assuming that the road freight rate between all nodes is 0.35 yuan/ton • km, it is unnecessary to consider the problem of different unit freight rates in the location model. The initial model obtained by matching the data in Table 4 to the map of Guangxi is shown in Fig. 1.

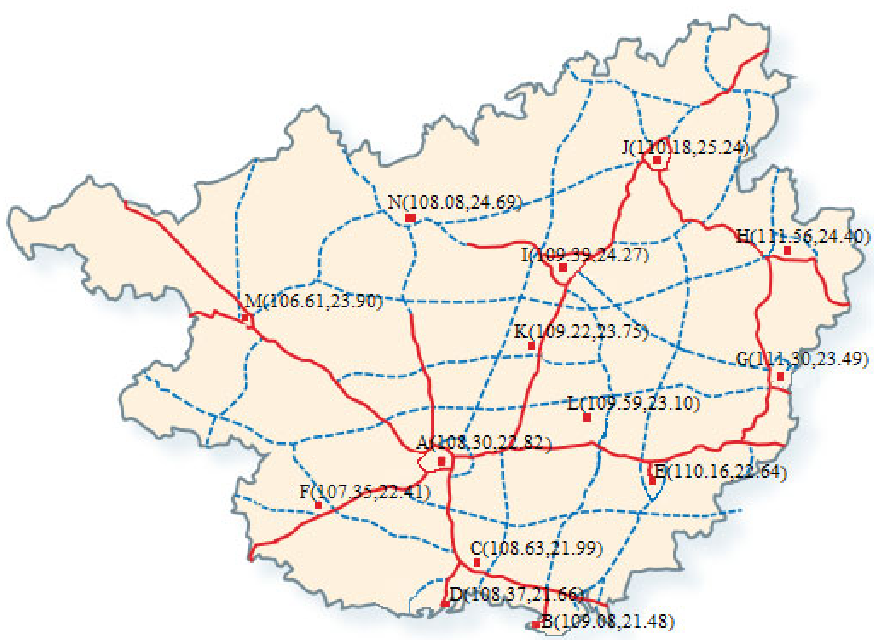

Fig. 1. Initial location model of tropical cyclone disaster emergency supplies reserve center in 14 prefecture-level cities of Guangxi

Data can be put in the Table 3 and Table 4 to generate the Eq. (3-3) get S^0 coordinates the (x^0, y^0) of (108.95, 22.16) (Tiandi Map find this coordinate 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 5.

Table 5

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

Emergency supplies 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 5 into Eq. (3-4), and the coordinates of S^1 (x^1, y^1) are (108.77, 22.01) (Tiandi Map find this 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 emergency supplies 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 6 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 emergency supplies reserve repositories in Guangxi (usually the food and reserve bureau of each city). And d_i^3 that obtained from Table 6 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 emergency supplies 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 6 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 emergency supplies reserve of 14 prefecture-level cities in Guangxi (usually the grain and reserve of each city). And d_i^5 that obtained from Table 6 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 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 tropical cyclone disaster emergency supplies reserve center are all located near Qinzhou East Railway Station, Qinnan District, Qinzhou (also near emergency supplies 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 tropical cyclone disaster emergency supplies reserve Center is within 3km of Qinzhou East Railway Station.

Table 6
The distance between the coordinates of four iterations and the emergency supplies reserve centers of 14 prefecture-level cities in Guangxi

Emergency supplies reserve warehouse No.	Longitude coordinate (x)	Latitude coordinate (y)	(x^1, y^1) S[1] (108.77, 22.01) d_i^2	(x^2, y^2) S[2] (108.70, 21.98) d_i^3	(x^3, y^3) S[3] (108.68, 21.97) d_i^4	(x^4, y^4) S[4] (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

The coordinates of the initial site selection point and the coordinate data obtained from the four iterations in Table 6 are matched to the map of Guangxi to obtain the best location of the Guangxi tropical cyclone disaster emergency supplies Reserve Center, as shown in Fig. 2.

Fig. 2. Optimal scheme of location selection model for tropical cyclone disaster emergency supplies reserve Center in 14 prefecture-level cities of Guangxi

5. Discussion

The location model of the center of gravity method is suitable for the location of a single logistics center in a large area. The center of gravity method does not restrict the selection of specific points, and has great flexibility. Its calculation method is relatively simple and the degree of freedom is relatively large. One disadvantage of the center of gravity method is that the distance between two points ignores the actual road condition 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. In the location model based on GIS, the spatial entities in the location region (including roads and various logistics bases) have been digitized, which can easily obtain the road conditions and transportation conditions between the places of origin and demand, so as to better conform to the actual and objective conditions, and overcome the disadvantages of the center of gravity method to win the linear distance between the places of origin and demand. It can be seen that compared with the traditional location model of the center of gravity model, GIS is more in line with the actual situation, and is a more convenient and effective logistics center location method.

6. Conclusions

An Optimal Location Model of the emergency supply reserve center for tropical cyclone disasters in Guangxi was established using the improved center of gravity method 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 Guangxi tropical cyclone disaster emergency supplies reserve center to ensure the fastest and lowest cost delivery of emergency supplies to the disaster areas in Guangxi. According to the Tiandi 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 that the proportion of emergency material demand of urban node C and surrounding cities B, D, E, F and A in Table 3 is more than 91%.

Acknowledgments

This work is supported by the Financial Support Criteria for Thesis and Oral Presentations for National or International Conferences of Graduate Students of the Faculty of Logistics and Digital Supply Chain, Naresuan University. This work is also supported by the general project of the 2020 National Social Science Foundation, "Research on the Dynamic Mechanism and Policy of High-quality Development of Logistics Industry in Southwest Economic Belt along the Border" (Approval number: 20BJY187).

References

Afshar, A., & Haghani, A. (2012). Modeling integrated supply chain logistics in real-time large-scale disaster relief operations. *Socio-economic planning sciences*, *46*(4), 327-338.

Bo, W. (2006). Application of Uncertain Multiple Attribute Decision Model in Logistics Center Location. *Logistics Technology*, *10*, 30-32.

Cong, W. (2020). Study on the location of regional emergency supplies storage under typhoon disaster scenario (Master thesis). Hangzhou university of electronic science and technology, Hangzhou.

Jiang, T., & Zhu, J. (2007). A robust optimization method for central location in the case of weight uncertainty. *Statistics & Decision*, (5), 32-34.

Jiang, W., & Qian, Y. (2021). Research on optimization model of emergency supplies reserve location from digital perspective. *Transport Business China*, (13), 60-62.

Li, Q., Wang, J., Wang, Y., & Lv, J. (2022). A two-stage stochastic programming model for emergency supplies pre-position under the background of civil-military integration. *Sustainability*, *14*(19), 12080.

Liu, F. (2009). Application of improved, gravity method in location of logistics distribution center. *Logistics Sci-tech*, *32*(6), 19-21.

Ni, W., & Chen, T. (2021). Location selection of emergency logistics distribution center based on clustering-center of gravity method. *Journal of Nanjing University of Technology (Natural Science Edition)*, *43*(2), 255-263.

Rath, S., & Gutjahr, W. J. (2014). A math-heuristic for the warehouse location–routing problem in disaster relief. *Computers & Operations Research*, *42*, 25-39.

Rawls, C. G., & Turnquist, M. A. (2010). Pre-positioning of emergency supplies for disaster response. *Transportation research part B: Methodological*, *44*(4), 521-534.

Sheu, J.-B., & Pan, C. (2014). A method for designing centralized emergency supply network to respond to lager-scale natural disasters. *Transportation Research Part B: Methodological*, *67*(9), 284-305.

Wang, L., & Zhao, X. (2008). An inventory-location problem with stochastic demands. *Operations Research and Management Science*, *17*(3), 1-6.

Wang, Y., Fan, J., Wu, S., & Yang, Y. (2022). A heuristic algorithm optimizing emergency resource storage and location in the South China Sea. *Ocean Engineering*, *268*(12), 113254.

Wen, Y., & He, S. (2007). Research on LRP model based on stochastic correlative chance goal programming. *China Storage & Transport*, (2), 114-116.

Xu, L., Cao, Y., & Lin, P. (2020). Location and Dispatching of Multiple Emergency Materials Center Based on Fusion Immune Optimization and Genetic Algorithm. *Journal of Guangxi Normal University (Natural Science Edition)*, *38* (6), 1-13.

Xu, S. (2020). Study on location selection and route of emergency logistics considering distribution center failure (Master thesis). Dalian Maritime University, Dalian.

Xu, W., Xu, J., Proverbs, D., & Zhang, Y. (2022). A hybrid decision-making approach for locating rescue materials storage points under public emergencies. *Kybernetes*, Vol. ahead-of-print No. ahead-of-print.

Yu, W. (2021). Pre-disaster location and storage model for emergency commodities considering both randomness and uncertainty. *Safety Science*, *141* (5), 105330.

Yue, G., & Zhang, Z. (2013). Study on optimal location model of single-site logistics centers based on GIS. *Logistics Technology*, *32*(23), 205-207.

Zhao, F., & Jin, Y. (2007). Research on RDC location problem in uncertain environment. *Economic & Trade Update*, (SA), 228-229.

Zheng, X., & Ma, L. (2020). Research on emergency material LRP problem considering post-disaster zoning. *Operations Research and Management Science*, *29*(11), 66-77.