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Research on Regional Territorial Development Risk Evaluation Zoning Model Based on Carrying Capacity Theory

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Abstract: The situation of national territorial and ecological security is getting more serious in China. In this study, it is necessary to conduct relative study on territorial development risk evaluation which is from the aspect of based on carrying capacity theory. The relative study can provide an essential method to guide reasonable territorial development, optimize the spatial structure of territorial development and implement the spirit of ecological civilization construction in 18th NCCPC report. In this study, an elaborate review of previous research was carried out firstly, followed by the theoretical discussion on the meaning, conception models and evaluation methods of territorial development risk evaluation. Then two models were built, respectively, which are territorial development risk conception model based on D-P-S-I-R framework and three-dimensional risk matrix evaluation zoning model. Finally, an empirical study was carried out based on North Bay Economic Zone in Guangxi province with reference to these two models. The result shows that territorial resource and its security condition is not in optimistic situation in this region. This study can make up some blanks of current research in some extent and point out the direction for further study. In the meantime, this study hopes to provide scientific basis for making regional territorial development decision and perfecting the management institution of territorial development.

Key words: Territorial development risk, resource-environment carrying capacity, sustainable development, north bay economic zone in guangxi province

INTRODUCTION

With the rapid economic development in China, territorial development extent has been intensified recently. Related issues like resource shortage, environment pollution and ecological system deterioration have become worsen and worsen. In this context, the theme of regional sustainable development has become more and more important in China. As main contributor of territorial development and ecological security provider, the government should conduct study on status quo of regional territorial development and its carrying capacity when developing territorial planning, spatial development planning and resource management. It is to achieve the goal of resource sustainable development, ecological and environmental security and social harmony. Relative study can also make scientific prediction of development risk in future, make reasonable territorial planning and make reasonable layout of regional development. Only in

this way can the risk of territorial development be minimized fundamentally. The 18th National Congress of the Communist Party of China has highlighted the importance of ecological civilization and put it into the layout of socialism with Chinese characteristics. Territorial development risk evaluation is the fundamental work to conduct regional development planning and optimize the spatial development structure, it has strategic and reality meanings in carrying out the ecological civilization strategy and resolving the main tasks in territorial development. Theoretical speaking, territorial development risk evaluation is the further development of environment and resource carrying capacity theory, it can perfect the development of sustainable development theory.

Study of risk evaluation can data back to 1930s (Wu, 2004), it was firstly brought up in the area of financial risk evaluation, enterprise risk evaluation, project risk evaluation, social security risk evaluation,

information security evaluation, etc., (He, 2008; Beck, 2000; Zhang *et al.*, 2010; Yi *et al.*, 1995; Wang and Huang, 2005). In 1970s, environmental risk evaluation was brought up based on risk evaluation and security evaluation. With the involvement of environment management goals and environment concepts, ecological risk evaluation was brought up and witnessed rapid development. Therefore, the theories and methods of ecological risk evaluation have become more and more mature in 1990s, which makes it still the hot topic and leading area in global environmental scientific research (Haith, 2010; Boekhold, 2008; Deng *et al.*, 2011). Disaster risk evaluation is the new edge discipline in risk research area and was on the rapid growth path since 1980s. Nevertheless, disaster risk evaluation in different disciplines is still in the stage of discussion and summarizing (Lu *et al.*, 2003), the leading topic in geological disaster research and environment geological disaster risk evaluation becomes geological research. Related researches in environmental risk evaluation, ecological risk evaluation and disaster risk evaluation all have close relationship with territorial development risk evaluation. With the growing demand of management for territorial development, territorial development risk evaluation has get attention gradually by government managers and scholars. Wu and Pan (2003) brought up the definition of territorial development risk evaluation, Zhou and Zhou (2009) discussed the meaning of territorial security, its evaluation methods and risk avoid methods. Nevertheless, there's little research on territorial development risk evaluation in general, no matter home and abroad (Xia and Song, 2007).

From the review of previous researches, it can be concluded that, most of the research are project risk evaluations from micro perspective, or they are researches from single risk resource and single subject. Due to the complication of risk and shortage of monitoring data, most of the evaluations are qualitative and rough analysis, the quantitative research in different scales are still in the discussion stage (Xu *et al.*, 2001; Wang *et al.*, 2001). Regional comprehensive territorial development risk evaluation and zoning research from macro perspective are still rare because of their characteristics of multi-resources, multi-subjects and multi-risk categorizes and there's no consensus on the research framework and method. In this study, the theory of ecological risk evaluation and resource-environment carrying capacity theory was adopted as reference, in order to discuss the meaning, models and evaluation methods of territorial development risk evaluation. Then, empirical study was conducted on North Bay Economic Zone in Guangxi

province, in order to make up some blanks of current research and provide scientific basis for perfecting regional territorial administration system.

RELATED CONCEPTION AND DEFINITION

Risk is the combination of occurring possibility of some certain dangerous condition and its results. Territorial development risk evaluation is the quantitative evaluation of impact and loss on resource, environment and ecology that brought by territorial development. The evaluation goal is to reflect the comprehensive level, characteristic, potential hazard and spatial structure of territorial development risk. The evaluation result is scientific basis for guiding territorial development, territorial management and ecology protection.

Theoretical speaking, there're three levels of meaning for territorial development risk: Firstly, territorial development may bring loss to resource, environment and ecology. Secondly, territorial development may bring benefits to resource, environment and ecology. Thirdly, territorial development doesn't have any impact on resource, environment and ecology. In this study, from the point view of territorial development and its practical management work, territorial development risk was defined as the loss on resource and environment that brought by territorial development. It is also can be described as the damage and unbalance of "nature-economy-society" system on its structure and function. All of these are brought by the un-appropriate development of land and resource and it can also bring environmental risk, ecological security risk, resource sustainable usage risk and economic and social risk. Territorial development has the characteristics as follow: Objectivity, universality, inevitability, identified, controllability, damageable, uncertainty and sociality.

ORETICAL BASIS

P-S-R carrying capacity model: In the research of carrying capacity, OECD (Organization for Economic Co-operation and Development) firstly brought up "Pressure-State-Response" (P-S-R) framework model in 1991. P-S-R model is one of the most classic and fundamental indexes system methods for quantifying the carrying capacity, it was developed on system theory and has a clear logic framework. Human activity will put pressure on environment and it will bring some change to environmental condition, in the meantime, human society will respond to this environmental change in order to restore environmental quality or prevent the environmental degradation (Wang, 2007). In this system,

“pressure” means the human activity’s direct impact on environment; “state” means the current situation or environmental development trend, also it is environmental issues’ measureable physical characteristics that brought by human activity’s pressure; “response” means the resource and environment policies adopted by the government which can affect “pressure” or “state” directly or indirectly. “P-S-R” framework emphasizes on the resource of environmental pressure. In the meantime, it brings up policies in the process of three stages mentioned above. Therefore, it has a great populous in the work of resource development, plus in the work of ecology environmental management and decision-making. UNEP (United Nations Environment Programme) use the “P-S-R” framework theory in 1995 to evaluate environmental system and its function and build up relationship between human activity’s impact and environment factors. “P-S-R” framework theory has also been used in World Bank’s environmental development indexes system and FAO’s (Food and Agriculture Organization) LQI (Land Quality Indicator) indexes system (FAO, 1997).

Taking “P-S-R” framework theory as foundation, “P-S-I-R”, “D-P-S-I-R” and other framework was developed in the research of carrying capacity conceptual framework. D (“Driving Force”) means those social economic or social cultural factors that can increase or reduce environmental pressure; I (“Impact”) means environmental situation’s effect on human economic and social system. “P-S-I-R” and “D-P-S-I-R” framework have perfected the theory and connotation of comprehensive carrying capacity evaluation on “natural-economic-social” system, meanwhile, it maintains the virtue of “P-S-R” framework system.

Territorial development risk model based on “D-P-S-I-R”: Resource-environment carrying capacity theory (Zhang *et al.*, 2009; Gao, 2001; Tang *et al.*, 2010) and regional territorial development risk theory are both the indispensable part of sustainable development system, which represent different part of regional sustainable development system. Carrying capacity theory emphasizes how the resource-environment system support economic and social sustainable development from the perspective of natural background, while territorial development risk evaluation emphasizes on postnatal effect of human activity. In the meantime, it put more emphasis on security of the process and structure, the functional condition of comprehensive system of “nature-economy-society”. Compared to resource-environment carrying capacity evaluation theory, territorial development risk evaluation evolves

both in temporal and systemic scale. In temporal scale, it studies how to distinguish and shape future structure and regulate the process when obtaining the basic conditions; while in systemic scale, it enlarges the scope from resource-environment system to human social system.

There’s similarity between territorial development risk evaluation and resource-environment carrying capacity on basic elements and functional mechanism, therefore “D-P-S-I-R” conceptual model can be used in territorial development risk evaluation. In order to meet the demand of sustainable development research, theoretical framework of territorial development risk evaluation should reflect some key issues of territorial development risk, such as the connotation, basic elements, the object of risk, scale and data, the relationship between inside system and outside system. which can contribute to the selection of evaluation indexes and the calculation of territorial development risk. In this study, in order to meet the demand of territorial development and its management work, conceptual model of territorial development risk evaluation are developed which is based on resource-environment carrying capacity theory and “D-P-S-I-R” conceptual framework. There’re four modules in “D-P-S-I-R” conceptual framework, which are motivation of territorial development, resource-environment carrying capacity, territorial development risk and territorial development risk prevention (Fig. 1).

Motivation of territorial development-D: Motivation of territorial development is corresponding to driving factor in this framework: It represents the driving factors in social and economic development process that have direct effect on territorial development.

Resource-environment carrying capacity and territorial development potential -P+S: Resource-environment carrying capacity is corresponding to “Pressure” (P) and “State” (S). It represents the relationship between resource-environment and economy-society system, which includes the indexes of carrying capacity in current state and potential indexes of territorial development carrying capacity in future.

Territorial development risk-I: Territorial development risk is corresponding to “Impact” (I). The un-appropriate territorial development may bring damage and unbalance to “nature-economy-society” system’s structure and function, it can also bring out environmental risk, ecological security risk, resource sustainable usage risk and economic and social risk.

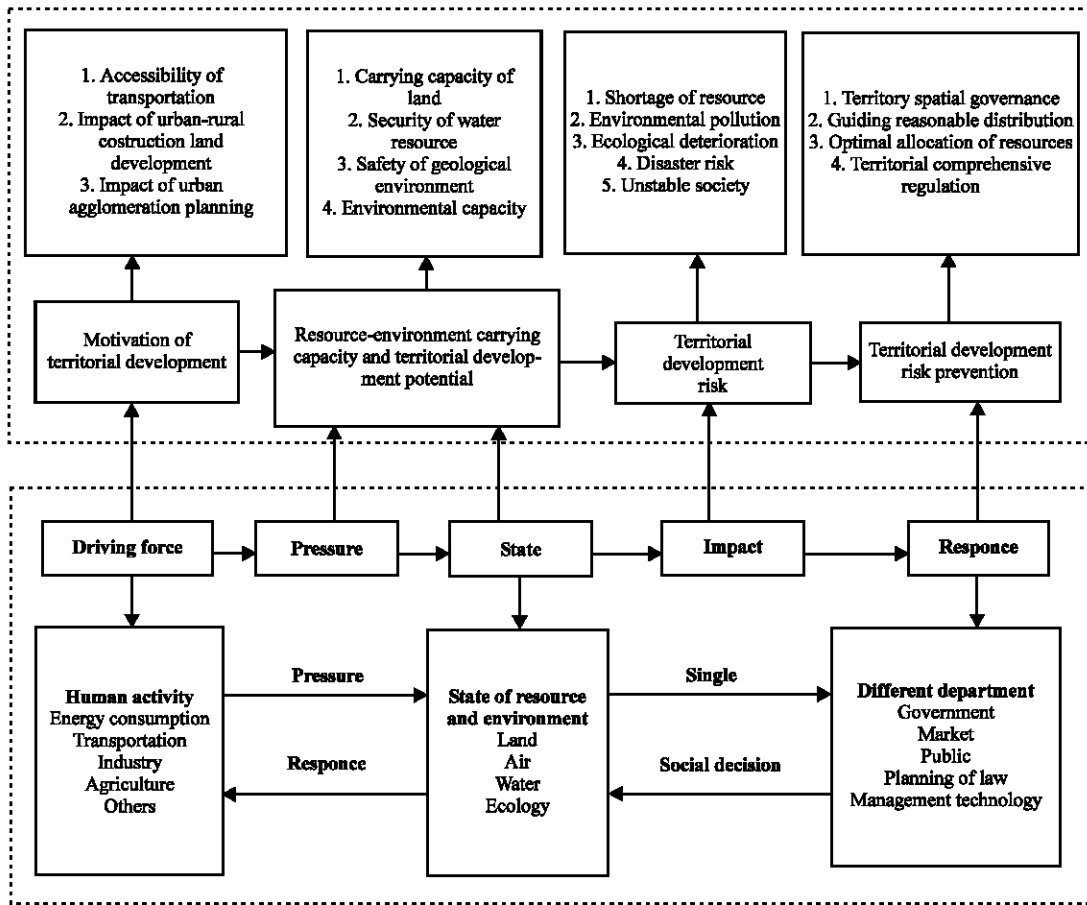


Fig. 1: Conceptual model of territorial development risk evaluation based on resource-environment carrying capacity evaluation

Territorial development risk prevention-R:

Decision-makers will take measures to prevent territorial development risk, like adjusting the scale, distribution and structure of territorial development, conducting comprehensive territorial regulation.

MATERIALS AND METHODS

Generally, speaking, most common used methods for risk evaluation can be defined as two types, which are quantitative and qualitative, respectively. Steps of quantitative methods are as follow: building up mathematic models and collecting some data, then calculating and analyzing the indexes based on the models. The most common used quantitative methods are Risk Matrix Method, Temporal Sequence Analysis Method, Markov Analysis Method, Factors Analysis Method, Decision Tree Method, Entropy Weight Coefficient Method, etc., Qualitative methods are mostly

rely on analyst’s experiences and institutions, it usually use the qualitative indexes to conduct analysis on the system. The most common used qualitative methods are Delphi Method, The Operationally Critical Threat, Asset and Vulnerability Evaluation Method, etc. Risk Matrix Method is a quantitative method mostly used in financial risk evaluation. The process of Risk Matrix Method are as follow: Firstly it divide “Risk Severity” and “Risk Possibility” into different levels according to their characteristics; Then it formulate the risk evaluation matrix and assign weighted values on it in order to determine the level of risk (Li *et al.*, 2010).

Three-Dimensional Rubik’s Cube Figure Method (also known as Three-Dimensional Risk Matrix Method) is based on conceptual model of territorial development risk evaluation and it’s the deepening and modification of risk matrix method. It takes the principle of double criterion risk evaluation matrix as reference and then it brings up the three-dimension matrix evaluation model

after combing the conceptual model of territorial development risk evaluation. In this method, three categories of indexes were brought into one framework, which are resource-environment carrying capacity, territorial development potential and current development driving force. It formulates a three plus three plus three Rubik's Cube Figure in the three-dimensional space, which means there are twenty-seven combination categorizes and each category represents different development risk in that region. Specifically speaking, three categories of indexes were sorted according to their values in each evaluation unit; the catastrophe points were distinguished in the value sequence and then classify the comprehensive value of three categories of indexes into three types. The first type is the ones with high value which coordinate is defined as "three"; the second type is the ones with middle value which coordinate is defined as "two"; the third type is the ones with low value which coordinate is defined as "one". In this way each country's coordinate can be represented with the combination of one, two and three, each combination can represent one Rubik's Cube in Three-Dimensional Rubik's Cube Figure. Since each Rubik's Cube has the corresponding level of risk, the level of risk in each area spontaneously can be evaluated (Fig. 2, Table 1).

RESULTS

Evaluation indexes system: In order to testify the scientific and practical of the model, empirical study of territorial development risk evaluation is conducted on North Bay Economic Zone in Guangxi province. North Bay Economic Zone in Guangxi province is the only coastal economic zone in west China. In this area, port resource, water resource, biological resource and tourism resource is abundant, which indicates that environment capacity in this area is high, ecological system is in good

condition and development potential is huge. In the meantime, with the construction of coastal port and development of coastal industries, territorial development has been intensified in this area, which indicates that environment-resource system is facing huge challenge. Based on development framework of "D-P-S-I-R", territorial development risk evaluation indexes system was built up by combining the environment-resource and development stage conditions in North Bay Economic Zone, to analyze its resource-environment carrying capacity, territorial development motivation and potential (Table 2).

Materials: Research data are from these areas: Land use survey data of Guangxi province in 2010 (plotting scale 1: 200000), Mineral resources statistics data, Water resource bulletin, Territorial resource bulletin, Geological disaster survey data, Environment condition bulletin, Ecology survey report, Meteorological observation data downloaded from China Meteorological Data sharing service (rainfall, temperature, days of sunshine etc.), DEM and slope data (30 m resolution) downloaded from

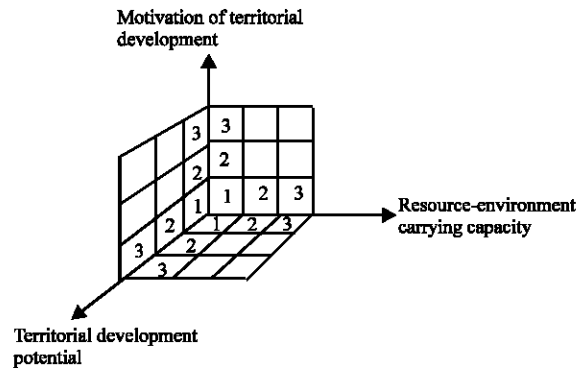


Fig. 2: Zoning model of territorial development risk in Three-dimensional rubik's cube figure

Table 1: Judging criteria of territorial development risk zoning model in three-dimensional rubik's cube figure

Risk grade of territorial development	Carrying capacity level, development motivation level, development potential level	Note
High-risk area	(1, 2, 1) (1, 1, 1) (1, 2, 2) (1, 2, 3) (1, 1, 3) (1, 3, 1) (2, 3, 1) (2, 2, 1) (2, 2, 2)	In this area, resource-environment carrying capacity is low, development motivation is high, while the development potential is low. Territorial development should be appropriate in prerequisite of fully protection of resource and environment
Medium-risk Area	(1, 3, 3) (1, 3, 2) (2, 3, 3) (2, 3, 2) (3, 3, 3) (3, 3, 2) (3, 3, 1) (1, 1, 2)	In this area, resource-environment carrying capacity is low, development motivation is high, while the development potential is still high
Low-risk area	(3, 2, 2) (3, 2, 1) (3, 1, 1) (2, 2, 3) (2, 1, 2) (2, 1, 1)	In this area, resource-environment carrying capacity is high, development motivation and potential is low. This area can be defined as potential area of mass development and the impact on ecological environment should be minimized
Lowest-risk area	(3, 1, 3) (3, 2, 3) (3, 1, 2) (2, 1, 3)	In this are, resource-environment carrying capacity is high, development motivation is low while the development potential is high. Mass development can be conducted in this area and the development risk is low

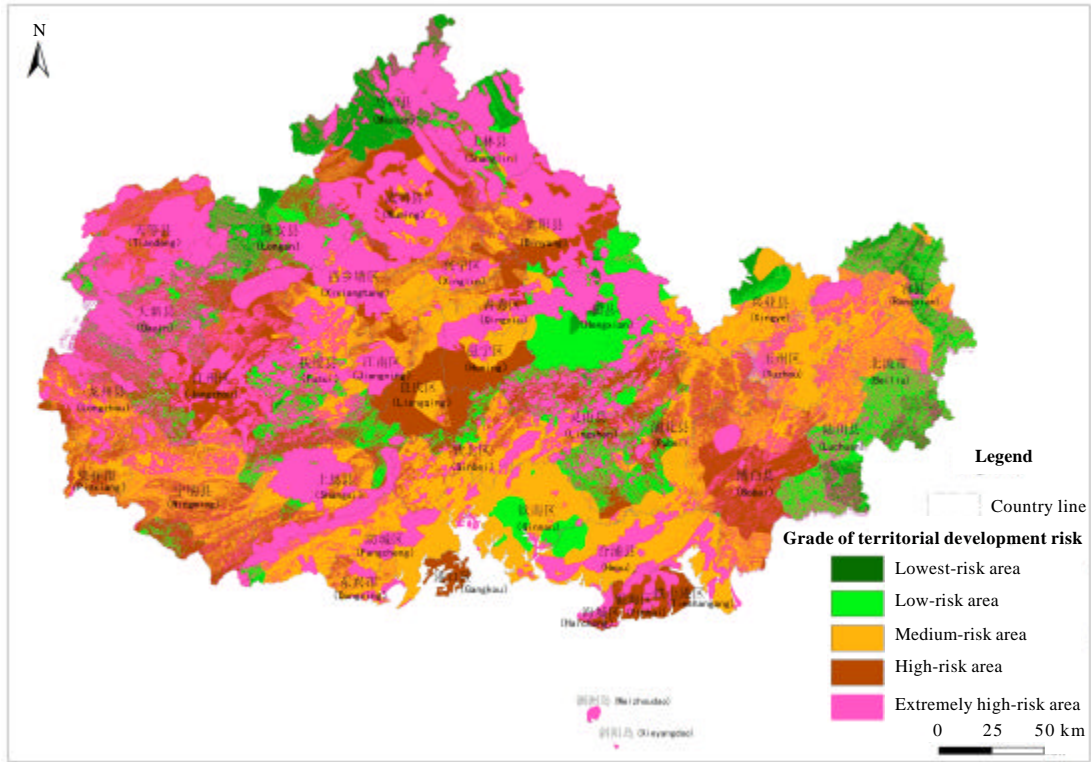


Fig. 3: Map of territorial development risk evaluation in north bay economic zone

Table 2: Territorial development evaluation indexes based on resource-environment carrying capacity

First-grade index	Second-grade index	Third-grade index
Territorial development risk based on carrying capacity		
Motivation of territorial development	Driving force of transportation	Accessibility of transportation
	Driving force of urban development	Impact of urban-rural construction land development
Resource-environment carrying capacity	Security of resource	Impact of urban agglomeration planning
		Security of land resource
		Security of water resource
	Environment capacity	Security of mining resource
		Security of marine resource
Territorial development potential	Ecological flexibility	Security of geological environment
	Used construction land	Remaining environment capacity of air
		Potential of construction land for future development
		Ecological vulnerability
		Current construction land area
		Transportation land
		Constrain of terrain
		Constrain of climate
		Constrain of food security
		Constrain of ecology security

International Scientific Data Service Platform, Distribution map of soil (plotting scale 1:1 million) downloaded from the Environmental and Ecological Data Center for West China (<http://westdc.westgis.ac.cn>) and urban agglomeration planning for “territorial planning of North Bay Economic Zone (2011~2030)”, etc.

DISCUSSION

Make out zoning of North Bay Economic Zone using three-dimensional matrix method and the result is displayed in Fig. 3. According the result it can be found that, lowest-risk area accounts for 16.53% of total area in

North Bay Economic Zone; low-risk area accounts for 13.32% of total area; Medium-risk area accounts for 27.56% of total area; high-risk area accounts for 20.47% of total area; Highest-risk area accounts for 22.12% of total area. Spatially speaking, western and northern areas are on high-risk level, while middle and eastern areas are on low-risk level. Generally, speaking, territorial development is not in optimistic situation in this region. In this way, resource-environment carrying capacity and the result of territorial development risk evaluation should be taken as basis in the work of urban construction, industry park planning and infrastructure construction. In addition, the principle of ecological benefits should be considered firstly, followed by economic and social benefit secondly. The carrying out situation of related planning should be adjusted according to the constrain conditions in research areas. Finally, territorial development risk evaluation can guide territorial development reasonable and make out some matching policies, early warning and emergency methods in order to promote sustainable development in this area.

CONCLUSION

In this study, conceptual model, indexes system and calculation model were developed and applied to evaluate regional territorial development risk based on carrying capacity. This model combines human activity with resource-environment system, which is an innovative attempt of carrying out territorial development risk comprehensive evaluation on regional scale. The empirical study shows that this model is scientific and feasible. This study emphasizes on theoretical research while little effort has been put on empirical study of risk evaluation. Comparing this study with previously studies, they are different in three aspects. First, the scale is different. Most of previous relative studies were developed for project risk or territorial development risk on micro-scale, like the risk of geological disasters and the heavy metal pollution risk of soil and so on. This study is carried out on regional macro-scale. Second, the objectives are different. This study emphasizes the spatial zoning based on risk evaluation, rather than risk loss. Third, the methods are different. This study combines natural, economic and social factors well based on the concept model of D-P-S-I-R.

Due to the openness of comprehensive “nature-economy-society” system and unlimited boundary of development, there’s no absolute criterion of territorial development risk, on the contrary, the criterion should be dynamical and relatively. In the empirical study of territorial development risk evaluation in North Bay

Economic Zone, the risk level is classified as relative high or low. Because the ecological process and impact mechanism of different ecological effect is still ambiguous and territorial development risk evaluation which is based on resource-environment carrying capacity theory is still in the stage of risk classification. Previous researches on territorial development risk evaluation are mostly qualitative and there’s little research on mathematical or physical models, there’re many issues that still need further discussion. Especially in the areas as follow: regional risk formation mechanism, factors related to uncertain, contribution level and relativity, spatial transformation rules, coupling effect, risk resource analysis, indexes system formation, risk measurement methods, risk management policy system and mechanism construction.

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