CHINESE GEOGRAPHICAL SCIENCE
Volume 15, Number 2, pp. 145–150, 2005
Science Press, Beijing, China

THEORIES AND METHODS OF STRATEGIC ENVIRONMENTAL ASSESSMENT OF MODERN LOGISTICS DEVELOPMENT
—A Case Study of Dalian City, China

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ABSTRACT: Modern logistics is a new industry during the construction of national economy. Based on analyzing the environmental problem that was led by the limitation of the strategy during enacting the program of the modern logistics, SEA for modern logistics was implemented. In this paper, procedure and indicator system in the SEA are constructed, and Environmental Check List to identify environmental impact factors of SEA for modern logistics is established. And a conception that indicates friendly degree of logistics system with resources and environment, degree of green, is introduced. With the example of modern logistics program of Dalian in China, two methods are applied, AHP and Fuzzy Comprehensive Evaluation Method, in the implement of SEA for modern logistics development. It is concluded that degree of green of modern logistics in Dalian is high. However, several important factors should be paid much attention to in the SEA for modern logistics as well as in the formulation and implement of modern logistics in Dalian.

KEY WORDS: modern logistics; strategic environmental assessment (SEA); degree of green; Dalian

CLC number: X32 Document code: A Article ID: 1002-0063(2005)02-0145-06

1 INTRODUCTION

As a rising industry, modern logistics play a vital role in the development of urban economy. Meantime, many experts in the world are interested in modern logistics. Study on modern logistics is mostly focused on management and program (HESSE and RODRIGUE, 2004; SLACK, 1998; HANDFIELD and NICHOLS, 1999; WANG and YANG, 2001; ZHANG *et al*., 2004). Modern logistics that is formed by integrating the various function, namely, transportation, packaging, loading/unloading, carrying, consignment, storage, distribution processing, distribution, returned processing and information processing, is a comprehensive mode of the logistics activity, based upon the technology of the modern information (WANG, 2004a). With Chinese economy's internationalization, modern logistics industry has become a new rising-point in the construction of national economy. After entering the WTO, the local development programs of the modern logistics come on. However, before, in and after the implement of the programs, sustainable development of urban environment is negatively affected. In order to coordinate the relation between development and environment, and control environmental degradation from the decision-making sources, Strategic Environmental Assessment (SEA) for modern logistics should be implemented.

SEA is the application of Environmental Impact Assessment (EIA) to strategic actions such as policy, plan or program (PPPs). More detailed SEA is: "The formalized, systematic and comprehensive process of evaluating the environmental impacts of a policy, plan or program and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly accountable decision-making" (THERIVEL *et al*., 1992). Study on SEA has still been in the starting period in China, both theories and methods of SEA have not been perfect yet (ZHANG *et al*., 2002b; CHE and SHANG, 2004; REN and SHANG, 2005).

Received date: 2005-02-03
Foundation item: Under the auspices of the key project of Shandong Provincial Environmental Protection Bureau (No. 2003447)
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Radically, SEA for modern logistics may solve problems led by the formulating of strategy, for instance, lands occupied by the infrastructure facilities of transportation (road, dock and airport); exhaust gas emission of automobile and noise pollution of railway, port and airport; environmental problems in the distribution processing; water pollution from washing truck and carrying chemical and poisonous substances, and SEA for modern logistics may also ensure that the development programs of modern logistics are effectively implemented, that comprehensive decision-making is scientific, and that the comprehensive mechanism of decision-making of environment and development are better constructed. Therefore, in order to solve the environmental problems led by the operation of modern logistics radically, SEA for modern logistics should be implemented in the decision-making as soon as possible, that is, environmental impacts led by programs and alternatives in the decision-making of the modern logistics are considered under sustainable development, and the relation between development and environment at the program level is coordinated, the negative impacts on sustainable development of the urban environment, which is led by government's decision-making misplay of the market macro-control, are avoided or reduced as much as possible, so that environmental degradation can be controlled from the decision-making sources.

2 THEORY SYSTEM OF STRATEGIC ENVIRONMENTAL ASSESSMENT FOR MODERN LOGISTICS

2.1 Work Procedure

SEA at the program level in China has some experiences, however, its work procedure is not uniform and perfect. In this paper, based on domestic and overseas experience of practice, the work procedure of SEA for modern logistics was developed and applied to SEA for modern logistics in Dalian (Fig. 1). The work procedure is composed of three steps, including establishment of appraisal project (first step), implement of assessment (second step) and track management of environment (third step), and each step includes several parts.

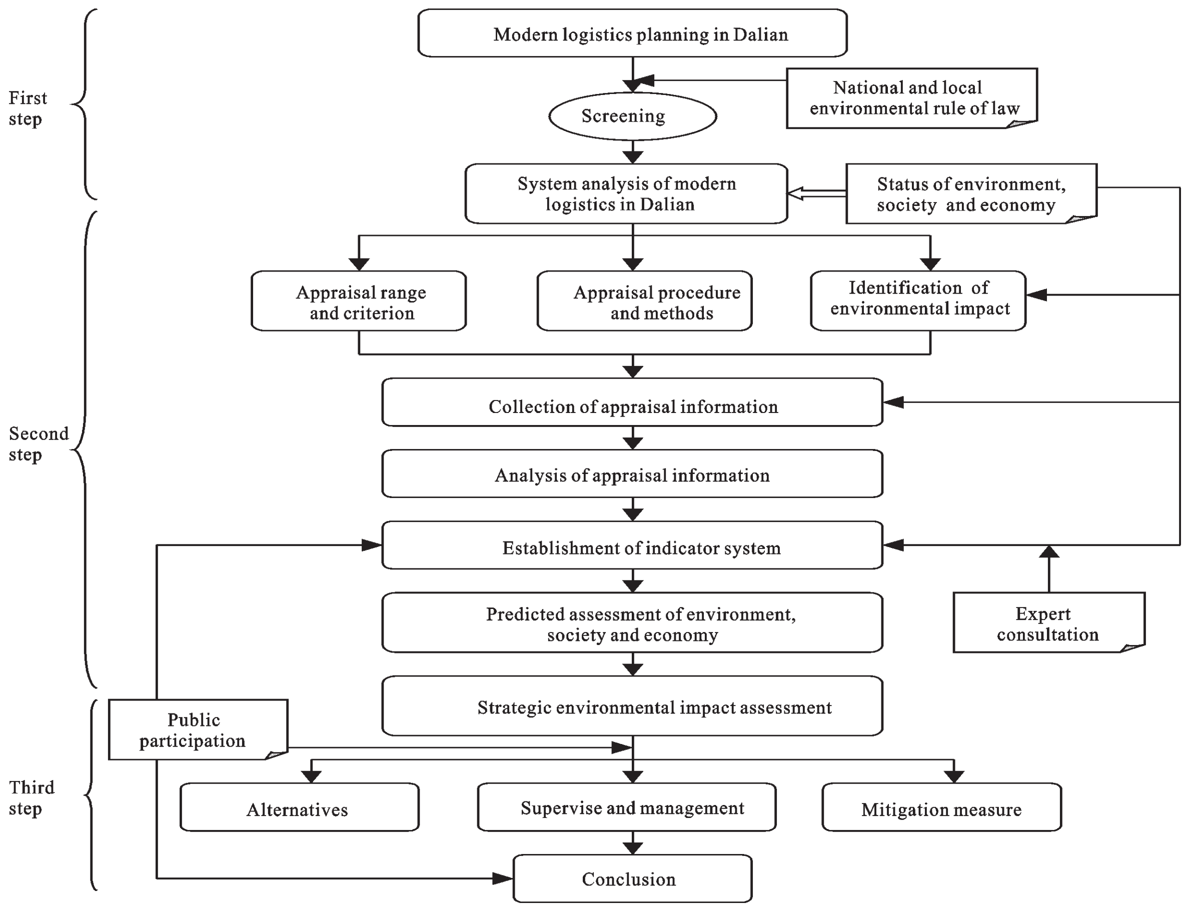

Fig. 1 SEA work procedure of modern logistics development in Dalian

2.2 Theories of SEA for Modern Logistics

2.2.1 Theory of sustainable development

Sustainable development is a development strategy based on sustainable-use resources and environmental substance, including the rising of socio-economy, sustainable using of resources, solving environmental problem in the development, and improving quality of social life and environment. In the development of modern logistics, SEA for modern logistics as a prescient, pioneer and comprehensive systems engineering can promote sustainable development of modern logistics. In the process, environment-economy-society comprehensive system should be sustainably, steadily and well developed, on the basis of environmental sustainability, and on the condition of economic-social sustainability.

2.2.2 Theory of systems engineering

The system of modern logistics is a complicated systems engineering, relating to aspects of environment, economy and society. Through analyzing the structure, function, integrity and correlation of the system, the effect of its sub-system is well understood so that the coordinative development of modern logistics system can be ensured. The basic idea of systems engineering is that parts are entirely considered, and the relation between parts is disposed. It overcomes the traditional disadvantage, that is, singly considering a certain section or object or factor, and it can more correctly deal with complicated space structure of a system than before under comprehensive management so that profits of systemic integrity are obtained as much as possible (ZHANG *et al*., 2002a).

2.3 Study Methods of SEA for Modern Logistics

This paper introduces Assessment of Sustainable Development (ASD) method. ASD assesses the status and trend of sustainable development on the condition of special history and regional environment. It includes many hierarchies, such as indicators, appraisal criterion, developmental speed etc. Ultimately, it will raise the indicators of sustainable development and determine the coordination degree among social and economic development, enhancement of population quality, and carrying capacity of resources and environment (HUANG *et al*., 2003). It also provides SEA for modern logistics with a new method, so that environmental impact in the decision-making of modern logistics is completely showed by the environmental impact on sustainable development, that is, by analyzing the capability change of sustainable development before and after implementing modern logistics program, strategic environmental impact is quantitatively assessed. Its methods include Synthesis Assessment Analysis, Time Sequence Analysis, Fuzzy Synthesis Assessment, Analytical Hierarchy Process and Space Analysis etc.

3 CASE STUDY

3.1 Assessment Frame

For the purpose of ensuring degree of green for logistics system, SEA for modern logistics is implemented. Degree of green for logistics system is a concept that indicates friendly degree of logistics system with resources and environment, namely, a comprehensive measurement of performance of environment, resources, economy and society in an assessed logistics system (WANG, 2004b). Less impact of logistics system on resources and environment is, higher friendly degree and degree of green are. Therefore, friendly degree of every subsystem of logistics system should roundly be considered in the assessment, including environmental impact in the process of production and supply (Fig. 2).

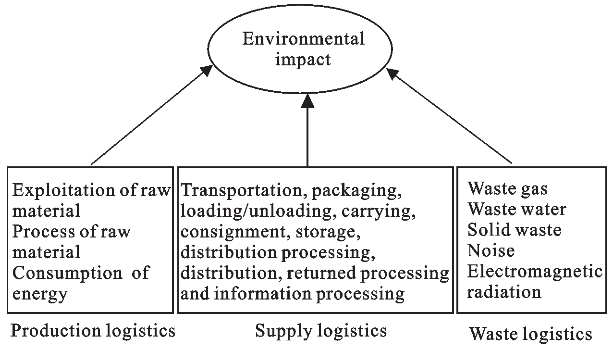

Fig. 2 SEA framework of modern logistics development in Dalian

3.2 Identification of Environmental Impact

Identification of environmental impact is composed of identification of impact type, impact range, impact time and impact character. Identification of environmental impact can make it sure if environmental impact in the implement of logistics program is significant, and find pivotal environmental impact factors. Environmental impact factors in the development of modern logistics in Dalian are identified (Table 1) by using simple environmental check list.

3.3 Establishment of Indicator System

SEA for modern logistics is not only a process that quantifies and assesses degree of green for logistics system, but also a complicated systems engineering that assesses environmental impact in the development of modern logistics. Moreover, modern logistics system is a nonlin-

Table 1 Environmental check list of development of modern logistics

Development performance		Environmental impact	Non-significant impact	Significant impact		
				Little	Moderate	Great
Site selection	Social-economic impact	Dissatisfaction of dweller around	√			
	Land use	Land changing from agriculture into industry			√	
	Augment of transportation	Augment of noise and waste gas emission				√
Construction	Emission of poisonous material	Damage to quality of water, soil and air		√		
	Vibration and noise	Harming factories and dweller around			√	
	Destruction of environmental aesthetics	Destruction of environmental aesthetics	√			
Run	Logistics transportation	Augment of environmental load				√
	Logistics storage	Pollution of surrounding		√		
	Sanitation and water supply of park	Sanitation and water supply of park	√			
	Distribution processing	Producing "three waste"			√	
	Logistics packaging	Resources waste and augment of solid waste				√
	Logistics loading and unloading	Leakage of poisonous material			√	
	Information flat	Impact on environment	√			

ear, multi-factor, dynamic system, and its impact factors of degree of green for modern logistics are also complicated and multi-level, so its indicator system is different from that of SEA for other programs. Therefore, appraisal criterion and indicators are established by referring to development of modern logistics in Dalian, based on domestic and overseas experience of SEA (CHEN, 2001; LI and ZOU, 2003; BELTRAN, 2002; STOCK, 1992) (Table 2).

3.4 Calculation of Indicator Weight Using AHP

Appraisal model is established by using Analytic Hierarchy Process (AHP) that can solve fuzzy problem for indicator system. After consulting experts, relative weights of appraisal indicators are calculated according to the important degree of impact of sub-level appraisal indicators on level appraisal indicators. Then, consistence is tested. Finally, comprehensive weights of SEA indicator for modern logistics development in Dalian are concluded (Table 3).

3.5 Comprehensive Assessment

The indicator system of SEA for modern logistics in Dalian is so multi-attribute and fuzzy that it is difficult to quantify the appraisal indicators correctly, therefore, Fuzzy Comprehensive Evaluation Method is used in the SEA for modern logistics in Dalian. The appraisal steps are listed as follows: 1) Establishing appraisal factor set including indicator factor set $U=\{U_1, U_2, U_3, \cdots U_{33}\}$. 2) In order to calculate simply, choosing factor remark set $V=\{$high, moderate, low$\}$. Fuzzy Comprehensive Evaluation is a process that computes factor weights and appraises single factor (TAN, 2002), so it is of importance to compute weights. 3) Referring to involved data and status of modern logistics in Dalian, computing weight set A applying AHP method (Table 3). After having consulted experts and established matrix of fuzzy relation (matrix of single factor evaluation), authors apply DPS Data Processing System for Practical Statistics to calculating and normalizing results, finally draw a conclusion of comprehensive appraisal, $b=(0.54645, 0.25761, 0.19594)$.

However, indicator factors are so many in the evaluation that some information is screened in the "maximal value" and "minimal value", and appraisal results are error. Therefore, weight set should be adjusted, that is, when numbers of indicator factors are more than that of remark factors, weight of every factor is adjusted in terms of following formula (TANG and FENG, 2002), and final results are listed in Table 4.

$$a'_i = a_i \cdot n/m$$

where a_i' is adjusted weight; a_i, original weight; n, number of indicator factors; m, number of factor remark.

It is concluded that degree of green of modern logistics in Dalian is high according to Maximal Subjection Principle, that is, system of modern logistics in Dalian is friendly with resources and environment highly. However, it is noted that weight values of several factors are higher among factors influencing degree of green of logistics system in Dalian, that is, extent of impact on resources and environment is greater. They include D_2 (total volume of SO_2 emission) (0.062), D_3 (up-to-standard rate of automobile exhaust) (0.122), D_8 (average value of urban traffic artery) (0.066), D_{12} (percentage of solid waste treatment) (0.140), D_{13} (percentage of recycle utilization of resources in processing) (0.074), D_{16} (energy consumption in production process) (0.074). The above important factors should be paid much attention to in the SEA for modern logistics as well as in the formulation and implement of modern logistics in Dalian.

Table 2 Indicator system of assessment of modern logistics in Dalian

Objective level	Rule level	Indicator level	Sub-indicator level	
Degree of green	Environment performance (B_1)	Air pollution	Total volume of waste gas emission	(D_1)
			Total volume of SO_2 emission	(D_2)
			Up-to-standard rate of automobile exhaust	(D_3)
		Water pollution	Total waste water discharge	(D_4)
			Percentage of treated industrial waste water	(D_5)
			Percentage of discharge of industrial waste water up to the standard	(D_6)
			Average value of inshore pollutant	(D_7)
		Noise pollution	Average value of urban traffic artery	(D_8)
			Average value of regional noise	(D_9)
			Equivalent sound level of noise	(D_{10})
		Solid waste	Industrial solid waste	(D_{11})
			Percentage of solid waste treatment	(D_{12})
	Resources performance (B_2)	Raw material	Percentage of recycle utilization of resources in processing	(D_{13})
			Degree of effective utilization of packing material	(D_{14})
			Percentage of resources utilization in distribution processing	(D_{15})
		Energy	Energy consumption in production process	(D_{16})
			Energy consumption for vehicle	(D_{17})
		Other resources	Percentage of arrangement and utilization of infrastructure	(D_{18})
			Availability of information	(D_{19})
	Economy performance (B_3)		Gross industrial output value	(D_{20})
			Increasing rate of GDP	(D_{21})
			Product sale income	(D_{22})
			Composite index of transportation benefit	(D_{23})
	Society performance (B_4)	Transportation	Total volume of port cargo and container	(D_{24})
			Density of transport net	(D_{25})
			Increase rate of total volume of annual transport	(D_{26})
			Average volume of annual turnover	(D_{27})
		Population	Population	(D_{28})
			Population density	(D_{29})
			Percentage of labor force for tertiary industry	(D_{30})
		People's livelihood	Engel's coefficient	(D_{31})
			Per capita gross retail sales of social consumables	(D_{32})
			Per capita monthly income of town resident	(D_{33})

Table 3 Comprehensive weight of SEA indicator of modern logistics development in Dalian

Indicator	B_1	B_2	B_3	B_4	Comprehensive weight	Indicator	B_1	B_2	B_3	B_4	Comprehensive weight
	0.556	0.252	0.097	0.097			0.556	0.252	0.097	0.097	
D_1	0.019				0.011	D_{18}		0.061			0.015
D_2	0.109				0.061	D_{19}		0.028			0.007
D_3	0.219				0.122	D_{20}			0.136		0.013
D_4	0.017				0.009	D_{21}			0.543		0.053
D_5	0.021				0.012	D_{22}			0.076		0.007
D_6	0.023				0.013	D_{23}			0.244		0.024
D_7	0.044				0.024	D_{24}				0.234	0.023
D_8	0.118				0.066	D_{25}				0.119	0.012
D_9	0.067				0.037	D_{26}				0.127	0.012
D_{10}	0.067				0.037	D_{27}				0.259	0.025
D_{11}	0.046				0.026	D_{28}				0.021	0.002
D_{12}	0.251				0.140	D_{29}				0.021	0.002
D_{13}		0.295			0.074	D_{30}				0.072	0.007
D_{14}		0.132			0.033	D_{31}				0.038	0.004
D_{15}		0.091			0.023	D_{32}				0.069	0.007
D_{16}		0.295			0.074	D_{33}				0.041	0.004
D_{17}		0.098			0.025						

Table 4 Weight of fuzzy synthetic assessment of green degree of modern logistics in Dalian

Indicator	a	a'	Indicator	a	a'	Indicator	a	a'
D_1	0.011	0.121	D_{12}	0.140	1.540	D_{23}	0.024	0.264
D_2	0.061	0.671	D_{13}	0.074	0.814	D_{24}	0.023	0.253
D_3	0.122	1.342	D_{14}	0.033	0.363	D_{25}	0.012	0.132
D_4	0.009	0.099	D_{15}	0.023	0.253	D_{26}	0.012	0.132
D_5	0.012	0.132	D_{16}	0.074	0.814	D_{27}	0.025	0.275
D_6	0.013	0.143	D_{17}	0.025	0.275	D_{28}	0.002	0.022
D_7	0.024	0.264	D_{18}	0.015	0.165	D_{29}	0.002	0.022
D_8	0.066	0.726	D_{19}	0.007	0.077	D_{30}	0.007	0.077
D_9	0.037	0.407	D_{20}	0.013	0.143	D_{31}	0.004	0.044
D_{10}	0.037	0.407	D_{21}	0.053	0.583	D_{32}	0.007	0.077
D_{11}	0.026	0.286	D_{22}	0.007	0.077	D_{33}	0.004	0.044

4 CONCLUSIONS

In order to coordinate relation between society and environment at the program level, and control environmental pollution and degradation from the decision-making sources, SEA for modern logistics program should be developed so as to minimize the environmental impact and maximize the efficiency of resources utilization. This paper preliminarily studies SEA theories and methods of modern logistics program, introduces a conception of degree of green, implements SEA for modern logistics in Dalian using AHP Method and Fuzzy Comprehensive Evaluation Method. It is concluded that degree of green of modern logistics in Dalian is high according to Maximal Subjection Principle, that is, system of modern logistics in Dalian is friendly with resources and environment highly. However, because of limitation of available data, this paper just analyzes and assesses degree of green of modern logistics in Dalian semi-quantitatively and semi-qualitatively, and degree of green of modern logistics in Dalian needs to be further quantified in the future.

REFERENCES

BELTRAN L S, 2002. Reverse logistics: Current trends and practices in the commercial world [J]. *Logistics Spectrum*, 36 (3): 4–8.

CHE Xiu-zhen, SHANG Jin-cheng, 2004. Strategic environmental assessment for sustainable development in urbanization process in China [J]. *Chinese Geographical Science*, 14(2): 148–152.

CHEN Da, 2001. Research of modern green logistics management and its strategy [J]. *China Population, Resources and Environment*, 11(2): 111–113. (in Chinese)

HANDFIELD R B, NICHOLS E L, 1999. *Introduction to Supply Chain Management* [M]. New Jersey: Prentice-Hall.

HESSE M, RODRIGUE J-P, 2004. The transport geography of logistics and freight distribution [J]. *Journal of Transport Geography*, 12: 171–184.

HUANG Si-ming, OU Xiao-kun, YANG Shu-hua *et al*., 2003. *Assessment of Sustainable Development* [M]. Beijing: Higher Education Press; Heidelberg: Springer, 84–85. (in Chinese)

LI Hong-di, ZOU Zhu-yu, 2003. Sustainable development of transport and construction of its indicator system [J]. *Transport Environmental Protection*, 24(4): 17–19. (in Chinese)

REN Li-jun, SHANG Jin-cheng, 2005. Necessity and method of public participation in srategic environmental assessment of China [J]. *Chinese Geographical Science*, 15(1): 42–46.

SLACK B, 1998. Intermodal transportation [A]. In: HOYLE B, KNOWLES R(eds.). *Modern Transport Geography* [M]. Second edition. London: Wiley, 263–289.

STOCK J R, 1992. *Reverse Logistics* [M]. Florida: Council of Logistics Management, USA.

TAN Yue-jin, 2002. *Quantitative Analysis Methods* [M]. Beijing: China Renmin University Press, 135–137. (in Chinese)

TANG Ning, FENG Ming-guang, 2002. *DPS Data Processing System for Practical Statistics* [M]. Beijing: Science Press, 607–608. (in Chinese)

THERIVEL Riki, WILSON Elizabeth, THOMSON Steward *et al*., 1992. *Strategic Environmental Assessment* [M]. London: Earth-scan Publication Ltd.

WANG Chang-qiong, 2004a. *The Systems Engineering of Logistics* [M]. Beijing: Substance Press in China, 1–2. (in Chinese)

WANG Chang-qiong, 2004b. *Green Logistics* [M]. Beijing: Chemical Industry Press, 223–224. (in Chinese)

WANG Zhan-quan, YANG Dong-yuan, 2001. Study on modern logistics system development [J]. *Journal of Xi'an Highway University*, 21(3): 61–65. (in Chinese)

ZHANG Hua-liang, GU Zu-li, JIN Guo-bin, 2004. Transport package's dynamic reliability of modern logistics [J]. *Packagng Engineering*, 25(4): 135–138. (in Chinese)

ZHANG Yan, SHANG Jin-cheng, CHEN Chong, 2002a. Tentative analysis of strategic environmental assessment of green manufacturing [J]. *Environmental Science and Technique*, 25(2): 25–28. (in Chinese)

ZHANG Yan, SHANG Jin-cheng, YU Xiang-yi, 2002b. Strategic environmental assessment on land-use planning [J]. *Chinese Geographical Science*, 12(3): 262–267.