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A Demonstrative Study for Risk Factors of Green Supply Chain Management – with the Automobile Manufacturing Industry of Guangxi as an Example

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Abstract: Today a global significant issue is to reduce carbon emission and promote sustainable development of enterprises. As the low-carbon technology and philosophy has progressed, the green supply chain management marked by "low-carbon" will change the production style and life style of human society radically. Green supply chain is an industrial ecological system with low carbon as its key feature. Traditional manufacturers consume huge energy and produce low output, and thus green supply chain management is wanted to integrate the operational environments of the whole green supply chain. Any problem to any phase of the running green supply chain will impact the integrity of the whole green supply chain. Therefore, it's especially important to make correct assessment and cognition on the uncertainty and blindness intrinsic to the risks arising from the supply chain. Based on consulting literatures on green supply chain management home and abroad, this paper makes statistical analysis and study on risk factors of green supply chain management in the automobile manufacturing industry of Guangxi. Purpose of this paper is to cognize the risk factors for enterprises to implement green supply chain management, and thus to provide references to the government's making policies and enterprises' implementing green supply chain management.

Keywords: Green Supply Chain Management; Risk Factors; Factor Analysis; Automobile Manufacturing Industry of Guangxi

1. Introduction

Today a global significant issue is to reduce carbon emission and promote sustainable development of enterprises. As human beings have been in industrial time living, the manufacturing industry has been rapidly developed. It provides abundant products while causes shortage of resources and pollution to environment, protruding the conflict among population, resources, and environment.[1] A number of researchers has made studies into how the green supply chain management diminishes the negative influence brought by the manufacturing industry to the environment. The green supply chain management marked by "low carbon" will change the production style and life style of human society radically. Green supply chain is an industrial ecological system with low carbon as its key feature. As infinite factors are involved and the operational process is complicated, therefore, the management on green supply chain is highly risky. However, until now only a few studies had been made on the risks intrinsic to green supply chain management and related problems. For example, Yan Jiang (2007) deemed that huge risks are contained in the process of green supply chain management, and he analyzed the factors that influence risks contained in green supply chain management from the aspects of asymmetrical information, constraints of external environment, selection of distributors, cultural difference, and corporate morality etc., using the household appliance manufacturers of China as the demonstrative case.[2] In the opinion of Zheng Ren (2003), various risks will occur among cooperative enterprises linked by green supply chain management because of the existence of factors as asymmetric information, information distortion, uncertain market and change of factors as politics, economy, and laws. Moreover, he analyzed the source of risks in green supply chain management and their influential factors from the endogenous risks arising from causes of moral risks, distorted information, and individual rationality and from the exogenous risks arising from causes of political risks, war risks, economic risks, legal risks, and technical risks etc. At last he presented a theoretic model for preventing risks in green supply chain, with tools to increase information transparency and sharing, establish efficient incentive and disciplinary mechanism, and reinforce the mutual trust of partners. [3] Zeng Yan(2005) put forward an analysis into the source of risks intrinsic to green supply chain from the aspects including supplier management, contract violation by supplier or customer,

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change of market demand, and information asymmetry etc., and presented her attempt in clarifying risk alert mechanism and emergency responses of green supply chain.[4]

Risk control of supply chain becomes more important due to economic globalization. Typical risk control measures include four basis phases, namely risk cognition, risk assessment, risk decision, and managerial action taking and risk monitoring. An important subject in supply chain research is how to measure, transfer, and manage risks of supply chain. [5] Many scholars attached their attention to risk control of supply chain. [6-10] They probed into risk factors of supply chain from different aspects as internal or external environments of an enterprise, and endogenous, exogenous, or social or natural environment of an enterprise. However, their literatures did not cognize any risk factors from the aspect of complicated supply chain network. Until now still qualitative study is dominant, while quantitative study is seen scarcely. Studies in literatures[11—12] argued that in the uncertain, dynamic complicated system of the supply chain network, it is dangerous to make decision based on some static and simplified cognitive model. When risks arise, the system fluctuates as the disturbance factors are out of control. Therefore, they took it necessary to take account of dynamic complexity and feedback mechanism into the risk management of supply chain. Enterprises are in a dilemma when to implement green supply chain. On the one hand, they will fear the loss of core competence in the future if they neglect the green performance of supply chain. On the other hand, they shall shoulder risks when to implement green supply chain management. Based on such facts and situation, it is especially important for the government to cognize the risk factors in Chinese manufacturers' green supply chain management, and to encourage, conduct, and facilitate such manufacturers' implementing active environmental management policies.

This paper, based on its comprehensive survey over literatures home and abroad, its consideration on opinions from environmental management experts, using automobile manufacturing industry of Guangxi as an example, cognizes risk factors in Chinese manufacturers' implementing green supply chain management and analyzes the weak points, providing references for the government to facilitate Chinese enterprises to implement green supply chain management.

2. An Analysis into Risk Factors in the Green Supply Chain Management of the Automobile Manufacturing Industry of Guangxi

This paper surveyed the risk status of green supply chain in automobile manufacturers of Guangxi. From June to December 2009, totally 120 questionnaires were issued, and 100 valid questionnaires were recovered, with a validity ratio of 83.3%. The surveyed manufacturers are mainly in the sectors of entire vehicle manufacturing, auto parts, components and accessories manufacturing, modified vehicle manufacturing, automobile repair, and electric vehicle manufacturing etc. Among the surveyed manufacturers 6 are for entire vehicle manufacturing (6%), 56 are for parts, components, and accessories manufacturing (56%) , 8 are for modified vehicle manufacturing (8%), 22 are for automobile repair (22%), and 8 are for electric vehicle manufacturing (8%). The automobile manufacturing industry of Guangxi has certain high influence in South China. As an industrial city of Guangxi, Liuzhou owns an industrial cluster of automobile manufacturing. In order to make the survey and analysis results reflect fully the facts of the automobile manufacturing industry of Guangxi, samples selected and surveyed in this paper are mainly automobile manufacturers, with Liuzhou as the key premise. Questionnaires are issued through two ways: 1) Field issuing to enterprises (generally joint ventures and sole proprietorship enterprises) in Nanning and at the automobile manufacturing base of Liuzhou, Guangxi (based on GDP). 2) Sent to experts of the manufacturing industry of Guangxi (all are experts who have outstanding accomplishments and rich experience in the manufacturing industry).

The questionnaire includes five parts, namely: background, profile of risks in green supply chain of traditional manufacturing industry of Guangxi, risk factors of green supply chain, results from risk control of green supply chain, relationship between risk control of green supply chain and traditional automobile manufacturing industry. Totally 9 risk factors and 53 variables (see Table 1) are included. For every particular problem, Likert scale is used to design five grades based on particular implementation and effects; they are: 1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high.

We gave a brief introduction on the risks of green supply chain before everyone filled out the questionnaire. This is to improve the validity of the recovered questionnaire. SPSS software was used to make descriptive statistical analysis, factor analysis, and path analysis on effective questionnaires.

2.1. Descriptive Analysis

Table 1. Descriptive Sta1tistical Analysis

Risk Factors	Risk Variables	Sample Number N	Mean Value	Standard Deviation
Environmental Factors	Risk of Natural Environment	100	3.28	0.60744
	Risk of Social Environment	100	1.24	0.51745

	Risk of Economic Environment	100	1.04	0.19795
	Risk of Policy Change	100	1.08	0.27405
	Other Unexpected Risks	100	1.04	0.19795
	Risk of Management Cognition	100	1.00	0
	Risk of Environmental Concept	100	1.76	0.43142
Cultural Factors	Risk of Humanity's Status	100	1.22	0.50669
	Risk of Stuff and Skill	100	1.44	0.86094
	Risk of Cultural Awareness	100	3.02	0.68482
	Risk of Value Idea	100	3.32	0.620732
	Risk of Customer Change	100	2.86	0.45221
	Risk of Public Relations	100	3.88	0.59385
Demand Factors	Risk of Service Quality	100	3.94	0.42426
	Risk of Customer's Finance	100	1.56	0.73290
	Risk of Demand Fluctuation	100	1.34	0.59281
	Risk of Competitor's Replacement	100	1.54	0.86213
	Risk of Purchase Price	100	2.54	1.44575
	Risk of Exchange Rate Fluctuation	100	2.40	1.4983
Purchase Factors	Risk of Supplier Selection	100	2.60	1.4846
	Risk of Product Purchase	100	1.64	1.10213
	Risk of Core Product	100	1.60	1.12486
	Risk of Supplier's Supply Capability	100	2.18	1.17265
Supply Factors	Risk of Supplier's Market Competence	100	2.56	1.37262
	Risk of Supplier's Supply Period	100	1.24	0.82214
	Risk of Supplier's Technical Innovation	100	1.78	1.41839
	Risk of Inventory Control	100	1.12	0.59385
	Risk of Alert Mechanism	100	3.14	0.83324
Control Factors	Risk of Financial Mechanism	100	3.06	0.61974
	Risk of Legal Duties	100	2.36	0.66271
	Risk of Management System	100	1.50	0.90914
	Risk of Operational Safety	100	1.00	0
	Risk of Self-serving	100	2.66	0.74533
	Risk of Morality	100	1.98	0.714
Cooperation Factors	Risk of Trust	100	1.56	1.14571
	Risk of Interest Allocation	100	1.10	0.50508
	Risk of Evasion	100	1.02	0.14142
	Risk of Structure	100	2.36	1.43939
	Risk of Authorization	100	1.82	1.24031
System Factors	Risk of Flexibility	100	1.24	0.77090
	Risk of Network	100	1.20	0.69985
	Risk of Technical Use	100	1.68	1.30055
	Risk of Software	100	1.96	1.22824
Process Factors	Risk of Business Process	100	2.38	0.69664
	Risk of Production Capability	100	1.86	0.83324
	Risk of Product Pricing	100	2.12	1.08119
	Risk of Human Resource	100	1.96	1.38446
	Risk of Information Sharing	100	2.28	0.80913
	Risk of Knowledge Sharing	100	3.96	0.44994
	Risk of Product Safety and Environmental Protection	100	3.70	1.32865
	Risk of Lawsuit	100	3.56	0.92934
	Risk of Natural Environment	100	2.18	0.74751
	Risk of Social Environment	100	1.96	0.49322

From Table 1 we know that among 100 investigated enterprises, 23 risk variables are subject to 9 risk factors of green supply chain, with mean value bigger than 2. This means that 23 risk variables have largest impact to the green supply chain management of the automobile manufacturing industry of Guangxi, and this manufacturing industry faces the challenges from pressures of society, environment, and market. Moreover, enterprises of this manufacturing industry have realized what means the cognition to risk factors of green supply chain on their survival and development.

2.2. Factor Analysis

We selected 23 risk variables in descriptive statistical analysis for factor analysis. Only variables with shared commonness can be used for factor analysis. Correlation analysis can be used to test the commonness among variables. Therefore, firstly we used SPSS to make correlation analysis on 23 risk variables. We found that correlation exists among these 23 risk variables, and most variables have correlation coefficient bigger than 0.5. Meanwhile when the significance level is 0.05, these risk variables are correlative statistically[13]. Therefore, factor analysis can be made on these risk variables.

Kaiser-Meyer-Olkin(KMO) Measure is an index to compare the simple correlation coefficient and partial

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correlation coefficient of variables. Its value is between 0 and 1. When the sum of the squares of the simple correlation coefficients of all variables is far bigger than the sum of the squares of partial correlation coefficients of such variables, KMO value approximates 1. This means variables have strong correlation and they can be used for factor analysis. Generally KMO value > 0.75 means the variables are suitable for factor analysis. [14] Factor analysis made on 23 risk variables produced KMO value 0.677, which means that the variables shall be adjusted before any factor analysis is made. With principal factors/components extracted according to characteristic root bigger than 1 and the varimax rotation method, 3 principal factors are extracted from 23 variables to contribute to 87.175% in an accumulated way. This means that these 3 principal factors can reflect 87.175%contents of 23 risk variables.

In order to reduce the number of risk variables and simplify the process of data analysis, firstly we delete those risk variables that have proximate load values larger than 0.35 on two or more variables. Then we made factor analysis on the remained risk variables, till we got the simplified results as requested, namely no value of the load of any risk variable on two or more variables is bigger than 0.35, and their values are proximate. [15][16] Given such a situation, seven risk variables, including risk of humanity's status, risk of stuff and skill, risk of supplier's technical innovation, risk of inventory control, risk of management system, risk of supply chain sharing, and risk of product safety and environment protection, were deleted after we finished the first factor analysis. Next we made factor analysis on the remained 16 risk variables with KMO value 0.849. Using the same method we extracted 3 principal factors (marked as Y_1, Y_2 and Y_3), whose accumulated contribution is 90.498%. Characteristic values and contribution rates of these 3 principal factors are shown in Table 2.

Table 2. Characteristic Values and Contribution Rates of 3 Principal Factors

Principal factors	Y_1	Y_2	Y_3
Characteristic value	7.019	3.976	3.484
Contribution rate (%)	43.87	24.851	21.777
Accumulative Contribution rate (%)	43.87	68.721	90.498

After varimax rotation was made on these three factors, we got the factor loading matrix of Table 3.

Table 3. Factor Loading Matrix of Orthogonal Rotation

Risk Variables	Extracted Principal Factors			Reliability Test
	Y_1	Y_2	Y_3	
Risk of Demand Fluctuation	0.948	0.248	0.108	0.981
Risk of Competitor's Replacement	0.900	0.308	0.074	
Risk of Purchase Price	0.951	0.201	0.116	
Risk of Product Purchase	0.821	0.514	0.100	
Risk of Core Product	0.937	0.276	0.127	
Risk of Interest Allocation	0.827	0.531	0.077	
Risk of Business Process	0.885	0.307	0.123	
Risk of Information Sharing	0.805	0.280	0.377	
Risk of Natural Environment	0.306	0.897	0.207	0.960
Risk of Alert Mechanism	0.353	0.887	0.010	
Risk of Technical Use	0.414	0.851	0.204	
Risk of Product Pricing	0.507	0.741	0.288	
Risk of Cultural Awareness	0.264	0.049	0.883	0.917
Risk of Value Idea	0.103	0.043	0.956	
Risk of Customer Change	0.018	0.096	0.800	
Risk of Human Resource	0.113	0.326	0.873	

Note: The method of principal component analysis is used to extract factors, with 3 times of varimax rotation.

In order to verify the variables subject to the principal factors are for the measurement of the same property, further internal reliability analysis shall be made on the screened data based on factor analysis. We got 3 Cronbach's alpha coefficients 0.981, 0.96, and 0.917 from the risk factors of the green supply chain in the automobile manufacturing industry of Guangxi. All these 3 Cronbach's alpha coefficients are larger than 0.80[17], thus the information of the scale is acceptable. This guarantees the consistency and validity of the variables that construct the analyzed factors.

Based on the basic theory of factor analysis, we know that these 3 principal factors have no correlation. However, every principal has strong correlation with the risk variables it contains. Coefficients of Table 3 are the estimated load values of the orthogonal rotated factors. Statistically these coefficients relate the correlation between risk variables and principal factors, namely the load. According to the results of statistic analysis and the information expressed by three 3 principal factors, we may re-define them as: Y_1 the market environment an enterprise faces, Y_2 the internal and external crises that challenge an enterprise, and Y_3 the humanity resource crisis of an enterprise. Table 4 shows the extracted prin-

cipal factors and their meaning.

Table 4. Extracted Principal Factors and their Meaning

Principal Factor	Meaning	Contribution rate a_i	Normalized result Ai
Y_1	Market environment an enterprise faces	43.87	0.4848
Y_2	Internal and external crises that challenge an enterprise	24.851	0.2746
Y_3	Humanity resource crisis of an enterprise	21.777	0.2406

Using the weighted calculation formula, the normalization of the contribution rates of these principal factors is as following

$$A_i=a_i / (a_1+a_2+\dots +a_n) \quad (1)$$

(In this case n=3) Then we got the expression of Y the risk factor of the green supply chain in the automobile manufacturing industry of Guangxi as following:

$$Y=0.4848y_1+0.2746y_2+0.2406y_3$$

The formula above explained that the risk of market environment an enterprise faces is the first factor that produces risks in the green supply chain of the automobile manufacturing industry of Guangxi; it contributes to 48.48% of total drive. Next the internal and external crises are the important driver that generates risks in the green supply chain of automobile manufacturers; it contributes to the 27.46%of drive. At last the humanity resource crisis of enterprises is also one of the factors that cause risks in the green supply chain of the automobile manufacturing industry of Guangxi; it contributes to 24.06%of drive. The third one has a less drive role when it is compared to the first two factors.

2.3. Influence Analysis

In order to further the analysis on the influence brought by various risk variables on the green supply chain management of the automobile manufacturers in Guangxi, here we use the formula for calculating out the influence W_{ij}:

$$W_{ij}=A_i\times B_{ij}^{[18]} \quad (2)$$

$$Y_1=0.202x_{11}+0.175x_{12}+0.214x_{13}+0.100x_{14}+0.191x_{15}+0.099x_{16}+0.169\ x_{17}+0.143\ x_{18}$$

$$Y_2=0.365x_{21}+0.364\ x_{22}+0.315x_{23}+0.229x_{24}$$

$$Y_3=0.284x_{31}+0.316x_{32}+0.262x_{33}+0.264x_{34}$$

Firstly we calculated out the weight B_{ij} of these 16 risk variables on the corresponding 3 principal factors. Based on the factor/component score coefficient matrix (See Table 5), we express the relationship between the 3 principal factors and the 16 risk variables they contain in mathematic formulas[19] as following:

$$Y_1=0.202x_{11}+0.175x_{12}+0.214x_{13}+0.100x_{14}+0.191x_{15}+0.099x_{16}+0.169\ x_{17}+0.143\ x_{18}$$

$$Y_2=0.365x_{21}+0.364\ x_{22}+0.315x_{23}+0.229x_{24}$$

$$Y_3=0.284x_{31}+0.316x_{32}+0.262x_{33}+0.264x_{34}$$

Table 5 Factor/Component Score Coefficient Matrix

Risk Variables	Extracted Principal Factors		
	Y_1	Y_2	Y_3
Risk of Demand Fluctuation x_{11}	0.202	-0.118	-0.021
Risk of Competitor's Replacementx_{12}	0.175	-0.073	-0.036
Risk of Purchase Price x_{13}	0.214	-0.143	-0.015
Risk of Product Purchase x_{14}	0.100	0.050	-0.040
Risk of Core Product x_{15}	0.191	-0.103	-0.016
Risk of Interest Allocation x_{16}	0.099	0.059	-0.049
Risk of Business Process x_{17}	0.169	-0.074	-0.018
Risk of Information Sharing x_{18}	0.143	-0.088	0.073
Risk of Natural Environment x_{21}	-0.145	0.365	-0.013
Risk of Alert Mechanism x_{22}	-0.121	0.364	-0.081
Risk of Technical Use x_{23}	-0.103	0.315	-0.015
Risk of Product Pricing x_{24}	-0.053	0.229	0.018
Risk of Cultural Awareness x_{31}	0.027	-0.111	0.284
Risk of Value Idea x_{32}	-0.020	-0.080	0.316
Risk of Customer Change x_{33}	-0.051	-0.019	0.262
Risk of Human Resource x_{34}	-0.084	0.069	0.264

By the following formula,

$$B_{ij}=b_{ij} / \sum b_{ij} \quad (3)$$

We normalized the coefficients of the three regression equations mentioned above separately (in this case i=1,2,3, j=8,4,4) to calculate out the weight value B_{ij}, and got the results shown in Table 6.

Using the weight value Ai of Table 4, the weight value Bij mentioned above, and Wij=Ai×Bij of Formula (2), we got the weights of these 23 risk variables on the general target, as shown in Table 6. Values of the column

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(influence Wij) are the influences of the risk variables on the green supply chain management of the automobile manufacturers in Guangxi.

Table 6. Regression Coefficients and Risk Variables' Weights

Risk Factor	Risk Variables and their Weights	Regression Coefficient b_{ij}	Mean Value $\bar{b}_{ij}$	Weight of Variables on Their Principal Factors B_{ij}	Influence W_{ij}
Market Environment an enterprise Faces 0.4848	Risk of Demand Fluctuation x_{l1}	0.202	2.54	0.0547	0.0265
	Risk of Competitor's Replacement x_{l2}	0.175	2.40	0.0474	0.0230
	Risk of Purchase Price x_{l3}	0.214	2.60	0.0580	0.0281
	Risk of Product Purchase x_{l4}	0.100	2.18	0.0271	0.0131
	Risk of Core Product x_{l5}	0.191	2.56	0.0517	0.0251
	Risk of Interest Allocation x_{l6}	0.099	2.36	0.0268	0.0130
	Risk of Business Process x_{l7}	0.169	2.12	0.0458	0.0222
	Risk of Information Sharing x_{l8}	0.143	3.70	0.0387	0.0188
Internal and External Crises that Challenge an Enterprise 0.2746	Risk of Natural Environment x_{21}	0.365	3.28	0.0989	0.0271
	Risk of Alert Mechanism x_{22}	0.364	2.36	0.0986	0.0271
	Risk of Technical Use x_{23}	0.315	2.38	0.0853	0.0234
	Risk of Product Pricing x_{24}	0.229	2.28	0.0620	0.0170
Humanity Resource Crisis that Challenges an Enterprise 0.2406	Risk of Cultural Awareness x_{31}	0.284	2.86	0.0769	0.0185
	Risk of Value Idea x_{32}	0.316	3.88	0.0856	0.0206
	Risk of Customer Change x_{33}	0.262	3.94	0.0710	0.0171
	Risk of Human Resource x_{34}	0.264	3.96	0.0715	0.0172

2.4. Analysis on the Assessed Risk Factors of the Green Supply Chain Management in the Automobile Manufacturing Industry of Guangxi

From the analysis above we know that the factors causing the risks in the green supply chain of automobile manufacturers in Guangxi, being ordered in the sequence of influence, are: risk of purchase price, risk of natural environment, risk of alert mechanism, risk of demand fluctuation, risk of core product, risk of technical use, risk of competitor's replacement, risk of business process, risk of value idea, risk of information sharing, risk of cultural awareness, risk of human resource, risk of customer change, risk of product pricing, risk of product purchase, and risk of interest allocation.

It is notable that although the 6 risk factors, namely risk of demand fluctuation, risk of competitor's replacement, risk of purchase price, risk of business process, risk of alert mechanism, and risk of technical use, have higher influence, their mean value is relatively low. This explains that although such factors have high influence for the generation of risks in the green supply chain management of automobile manufacturers in Guangxi, until now the automobile manufacturers have weak awareness and countermeasures to cognize and control such risk factors. This is the critical phase and weak point for automobile manufacturers of Guangxi to conquer when to implement green supply chain management. Therefore, in the process of automobile manufacturers of Guangxi to assess and control risks of the green supply chain, the government and related authorities shall make effective policies and rules for such critical phases and weak points. Such policies and rules shall help automobile manufacturers of Guangxi implement green supply chain risks assessment and control strategy, building a solid foundation for the sustainable development of enterprises, society, and environment.

3. Contributions and Limitations of this Study

3.1. Contributions

From the demonstrative view this study analyzed the risk factors in the green supply chain management of automobile manufacturers of Guangxi, used the method of factor analysis to cognize and analyze the risk factors of green supply chain, and got relatively scientific and objective results based on mathematic and statistic analysis. The final weights of risk factors were acquired in mathematical transformations using path analysis and regression analysis. This study's fruits reflect the facts of enterprises in an objective way.

3.2. Limitations

The items investigated for risk factors cognition are designed by consulting literatures and experts. They may fail to include all the possible risk factors enterprises will face in the implementation of green supply chain management. Half a year's data tracking and surveying and sample quantity may be a little subjective. All these limitations are to be removed and avoided gradually in the further study of the future.

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