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Risk early warning model of manufacturing enterprises based on synergetic management pattern

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ABSTRACT

Based on the synergetic theory, system engineering and enterprise risk management, the operation mechanism of the manufacturing enterprises and the effects of the uncertainty risks on the coordinated operation of the system are analyzed. The risk early warning model of the manufacturing enterprises is constructed based on the system synergetic degree. With the application of the model, the current enterprise risk conditions of the manufacturing enterprises can be the identified accurately and the potential internal uncoordinated factors can be obtained systematically, helping the enterprises to carry out an effective risk management to ensure the stable realization of their strategic objectives.

KEYWORDS

Risk early warning; Synergetic management pattern; System synergetic degree; Manufacturing enterprises.

INTRODUCTION

With the significant changes in China's manufacturing business environment and the continually improved market, the demand and the implications for the risk early warning are increasing[1]. The system of the manufacturing enterprises is a nonlinear open system with a certain expected output or expected value for each interior component. The root cause of the deviation between the actual system outputs and the expected values is the impact of the uncertainty on the system operation. The nature of the synergetic management is the deviation minimization of the actual system outputs and the expected values under the disturbance of the internal and external uncertain risks of the system. The synergetic management of the manufacturing enterprises has two advantages. One is to enhance the synergetic degree of the enterprise internal system, i.e. to adapt the subsystem operation to the strategic objectives of the enterprises, thus enhance the ability to cope with the uncertainty risks of the enterprise internal system; the other is to improve the ability of the co-evolution of the enterprises and the external environment, i.e. to adapt the enterprise ability to the external demands, thereby increasing the ability to cope with the uncertainty risks of the enterprise external system.

LITERATURE REVIEW

In recent years, the related research about enterprise risks has made great achievements. Guo systematically reviewed the risk prediction models at home and abroad, compared and analyzed the basic principles, development and defects in detail[2]. Wang comprehensively summarized the analysis methods of the risk early warning of enterprises and made a systematic comparison of the SWOT analysis, scenario analysis, financial statements and ratio analysis, signal analysis and other methods[3]. Chen analyzed and selected the impact factors of the warning model for the economic operations and used the time difference correlation analysis to test the correlation between the selected economic indicators and the actual situation[4]. Shou and Zhang took the commercial banks for the study, used the AHP and the entropy method to build a risk early warning system and successfully validated the accuracy of the constructed system through the empirical study[5]. Basing on the contract theory, Xu and Shen described the nature and the properties of the two systems, i.e. the enterprise internal control system and the financial risk warning system, analyzed the major factors that affected the risk and the corresponding control strategies and ultimately built an analysis model in accordance with the factors and the strategies[6]. Zhang, etc. constructed a risk warning model of the centralized bank credit defaults based on the impact model[7]. Zhou, etc. built the early warning component of the oil price fluctuations to study their grading warning process[8]. Combining the specific characteristics of the China's listed companies, Qiu introduced the cash flow as a financial indicator and improved the Z-score model to better serve for the enterprise financial early warning mechanism[9].

From these studies, we can see that the enterprise risk warning system is the effective means to pre- control and resolve risks and minimize the loss caused by them. It has become one of the most important measures to carry out the risk analysis and management of the business activities, to prevent and mitigate the risks and minimize the loss to ensure the business activities and the greatest benefits of enterprises.

RISK EARLY WARNING MODEL

Synergetic management pattern system

The impact of uncertain risks on the enterprises can be shown by the synergetic degree changes of the Synergetic Management Pattern System (SMPS), i.e. the higher the synergetic degree, the better the operating conditions, and vice versa.

Relative coefficients

(1)The satisfaction coefficient θ_{ij} and the influence coefficient ξ_{ij}^{q}. The satisfaction coefficient factor $\theta_{ij} \in [0, 1]$ is the degree that the satisfaction value is met by the indicator value which is on the j-th layer of the i-th statistical value in the evaluation system. Scored by a number of experts, the mean is taken as the final satisfaction coefficient. The indicator satisfaction coefficient of its upper level θ_{i} is calculated as follow,

$$\theta_{i}=\sum_{j=1}^{n}\theta_{ij}\cdot\omega_{ij}, \quad (1)$$

where w_{ij}, determined by AHP, is the weight of the i-th indicator on the j-th layer.

(2) The influence coefficient $\xi_{ij}^{q} \in [0,1]$,($i=1,2\ldots 12$, $j=1,2\cdots n_{i}$, $q=1,2\cdots n_{i}$)represents the influence of the q-th reference layer on the j-th reference layer in the i-th indicators. Scored by a number of experts, the mean of ξ_{ij}^{q} is

taken as the final influence coefficient. $\xi_{ij}{}^{q}=0$ indicates no influence, and when j = q and $\xi_{ij}{}^{q}=0$, the indicator influence does not need to be considered.

Synergetic degree within the subsystems

(1)Let ξ_{ij} be the total influence of all the indicators on the indicators of the j-th reference layers within the i-th indicators, then

$$\xi_{ij}=\sum_{\substack{q=1\\q\neq j}}^{n_i}\xi_{ij}{}^{q}\theta_{\mathrm{iq}},\ (i=1,2\ldots 12,\ j=1,2\cdots n_{\mathrm{i}},\ q=1,2\cdots n_{\mathrm{i}}). \quad (2)$$

(2)Let R_{ij} be the synergetic coefficient between the j-th indicator and the other indicators within the i-th indicators, then

$$\mathrm{R}_{ij}=\frac{\xi_{ij}}{\sum_{\mathrm{j}=1}^{n_i}\xi_{ij}}\ (i=1,2,3\ldots 12). \quad (3)$$

(3)Let u_i be the internal synergetic degree of the i-th indicator, then

$$\mathrm{u}_i=\sum_{\mathrm{j}=1}^{n}\mathrm{R}_{ij}\cdot\theta_{ij}\ (i=1,2\ldots 12). \quad (4)$$

(4)Let u^{e} be the internal synergetic degree of the e-th subsystem, then

$$\mathrm{u}^{\mathrm{e}}=\sum_{i=1}^{3}w_i{}^{e}u_i, \quad (5)$$

where w_i^{e} is weight of the i-th indicator of the e-th subsystem.

Synergetic degree $\mathrm{u}_e{}'$ between the subsystems

(1) Let $\xi_{\mathrm{ei}}{}'$ be the total influence of the other subsystems on the indicators on the i-th the statistical layer of the e-th subsystem, then

$$\xi_{\mathrm{ei}}{}'=\sum_{\substack{j=1\\j\neq e}}^{4}\xi_{ei}{}^{j}\theta_{\mathrm{j}}=\sum_{\substack{j=1\\j\neq e}}^{4}\sum_{q=1}^{n_{\mathrm{j}}}\xi_{ei}{}^{jq}\theta_{\mathrm{jq}}\theta_{\mathrm{j}}, \quad (6)$$

where $\xi_{\mathrm{ei}}{}^{jq}\in[0,1]$,($e=1,2\ldots 4$, $i=1,2\ldots 12$, $j=1,2\cdots 4$, $q=1,2\cdots n_{\mathrm{j}}$,and $e\neq j$) denotes the influence of the indicators on the q-th statistical layer of the j-th subsystem on the indicators on the i-th statistical layer of the e-th subsystem. Scored by a number of experts, the mean of $\xi_{\mathrm{ei}}{}^{jq}$ is denoted as the final influence coefficient. θ_{jq} is the satisfaction of the q-th statistical layer in the j-th subsystem and θ_{j} is the satisfaction of the j-th subsystem.

(2)Let $\mathrm{R}_i^{\,e}$ be the synergetic coefficient of the i-th indicator in the e-th subsystem, then

$$R_i^e = \frac{\xi_{ei}'}{\sum_{i=1}^{n_e} \xi_{ei}'} . \quad (7)$$

(3)Let $u^{e'}$ be the synergetic degree between e-th subsystem and other subsystems, then

$$u^{e'} = \sum_{i=1}^{n_e} R_i^e \cdot \theta_{ei} . \quad (8)$$

Total synergetic degree of SMPS

The total synergetic degree of the synergetic management pattern of the manufacturing enterprises can be calculated as follows

$$u = \sum_{e=1}^{4} w_{se} (\alpha_1 u^e + \alpha_2 u^{e'}) , \quad (9)$$

where w_{se} is the weight of the e-th subsystem; α_1 and α_2 are the undetermined coefficients ($\alpha_1 + \alpha_2 = 1$). The experts score based on the specific circumstances of the enterprises.

Warning intervals

According to the monitoring theory, let a variable $u \sim N(\mu, \delta^2), u_1, u_2, \ldots, u_n$ be a sample of the total synergetic degree u of the system, then this sample is a time series with the data length n and unknown $\delta^2 and \mu$.

(1)Take the historical data $u_1, u_2, \ldots, u_n$ of the indicator as a sample; calculate the mean $\bar{u}$ and the variance S^2 that can be replaced by the total variance δ^2.

(2) Calculate the estimated interval values of each region as a basic boundary value. Construct the variables as follows

$$T = \frac{\bar{u} - \mu}{\sqrt{\frac{S^2}{n}}} \sim t(n-1) , \quad (10)$$

$$P[|T| > \lambda] = \frac{\alpha}{2} , \quad (11)$$

where α is the test level and $1-\alpha$ the confidence level. According to the monitoring theory, the probability of the warning interval is required to be 0.5, so $\alpha = 0.5$. λ can be obtained from t (n-1) distribution table so that the confidence interval whose confidence level of μ is $1-\alpha$ can be obtained through $\frac{\bar{u} - \mu}{\sqrt{\frac{S^2}{n}}} < \lambda$ as follows

$$[\bar{u} - \lambda \sqrt{\frac{S^2}{n}}, \bar{u} + \lambda \sqrt{\frac{S^2}{n}}] . \quad (12)$$

This confidence interval can be used as the basic boundary value to determine the warning intervals. The alarm, alert and normal intervals can be denoted as $[0, \bar{u} - \lambda \sqrt{\frac{S^2}{n}})$, $[\bar{u} - \lambda \sqrt{\frac{S^2}{n}}, \bar{u} + \lambda \sqrt{\frac{S^2}{n}}]$, $(\bar{u} + \lambda \sqrt{\frac{S^2}{n}}, 1]$ respectively.

EMPIRICAL RESEARCH

Using the historical data of Harbin Hafei Automobile Industry Group Co Ltd (HAFEI Group) as the research object, the proposed crisis warming model evaluates the crisis profile of HAFEI Group in terms of the synergetic degree. Firstly, the data from January, 2009 to March, 2014 are selected and analyzed using factor analysis in spss17.0. The indicator weights of the subsystem layer and statistical layer are calculated using AHP. The index system of the competitiveness of the manufacturing enterprises (A) consists of four subsystem layers, i.e. Technical capacity (B_1, Weight=0.372), Organization and management (B_2, Weight=0.094), Human resources (B_3, Weight=0.372) and Marketing (B_4, Weight=0.162). B_1toB_4 have 3 statistical layers respectively. B_1consists of R & D capabilities (C_1, Weight=0.185), Conversion capacity (C_2, Weight=0.659) and Manufacturing capacity (C_3, Weight=0.156). B_2consists of Organization (C_4, Weight=0.105), Operational efficiency (C_5, Weight=0.258) and Coordination capacity (C_6, Weight=0.637). B_3consists of Employee constitute (C_7, Weight=0.105), Training (C_8, Weight=0.258) and Employee motivation (C_9, Weight=0.637). B_4consists of Service capability (C_{10}, Weight=0.200), Sales capability (C_{11}, Weight=0.200), and Supply chain support (C_{12}, Weight=0.600). $C_1$to C_{12} have their own the reference layers. C_1consists of R & D expenditure intensity (B_{11}), R & D intensification (B_{12}) and Number of the coordinated R & D projects (B_{13}). C_2consists of Rate of the research results into production (B_{14}), Output rate of the new products (B_{15}) and Number of patents (B_{16}). C_3consists of Advancement of the production equipments (B_{17}), Proportion of senior technicians (B_{18}) and Relative rate of the production costs (B_{19}). C_4consists of Desired level of the management magnitude (B_{21}) and Rationality of the management levels (B_{22}). C_5consists of Proportion of decision makers (B_{23}), Supporting degree of decisions (B_{24}) and Task completion rate (B_{25}). C_6consists of Introduction of management information systems (B_{26}), Completeness of the emergency plan (B_{27}) and Multi-project control capacity (B_{28}).

C_7 consists of Proportion of technicians (B_{31}), Proportion of managerial staff (B_{32}) and Proportion of Bachelor and higher degree holders (B_{33}). C_8consists of Annual training coverage (B_{34}) and Annual training funding ratio (B_{35}). C_9consists of Performance appraisal satisfaction (B_{36}),Salary competitiveness (B_{37}), Internal promotion rate (B_{38}). C_{10}consists of Rate of the qualified products (B_{41}), After-sale service satisfaction (B_{42}) and Cost performance satisfaction (B_{43}). C_{11}consists of Rate of the market share (B_{44}), Sales proportion of the core products (B_{45}) and Sales growth (B_{46}). C_{12} consists of Supplier satisfaction (B_{47}), Relative ratio of the total marketing cost (B_{48}) and Inventory Turnover (B_{49}).

Synergetic degree within the subsystems

The selected data from Jan. 2009 to Mar. 2014 of the enterprises were scored by the experts and the indicator satisfactions of the reference layer are shown in TABLE 1. The indicator influence coefficients are shown in TABLE 2. The system synergetic degree in 2009 was calculated as an example and the related results in other years could be obtained in the same way.

TABLE 1 : Indicator satisfaction

Satisfaction (Θ_{ij})													
Reference layer	2009	2010	2011	2012	2013	2014	Reference layer	2009	2010	2011	2012	2013	2014
B_{11}	0.771	0.677	0.751	0.607	0.527	0.501	B_{31}	0.613	0.637	0.677	0.741	0.777	0.749
B_{12}	0.763	0.614	0.621	0.628	0.547	0.504	B_{32}	0.614	0.624	0.619	0.732	0.737	0.701
B_{13}	0.793	0.811	0.751	0.672	0.703	0.572	B_{33}	0.571	0.573	0.643	0.691	0.711	0.713
B_{14}	0.787	0.601	0.551	0.567	0.537	0.527	B_{34}	0.611	0.513	0.621	0.811	0.813	0.807
B_{15}	0.727	0.761	0.831	0.627	0.567	0.57	B_{35}	0.667	0.65	0.647	0.771	0.784	0.764
B_{16}	0.684	0.717	0.839	0.729	0.601	0.567	B_{36}	0.537	0.507	0.751	0.749	0.761	0.757
B_{17}	0.807	0.797	0.79	0.776	0.804	0.801	B_{37}	0.561	0.611	0.601	0.692	0.707	0.702
B_{18}	0.723	0.741	0.797	0.805	0.807	0.801	B_{38}	0.576	0.611	0.647	0.677	0.689	0.71
B_{19}	0.747	0.749	0.757	0.748	0.75	0.747	B_{41}	0.681	0.706	0.71	0.717	0.731	0.744
B_{21}	0.531	0.577	0.571	0.779	0.787	0.789	B_{42}	0.742	0.747	0.74	0.761	0.781	0.779
B_{22}	0.563	0.567	0.566	0.789	0.791	0.79	B_{43}	0.692	0.715	0.761	0.759	0.763	0.76
B_{23}	0.671	0.681	0.683	0.813	0.826	0.822	B_{44}	0.693	0.69	0.71	0.741	0.777	0.767
B_{24}	0.611	0.617	0.675	0.763	0.775	0.771	B_{45}	0.611	0.724	0.73	0.727	0.711	0.704
B_{25}	0.641	0.647	0.639	0.859	0.857	0.861	B_{46}	0.693	0.677	0.691	0.711	0.727	0.729
B_{26}	0.587	0.577	0.571	0.891	0.897	0.89	B_{47}	0.512	0.666	0.556	0.601	0.617	0.61
B_{27}	0.613	0.621	0.623	0.877	0.871	0.872	B_{48}	0.521	0.537	0.567	0.707	0.69	0.684
B_{28}	0.413	0.427	0.439	0.767	0.771	0.773	B_{49}	0.674	0.667	0.687	0.67	0.621	0.637

TABLE 2 : Indicator influence coefficients of the reference layer in the technical capacity system

		B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}	B_{19}
Influenced indicators	B_{11}	0	0.51	0.73	\	\	\	\	\	\
	B_{12}	0.62	0	0.36	\	\	\	\	\	\
	B_{13}	0.45	0.47	0	\	\	\	\	\	\
	B_{14}	\	\	\	0	0.73	0.50	\	\	\
	B_{15}	\	\	\	0.50	0	0.63	\	\	\
	B_{16}	\	\	\	0.61	0.65	0	\	\	\
	B_{17}	\	\	\	\	\	\	0	0	0.73
	B_{18}	\	\	\	\	\	\	0	0	0.84
	B_{19}	\	\	\	\	\	\	0.61	0.53	0

Synergetic degree between the subsystems

The selected data from Jan. 2009 to Mar. 2014 of the enterprise are scored by the experts and the indicator influence coefficients of the statistical layer are shown in TABLE 3. The data in 2009 are calculated as an example and the related results in other years can be obtained in the same way.

TABLE 3 : Ndicatorthe I influence coefficients on the statistical layer

		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_8	C_{10}	C_{11}	C_{12}
Influenced indicators	C_1	/	/	/	0.62	0.71	0.54	0.81	0.73	0.45	0.36	0.47	0.51
	C_2	/	/	/	0.52	0.65	0.59	0.78	0.79	0.41	0.32	0.47	0.29
	C_3	/	/	/	0.36	0.66	0.57	0.70	0.71	0.41	0.34	0.34	0.41
	C_4	0.65	0.36	0.34	/	/	/	0.56	0.15	0.12	0.42	0.51	0.70
	C_5	0.15	0.49	0.45	/	/	/	0.62	0.70	0.76	0.34	0.42	0.68
	C_6	0.42	0.24	0.32	/	/	/	0.68	0.72	0.50	0.31	0.49	0.70
	C_7	0.70	0.67	0.74	0.65	0.54	0.46	/	/	/	0.12	0.27	0.67
	C_8	0.78	0.76	0.66	0.68	0.51	0.32	/	/	/	0.38	0.62	0.51
	C_9	0.25	0.49	0.39	0.35	0.47	0.37	/	/	/	0.32	0.52	0.65
	C_{10}	0.53	0.47	0.51	0.41	0.66	0.74	0.76	0.81	0.64	/	/	/
	C_{11}	0.25	0.32	0.24	0.32	0.46	0.59	0.50	0.81	0.69	/	/	/
	C_{12}	0.62	0.63	0.41	0.40	0.62	0.79	0.46	0.45	0.32	/	/	/

Evaluation results of SMPS

Using Formula (10), (11), (12) and the above calculation results, the risk warning intervals can be obtained and analyzed as shown in TABLE 4 and TABLE 5. First, the total synergetic degree of SMPS was good while the internal synergetic degree declined slightly in the first three months of 2014. Meanwhile, the synergetic degree within and between all the subsystems was stable except Technical capacity. Second, under the influence of the uncertainty risks, the major uncoordinated factor within the enterprise was the Technical capacity which should be timely adjusted. Third, the systematic adjustment and the optimization within the enterprise system should be focus on R & D capabilities (C_1) and Conversion capacity (C_2).

TABLE 4 : Synergetic degree of HAFEI group

	2009	2010	2011	2012	2013	2014	Alarm interval	Alert interval	Normal interval	Alarm interval	Alert interval	Normal interval
u	0.66	0.652	0.668	0.709	0.709	0.688	[0,0.644)	[0.644,0.694]	(0.694,1]	-	√	-
u^1	0.743	0.697	0.702	0.649	0.599	0.579	[0,0.616)	[0.616,0.708]	(0.708,1]	√	-	-
u^2	0.561	0.569	0.574	0.831	0.835	0.834	[0,0.597)	[0.597,0.805]	(0.805,1]	-	-	√
u^3	0.586	0.586	0.652	0.723	0.748	0.73	[0,0.619)	[0.619,0.725]	(0.725,1]	-	-	√
u^4	0.608	0.653	0.647	0.688	0.685	0.685	[0,0.638)	[0.638,0.684]	(0.684,1]	-	-	√
$u^{1\prime}$	0.764	0.717	0.713	0.675	0.655	0.614	[0,0.652)	[0.652,0.728]	(0.728,1]	√	-	-
$u^{2\prime}$	0.585	0.603	0.608	0.813	0.819	0.818	[0,0.622)	[0.622,0.794]	(0.794,1]	-	-	√
$u^{3\prime}$	0.61	0.612	0.643	0.735	0.767	0.739	[0,0.633)	[0.633,0.735]	(0.735,1]	-	-	√
$u^{4\prime}$	0.634	0.687	0.681	0.702	0.706	0.705	[0,0.666)	[0.666,0.706]	(0.706,1]	-	√	-

TABLE 5 : Synergetic degree of technical capacity of Hafei group in 2014

Indicator	Synergetic degree	Warning interval		
		Alarm interval	Alert interval	Normal interval
R & D capabilities (C1)	0.522	√	-	-
Conversion capacity (C2)	0.548	√	-	-
Manufacturing capacity (C3)	0.777	-	√	-

CONCLUSIONS

A risk early warning model of manufacturing enterprises based on the synergetic management is constructed and its risk warning process is demonstrated through the calculation of the system synergetic degree in the empirical case. The evaluation results of the model show that first, it can help manufacturing enterprises understand the synergetic degree within and between the various subsystems of SMPS; second, it can identify the specific risk affects within and between the various subsystems of SMPS; third, the potential uncoordinated factors and risk information under the risk influence can be clearly shown within and between the various subsystems of SMPS so that the enterprises can take timely countermeasures to effectively control risks and to ensure the smooth realization of their strategic objectives.

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