Evaluation of Coalmine Safety Management Risk Factors based on PR-SEM

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***Abstract* — Based on analyzing deep causes for frequent coalmine accidents, five coalmine safety management risk factors were analyzed and listed as follows: safety management organization, safety management ability, safety management mode, safety management elements, and safety management supervision. Then the algorithm Page Rank of random walk was used to do expert weight calculation that was introduced to questionnaire item value, the 18 key risk factors influencing coalmine safety management were uncovered precisely, which worked as exogenous latent variables, the three risk consequence indexes as endogenous latent variables. Then, a risk factor evaluation model was built according to PR-SEM, SEM and software STATA12.0 were used to verify the model. As a result, the combined influence of the risk factor cluster on coalmine safety management can be revealed.**

Keywords - coalmine, PR-SEM, safety management, risk factor, evaluation.

I. INTRODUCTION

Recent years, the intensity of strengthening coalmine safety management in China has caused coalmine accidents to reduce in a sense. At the same time, the major and larger coalmine accidents happened in China have also reduced evidently(Shown as Table1). But on the other hand, compared with those in western countries like America, Britain, Japan and Australia, the gross of coalmine accidents in China remains larger. Statistic data show the death toll in coalmine accidents in China still account for about 80% of that of the world [1].

TABLE1.STATISTICS OF COALMINE ACCIDENTS IN CHINA 2010 -2013

Year	Death toll	Number of accidents	Fatality each megaton
2010	2433	1403	0.749
2011	1973	1201	0.564
2012	1384	779	0.374
2013	1067	604	0.288
2014	931	546	0.225

Coalmine safety system is mainly composed of safety production system and safety management system of which factors like human, machine, environment and information permeate in each link of safety production system[2], and these factors play a leading role in safety production[3]. Researches reveal that human factor from management failure is the key factor in factors causing coalmine accidents. the paper was designed to identify coalmine safety management risk factors so as to locate influence relation among all the latent risk factors in coalmine safety management. Then a scientific practical evaluation model of coalmine safety management risk factors was built accordingly with the purpose of evaluating the risk factors so that faults in coalmine safety management were controlled, and so that safety accidents were decreased or even avoided [3]. On the one hand, relatively abstract concepts of coalmine safety management risk made it hard to do precise analysis; on the other hand, relation among factors remains complicated.

Structural equation proposed by Karl G Joreskog, a Swedish statistician, and his partner Dag Sorbom in 1960s-1970s can treat many dependent variables simultaneously. The equation works well in relation analysis of complicated factors, extraction of risk factor and optimization of evaluation index system. And it finds its wide use fields like social science, management, economics and behavioral science[4-8].

II. PRINCIPLES AND PROGRAMS OF EVALUATION OF COALMINE SAFETY MANAGEMENT RISK FACTORS BASED ON PR-SEM

A. *Principles of evaluation of coalmine safety management risk factors based on PR-SEM*

1) Expert weight definition based on Page Rank

Before evaluation of coalmine safety management risk factors was made, questionnaires are issued to coalmines, coalmine colleges and universities, experts needed to be interviewed. Usually when result data of questionnaires, interviews are being treated, emphasis was laid not on significance of experts but on statistical analysis result of data, so data processing was basically done according to even expert weight. But in fact, experts' qualification level, technical capacity, management experience differ so largely that their attitudes toward the same problem were various. To accurately investigate scientificity, rationality, and to accurately locate important risk factors influencing coalmine safety management, the paper introduced the algorithm Page Rank (PR) of random walk to determine expert weight. Page Rank is a sort of webpage ranking technique invented at Stanford University in 1998 by Larry Page, one of Google company founders, and Sergey Brin [9]. Since then value Page Rank has been regarded as one of key indexes of evaluating value of webpage, reflecting importance of webpage in internet [10-12].

2) Computational process of the value Page Rank

Nowadays, the algorithm Page Rank is widely used in various fields like computer, text information retrieval, periodical quality assessment, human resource allocation, and tag classification [13-16].The basic thought of the algorithm comes from traditional analysis of academic literature citation, namely, how important a document is relies on citation by other documents. When document A cites document B, document A votes for document B, meaning that document A shares out its value Page Rank to document B. In this way, when a document is cited many times, it will have a higher value Page Rank. Likewise, when a document is cited by another document with higher value Page Rank, it is more likely to have much higher value Page Rank. the specific algorithm of value PR is listed as follows :

$$PR(A) = (1-p) + p\left(\frac{PR(t_1)}{C(t_1)} + ... + \frac{PR(t_n)}{C(t_n)}\right) \quad ......(1)$$

Where $PR(A)$ means the value PR of A, $PR(t_1),...,PR(t_n)$ means the value PR that each document cites A, $C(t_1),...,C(t_n)$ means times the frequency that document A cites other documents. Usually the initial value Page Rank is set as 1, through the equation mentioned above, the solution can be achieved by using power iteration until the value PR tends to stabilization.

3) The basic principle of SEM

The structural equation includes measurement model and structural equation [17].

a) Measurement Model mainly indicated the link between latent variables and observational variables, namely, the link between exogenous latent variables and observational variables, the link between endogenous latent variables and observational variables, which was expressed as:

$$\begin{aligned} X &= \Lambda_x \xi + \delta \\ Y &= \Lambda_y \eta + \varepsilon \end{aligned} \quad ......(2)$$

Where X refers to exogenous indicator vector of $p \times 1$ order; Y to endogenous indicator vector of $q \times 1$ order. Λ_x means the link between exogenous latent variables and observational variables; Λ_y the link between endogenous latent variables and observational variables. δ means error item of exogenous indicator X, ε error item of endogenous indicator.

b) Structural Model mainly showed the link among latent variables, including the link between exogenous latent variables and endogenous latent variables , and the link among endogenous latent variables[18].

$$\eta = B\eta + \Gamma\xi + \zeta \quad ......(3)$$

Where ξ refers to exogenous latent variable vector of $m \times 1$ order, η to endogenous latent variable of $n \times 1$ order, B means regression coefficient among endogenous latent variable η ,reflecting the link among endogenous latent variables. Γ means regression coefficient between ξ and η, reflecting the influence of exogenous latent variables on endogenous latent variables, ζ refers to residual item, reflecting parts of η unexplained in equation.

B. Programs of evaluation of coalmine safety management risk factors based on PR-SEM

Evaluation of coalmine safety management risk factors based on PR-SEM includes three periods: preparation of evaluation model, construction of evaluation model and analysis and summary of evaluation result, (as shown in fig.1)

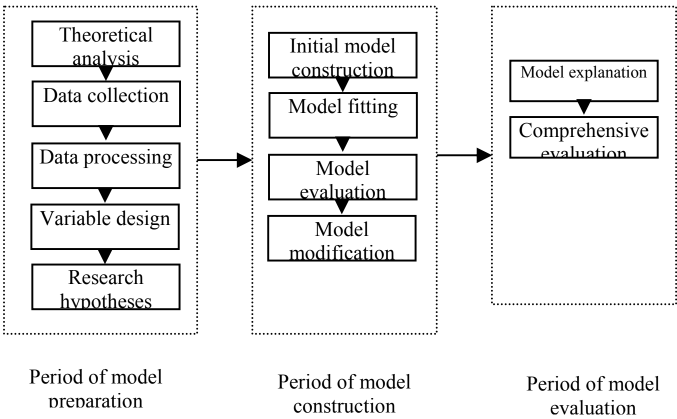

Figure 1. Three Periods of PR-SEM evaluation model

In the period of model preparation, theoretical analysis, data processing, variable design and presentation of research hypothesis were mainly performed. Data is the basis of building the model PR-SEM. Therefore, interviews, investigations and issuing questionnaires should be completed prior to research so that there will have sufficient data to be based on. Inner product of value expert weight and questionnaire item data acted as the preprocessing data that were analyzed in terms of reliability and validity in order to guarantee stability and reliability. Then links among variables were established, and finally research hypothesis was raised.

In the period of model construction, the initial model and model fitting were made. At the beginning, links of relevant parameter was designed when the model was built. model fitting means calculating the estimation value of model

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parameters, analyzing the fitness of solution of structural equation, convergence of iterative estimation, and reasonability of estimation value of all variables. Then the model was corrected according to theories and relevant hypothesis [19].

In the period of model evaluation, the final result model evaluation was systemized and concluded, the result of model evaluation was analyzed synthetically, path coefficient was calculated, and results of coalmine safety management risk evaluation was listed. In the end, the final result was concluded.

III. RESEARCH PROCESS

A. Sample selection and data processing

1) Sample selection

According to relevant research achievement home and abroad, combined with the research made in the paper, five coal colleges and universities and 12 typical coalmines in three provinces Shanxi, Henan, Anhui (including five private coalmines) were chosen as samples. 360 questionnaires were issued, 336 were retrieved. Of 336 questionnaires, there were 318 available, the recovery rate is 86.5%, and the questionnaires available accounted for 84.9%.

The questionnaire is composed of four parts: users instruction, basic information, risk factor expression and risk consequence. Multiple choice questions in the questionnaire adopt the seven-point Likert Scale.

2) Expert weight calculation of Page Rank and data preprocessing

The research investigated experts interviewed in 318 questionnaires to discover their social relations. The teacher-student relation was taken as an example, the valuation of teacher-student relation is 1, while the valuation of non-teacher-student relation was 0. Then, an social relation adjacency matrix of 318 order was established. Finally, the algorithm Page Rank based on random walk and programming computation Matlab7.0 were used to obtain the importance $PR(H_i)$ $i=1,..,n$ in each relation network of experts.

To make expert weight determination more accurate, the research built four relation networks of teacher-student, leader, citation and cooperation as well. In these four networks four adjacency matrixes were established respectively. Then, the four expert weight values $PR(H_1)$, $PR(H_2)$, $PR(H_3)$, $PR(H_4)$ were determined in these four networks. And then, the expert weight values were integrated linearly. In the end, weight value $PR(H)$ of each expert was determined.

Expert weight calculated by using the algorithm Page Rank and original data were calculated by inner product. Data systemized in questionnaire is $A=[a]_{318\times 18}$ consisting of 18 variables.

Here, the expert weight vector $V=(v_1,v_2,...,v_{318})$ was transformed into a diagonal matrix

$$G=\begin{bmatrix} g_{11} & 0 & 0 & 0 \\ 0 & g_{22} & 0 & 0 \\ ... & ... & ... & ... \\ 0 & 0 & 0 & g_{318} \end{bmatrix} \quad (4)$$

where $v_1=g_{11}$, $v_2=g_{22}$,…, $v_{318}=g_{318}$. Then,

$$W=G\bullet A=[w]_{318\times 18}=\begin{bmatrix} w_{11} & w_{12} & \cdots & w_{118} \\ w_{21} & w_{22} & \cdots & w_{218} \\ \cdots & \cdots & \cdots & \cdots \\ w_{3181} & w_{3182} & \cdots & w_{31818} \end{bmatrix} \quad (5)$$

Matlab7.0 was used to program. And the final value of each index variable was calculated, which works as the real analysis value. Coalmine safety management risk factors was identified and classified initially. According to statistical analysis of questionnaire, combined with results of expert interview, 18 key factors in five aspects including coalmine safety management organization, coalmine safety management mode, coalmine safety management capacity, coalmine safety management elements and coalmine safety management supervision worked as key index system of coalmine safety management risk evaluation. These factors are more likely to cause consequences of coalmine safety management risk.

After descriptive statistic of the data collected, software STATA12.0 was employed to obtain primary general statistic indexes including maximum, minimum, standard deviation, standard error, percentiles, median, asymmetry coefficient and kurtosis coefficient. Obtaining these indexes can help hold macroscopically the data as a whole in order to prepare the analysis to make. Results of descriptive analysis shows that there are no extremes, abnormal value in 18 risk evaluation indexes and 3 risk consequences.

3) Data normalization processing and analysis of reliability and validity

To remove the influence of each data dimension, it is necessary to normalize the data. After that, reliability and validity of data were analyzed so as to increase stability and reliability of the data. The stability and reliability of the data are listed as follows (table 2, table 3, table4)

TABLE2. RESULTS OF DATA RELIABILITY ANALYSIS

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.927	0.919	21

TABLE3.TEST OF KMO AND BARTLETT OF COALMINE SAFETY MANAGEMENT RISK FACTOR INDEX

Kaiser-Meyer-Olkin	Measure of Sampling Adequacy	0.887
	Approx. Chi-Square	1650.32
Bartlett's Test of Sphericity	df	300
	Sig.	.000

TABLE4. TEST OF KMO AND BARTLETT OF COALMINE SAFETY MANAGEMENT RISK CONSEQUENCE INDEX

Kaiser-Meyer-Olkin	Measure of Sampling Adequacy	0.736
	Approx. Chi-Square	1522.99
Bartlett's Test of Sphericity	df	200
	Sig.	.000

From Table2 to Table4, we know data totality Cronbach's Alpha value is 0.927, which is more than reference value, and also than each subscale. Generally speaking, when $KMO > 0.9$, it is quite suitable for factor analysis; when KMO remains between 0.8 and 0.9, it is suitable for factor analysis; when KMO is above 0.7, it is fine for factor analysis. Sphericity test Bartlett is used to test independence of each variable, and the larger its value is, the better it is. Therefore, results of KMO and Sphericity test Bartlett in Table 3 and Table 4 show that coalmine safety management risk evaluation index and risk consequence index are 0.887, 0.736 respectively, that Sphericity test Bartlett values of coalmine safety management risk evaluation index and risk consequence index are 1650.32, 1522.99 respectively, their corresponding probabilities Sig are all 0.000, which shows there exists remarkable difference. As a result, the reliability and validity of KMO looks quite good [20].

B. Research hypothesis

Coalmine safety management organization risk is the key factor influencing coalmine safety management. Coalmine safety management organization risk factors were analyzed from the following aspects like coalmine safety management organization, organization behavior, and organizational culture. Coalmine safety management mode is a set of safety management methods, programmes and systems constituted to solve coalmine safety management problems. Safety management capacity including administrative ability, behavior management ability, and information and innovation management ability is the direct factor influencing risk consequence. Information is the basis of coalmine safety management decision-making. For this reason, promptness, source and quality of information decides accuracy of safety management decision-making immediately. Dynamism of coalmine safety management requires innovation management ability of safety. On the other hand, coalmine safety is a dynamic system consisting of human, machine, environment and information, which demands ability of resource integration and administrative decision-making. Simultaneously, safety of machinery, equipment and environment is warranty of coalmine safety management. All in all, coalmine safety management work is a quite complicated systematic engineering influenced by a large variety of factors, asking for a well-designed safety management supervision system which can monitor all the links of safety management activity in real time, which can supervise relevant persons, objects and settings dynamically, and which can master the coalmine safety management process immediately. By doing so, risk factors possible in safety management process will be discovered in advance.

As mentioned above, the paper raised the following hypotheses:

H1: Coalmine safety management organization risk factors influence coalmine safety management risk consequences directly remarkably.

H2: Coalmine safety management mode influences coalmine safety management risk consequences directly remarkably.

H3:Coalmine safety management capacity influences coalmine safety management risk consequences directly remarkably.

H4: Coalmine safety management element risk factors influence coalmine safety management risk consequences directly remarkably.

H5: Coalmine safety management supervision risk factors influence coalmine safety management risk consequences directly remarkably.

Five aspects of coalmine safety management are not alone but interactive each other to influence coalmine safety management. Uncertainty of coalmine safety management organization structure, fuzziness of organizational obligation and irregularity of organization behavior will certainly influence coalmine safety management capacity and safety management mode so that risk consequence will caused. Also safety management mode, safety management elements and safety management supervision will certainly influence coalmine safety management capacity. At the same time, safety management supervision factor will influence safety management capacity, safety management factor, and is likely to cause risk consequence.

Based on the above, the paper raised the following hypotheses:

H6: Coalmine safety management organization risk will likely increase the risk probability of coalmine safety management capacity, causing risk consequence.

H7: Coalmine safety management organization risk factor will likely increase the risk probability of coalmine safety management mode, causing risk consequence.

H8: Coalmine safety management mode risk will likely increase the risk probability of coalmine safety management capacity, causing risk consequence.

H9: Coalmine safety management element risk will likely increase the risk probability of coalmine safety management capacity, causing risk consequence.

H10: Coalmine safety management supervision risk factor will likely increase the risk probability of coalmine safety management capacity, causing risk consequence.

H11: Coalmine safety management supervision risk factor will likely increase the risk probability of coalmine safety management elements, causing risk consequence.

After sufficient investigation of relevant research home and broad, and multiple group discussion, combined with the above, the paper proposed 11 research hypotheses. Risk factors from H1 to H5 influence coalmine safety management risk consequence directly; while risk factors from H6 to H11 are influencing each other, influencing coalmine safety management indirectly.

C. Model construction

According to theoretical analysis and research hypotheses mentioned above, the paper built an initial concept model including five exogenous latent variables, namely, SMO, SMM, SMA, AME, SMS, and also including one endogenous latent variable, hat is risk consequence. So there are 11 transmission paths between exogenous latent variables and endogenous latent variables, representing 11 risk revolution effects caused by coalmine safety management risk consequence. A model was then built according to covariance matrix of questionnaire items as basic data.

1) Construction of measurement equation of exogenous latent variables.

$$X = L_x x + s \qquad (6)$$

Based on the usual Equation 6, measurement equation of exogenous latent variable was established, as shown in Equation 7.

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \\ x_{10} \\ x_{11} \\ x_{12} \\ x_{13} \\ x_{14} \\ x_{15} \\ x_{16} \\ x_{17} \\ x_{18} \end{bmatrix} = \begin{bmatrix} \Lambda_{x1.1} & 0 & 0 & 0 & 0 \\ \Lambda_{x2.1} & 0 & 0 & 0 & 0 \\ \Lambda_{x3.1} & 0 & 0 & 0 & 0 \\ 0 & \Lambda_{x\,4.2} & 0 & 0 & 0 \\ 0 & \Lambda_{x5.2} & 0 & 0 & 0 \\ 0 & \Lambda_{x6.2} & 0 & 0 & 0 \\ 0 & \Lambda_{x7.2} & 0 & 0 & 0 \\ 0 & 0 & \Lambda_{x8.3} & 0 & 0 \\ 0 & 0 & \Lambda_{x9.3} & 0 & 0 \\ 0 & 0 & \Lambda_{x10.3} & 0 & 0 \\ 0 & 0 & \Lambda_{x11.3} & 0 & 0 \\ 0 & 0 & 0 & \Lambda_{x12.4} & 0 \\ 0 & 0 & 0 & \Lambda_{x\,13.4} & 0 \\ 0 & 0 & 0 & \Lambda_{x14.4} & 0 \\ 0 & 0 & 0 & \Lambda_{x15.4} & 0 \\ 0 & 0 & 0 & 0 & \Lambda_{x16.5} \\ 0 & 0 & 0 & 0 & \Lambda_{x17.5} \\ 0 & 0 & 0 & 0 & \Lambda_{x18.5} \end{bmatrix} \begin{bmatrix} SMO \\ SMM \\ SMA \\ SME \\ SMS \end{bmatrix} + \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \sigma_4 \\ \sigma_5 \\ \sigma_6 \\ \sigma_7 \\ \sigma_8 \\ \sigma_9 \\ \sigma_{10} \\ \sigma_{11} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{14} \\ \sigma_{15} \\ \sigma_{16} \\ \sigma_{17} \\ \sigma_{18} \end{bmatrix} \qquad (7)$$

2)Construction of measurement equation of endogenous latent variables

SMR of endogenous latent variables includes three observation indexes, namely, accident rate and predicted difference of coalmine safety management, sales perforamce and predicted difference of coalmine enterprises and loss of employees and money and predicted difference of coalmine safety accidents.

$$Y = L_y h + e \qquad (8)$$

According to the usual equation 8, measurement equation of endogenous latent variables, measurement equation of endogenous latent variables was established, as shown in Equation 9.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \begin{bmatrix} \Lambda_{y1.1} \\ \Lambda_{y2.1} \\ \Lambda_{y3.1} \end{bmatrix} \left[SMR \right] + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \qquad (9)$$

3) Construction of structure equation

In accordance with research hypotheses and the basic form of structure equation

$$h = bh + Gx + z \qquad (10)$$

the structure equation in the paper was decided as follows:

$$\left[SMR \right] = \begin{bmatrix} \beta_{11} \\ \beta_{21} \\ \beta_{31} \end{bmatrix} \left[SMR \right] + \begin{bmatrix} \Gamma_{11} & \Gamma_{12} & \Gamma_{13} & \Gamma_{14} & \Gamma_{15} \\ \Gamma_{21} & \Gamma_{22} & \Gamma_{23} & \Gamma_{24} & \Gamma_{25} \\ \Gamma_{31} & \Gamma_{32} & \Gamma_{33} & \Gamma_{34} & \Gamma_{35} \end{bmatrix} \begin{bmatrix} SMO \\ SMM \\ SMA \\ SMF \\ SMC \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix} \qquad (11)$$

Where the left of the equation refers to endogenous latent variables, representing coalmine safety management risk consequence; while the right means exogenous latent variables SMO、SMM、SMA、SME and SMS, standing respectively for the five risk factors influencing coalmine safety management.

4) Model fitting and correction

In terms of the entire fitting degree of the model and structure fitting degree of inner structure of the model, the paper evaluated the fitting degree of the model. Evaluation standards of each fitting index are shown in Table 5.

TABLE5. FITTING INDEX AND EVALUATION STANDARDS

Index classification	index	name	acceptance standard of the model
Absolute fitting index	c^2/df	chi-square value ratio degree of freedom	$3 £ c^2/df £ 5$, acceptable.
			$c^2/df < 3$, quite well.
	RMSEA	approximate error mean square root	$0.05 £ RMSEA £ 0.08$,acceptable.
			$RMSEA < 0.05$, quite well.
	AGFI	regulated fitting degree index	AGFI>0.8,acceptable.
Relative fitting index	CFI	compared fitting degree index	CFI>0.8,acceptable.
			CFI>0.9, quite well.
	IFI	increment fitting degree index	IFI>0.8, acceptable.
			IFI>0.9 ,quite well.
	NFI	general fitting degree index	NFI>0.8 ,acceptable.
			NFI>0.9 ,quite well.

The initial model was tested by fitting degree in terms of AMOS17.0According to suggestions of AMOS17.0 in model correction result shown in the analysis process of the model, the correction was made. Contrasted with the fitting degree indexes of the initial model, the indexes were largely improved after correction of the model. Contrast results are shown in Table 6.

TABLE6. CONTRAST OF GOODNESS-OF-FIT INDEX BETWEEN THE MODEL AFTER CORRECTION

name of goodness-of-fit	$c^2/_{df}$	GFI	AGFI	RMSEA	NFI	NNFI	CFI	IFI
The initial model	2.483	0.832	0.901	0.0698	0.845	0.852	0.897	0.876
The model after correction	2.321	0.914	0.942	0.0584	0.919	0.918	0.904	0.921

As shown in Table 6, significance probability of each index of the model after correction is all larger than 0.05. $\chi^2/_{df}$ is 2.321, meaning the model works well. RMSEA of the model after correction is 0.0584, NFI is 0.919, NNFI is 0.918, IFI is 0.921, they are all larger 0.9, explaining the fitting is good. And, the result of structure equation and operation is shown in Fig.2.

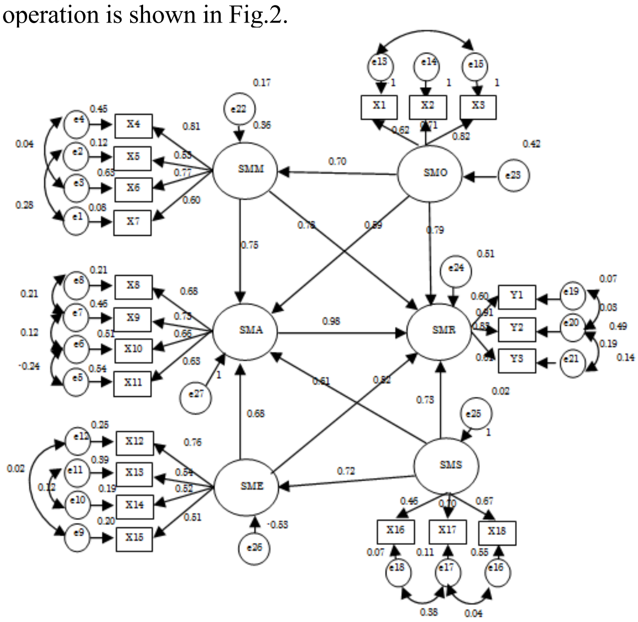

Figure 2. structure equation and operation result of coalmine safety management risk factor

IV. INTEGRATED EVALUATION OF COALMINE SAFETY MANAGEMENT RISK FACTOR

A. Hypotheses testing and path analysis

As shown in Table 7 and Fig.2, for H1, influence path parameter of *SMO* ® *SMR* is 0.79, the influence is remarkable, H1 was tested available, namely, coalmine safety management organization risk factors influence coalmine safety management risk consequences directly remarkably. For H2, influence path parameter of *SMM* ® *SMR* is 0.78, the influence is remarkable, H2 was tested available, namely, coalmine safety management mode influences coalmine safety management risk consequences directly remarkably. For H3, influence path parameter of *SMA* ® *SMR* is 0.98, the influence is remarkable, H3 was tested available, namely, coalmine safety management ability influences coalmine safety management risk consequences directly remarkably. For H4, influence path parameter of *SME* ® *SMR* is 0.68, the influence is remarkable, H4a was tested available, namely, the latent risk factors of coalmine safety management element influence coalmine safety management risk consequences directly remarkably. For H5, influence path parameter of *SMS* ® *SMR* is 0.73, the influence is remarkable, H5 was tested available, namely, coalmine safety management supervision risk factors influence coalmine safety management risk consequences directly remarkably.

As mentioned above, coalmine safety management supervision risk factors influence coalmine safety management ability, coalmine safety management factors and coalmine safety management risk consequences remarkably.

For H6, influence parameter of *SMO* ® *SMA* is 0.59, the influence is remarkable. Test showed that coalmine safety management organization risk factors exerted a certain influence on coalmine safety management capacity, and that it will cause coalmine safety management risk consequence through coalmine safety management ability risk. For H7, influence parameter of *SMO* ® *SMM* is 0.70, the influence is remarkable. Test showed that coalmine safety management organization risk factors exerted a certain influence on coalmine safety management mode, and that it will cause coalmine safety management risk consequence through coalmine safety management mode. For H8, influence parameter of *SMM* ® *SMA* is 0.75, the influence is remarkable. Test showed that coalmine safety management mode risk factors exerted a certain influence on coalmine safety management ability, and that it will cause coalmine safety management risk consequence through coalmine safety management ability. For H9, influence parameter of *SME* ® *SMA* is 0.68, the influence is remarkable. Test showed that the latent risk of coalmine safety management elements exerted a certain influence on coalmine safety management ability, and that it will cause coalmine safety management risk consequence through coalmine safety management ability risk. For H10, influence parameter of *SMS* ® *SMA* is 0.61, the influence is remarkable. Test showed that coalmine safety management supervision risk factors exerted a certain influence on coalmine safety management ability, and that it will cause coalmine safety management risk consequence through coalmine safety management ability risk. For H11, influence parameter of *SMS* ® *SME* is 0.72, the influence is remarkable. Test showed that coalmine safety management supervision risk factors exerted a certain influence on coalmine safety management elements, and that it will cause coalmine safety management risk consequence through coalmine safety management element risk.

B. *Integrated evaluation*

According to calculation value of path parameter, the path parameters of immediate effect of the five latent variables coalmine safety management organization, coalmine safety management mode, coalmine safety management ability, coalmine safety management elements and coalmine safety management supervision are 0.79, 0.78, 0.98, 0.82 and 0.73 respectively. Therefore, immediate effect of their influences on coalmine safety management risk consequence ranked in this way: coalmine safety management ability>coalmine safety management elements > coalmine safety management organization > coalmine safety management mode > coalmine safety management supervision.

TABLE7. PATH PARAMETER OF INTEGRATED EVALUATION INDEX

Evaluation objectives	Direct path parameter of the first level evaluation	Path parameter of the second level evaluation
coalmine safety management risk consequence	Safety management organization（SMO）（0.79）	Safety management organization structure（0.82）
		Safety management organization behavior（0.71）
		Safety management organization culture（0.62）
	Safety management mode（SMM）（0.78）	Stipulation and perfection safety management plan（0.81）
		Implementation and control of safety management plan（0.53）
		Safety incentive mechanism（0.77）
		Safety training and education（0.60）
	Safety management ability（SMA）（0.98）	Safety behavior management ability（0.68）
		Safety administration management ability（0.73）
		Safety technology management ability（0.66）
		Safety innovation management ability（0.63）
	Safety management elements（SME）（0.82）	Human factor（0.76）
		Machinery (equipment) safety（0.54）
		Environment safety（0.58）
		Information safety（0.51）
	Safety management supervision（SMS）（0.73）	The completion degree of standard and regulation of monitoring product（0.46）
		Calibration or maintenance promptness of monitoring system（0.70）
		The completion degree of safety management system（0.67）

Simultaneously, coalmine safety management organization exerted influence on coalmine safety management risk consequence through coalmine safety management ability and coalmine safety management mode. Its total influence parameter influencing coalmine safety management risk consequence was the sum of path parameter of immediate influence and that of indirect influence. And the indirect influence parameter is the product of each parameter along indirect path, that is

$$p_i = \sum_{j=1}^{n} p_{ij} \qquad j = 1, 2, \ldots, n \tag{12}$$

where p_i means effect path parameter of the ith exogenous latent variable on endogenous latent variable, p_{ij} means the ith exogenous latent variable effects endogenous latent variable through j paths, while j means the number of indirect path. Path parameter of evaluation at each level is shown in Table7.

Coalmine safety management organization posed an effect on coalmine safety management risk consequence through three paths. One is direct path, its parameter is 0.79; two are indirect paths, safety management organization posed an effect on coalmine safety management risk consequence through coalmine safety management ability, its corresponding path parameter is 0.59, the other one is that coalmine safety management mode caused coalmine safety management risk consequence via coalmine safety management ability, the path parameters are 0.70,0.75. As a result, the synthetical path parameter of coalmine safety management organization is as follows:

$$p_{smo} = 0.79 + 0.98(0.70 \times 0.75 + 0.59) = 1.88 \tag{13}$$

Coalmine safety management mode posed an effect on coalmine safety management risk consequence through two paths. One is direct path, its parameter is 0.78; the other is indirect path that coalmine safety management mode posed an effect on coalmine safety management risk consequence through coalmine safety management ability, the corresponding parameter is 0.75. As a result, the synthetical path parameter of coalmine safety management mode is as follows:

$$p_{smm} = 0.78 + 0.98 \times 0.75 = 1.52 \tag{14}$$

Coalmine safety management elements posed an effect on coalmine safety management risk consequence through two paths. One is direct path, its parameter is 0.82; the other is indirect path that coalmine safety management elements posed an effect on coalmine safety management risk consequence through coalmine safety management ability, the corresponding parameter is 0.68. As a result, the synthetical path parameter of coalmine safety management elements is as follows:

$$p_{sme} = 0.82 + 0.98 \times 0.68 = 1.37 \tag{15}$$

Coalmine safety management supervision posed an effect on coalmine safety management risk consequence through three paths. One is direct path, its parameter is 0.73; two are indirect paths, safety management supervision posed an effect on coalmine safety management risk consequence through coalmine safety management ability, its corresponding path parameter is 0.61, the other one is that safety management supervision caused coalmine safety management risk consequence via coalmine safety management ability, the path parameters are 0.72、0.68. As a result, the synthetical path parameter of coalmine safety management supervision is as follows:

$$\because p_{sms} = 0.79 + 0.98(0.72 ´ 0.68 + 0.61) = 1.87 \quad ....(16)$$

The effect of coalmine safety management ability on coalmine safety management risk consequence is direct, remarkable, its path parameter is 0.98.

Through synthetical computation and normalization processing, the total path parameter of five risk indexes of the first level influencing risk consequence is

$$W = (0.247, 0.199, 0.179, 0.245, 0.130).$$

The degree of their influence ranked like this: coalmine safety management organization > coalmine safety management supervision > coalmine safety management mode > coalmine safety management elements > coalmine safety management ability.

V. CONCLUSIONS

A conclusion is drawn from the above that influence of coalmine safety management ability on coalmine safety management risk consequence is the largest in the rank of all direct effects; and that influence of coalmine safety management ability on coalmine safety management risk consequence is the smallest in the rank of all indirect effects. This shows that coalmine safety management ability influences coalmine safety management risk consequence directly. Besides, coalmine safety management ability is also influenced by coalmine safety management organization, coalmine safety management mode, coalmine safety management elements. The latent risk factors of coalmine safety management organization, coalmine safety management mode, coalmine safety management elements will transmit or evolve to coalmine safety management ability risk, causing coalmine safety management risk consequence accordingly, and then the loss is made. Path parameters of the second level are

$$w_{smo} = (0.38, 0.33, 0.29), \; w_{sma} = (0.27, 0.26, 0.24, 0.23)$$

$$w_{sme} = (0.32, 0.23, 0.24, 0.26), \; w_{sms} = (0.25, 0.38, 0.37)$$

Magnitude of each parameter just reflects how indexes at the second level influence ones at the first level, indexes at the second level influence risk consequence through indexes at the first level.

In a word, heavy attention should be paid to both direct influence of all risk factors on coalmine safety management and interactions among all risk factors in the process of coalmine safety management. On the other hand, these risk factors influence coalmine safety management through all sorts of paths, and then cause risk consequence. Only when full importance is attached to influence path and degree of all sorts of risk factors on risk consequence, prompt measures are taken to remove influence of risk factors, to break transmission path of risk factors, can the probability of coalmine safety management be lowered down to the minimum, truly realizing refinement and essential management in coalmine safety.

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