Evaluation on Safety Benefits of Mining Industry Occupational Health and Safety Management System Based on DEA Model and Grey Relational Analysis

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***Abstract*—The mining industry safety production situation is becoming more and more severe in China with safety accidents occurring frequently, which is closely related to insufficient safety investments and unreasonable distribution. Additionally, it does not keep in line with the main purpose of occupation health and safety management system (OHSAS18001).In order to carry on the reasonable scientific disposition to the safety investments of the mining industry, increase safety investments efficiency and satisfy the requirements of OHSAS18001, data envelopment analysis (DEA) is adopted to calculate the safety investments, loss and output. Firstly, the analysis software MYDEA of DEA is used to calculate the results to obtain the evaluation result of safety benefits. Secondly, the target value of the improvement work in the aspect of investment is achieved by method of projection analysis when the decision making unit (DMU_{j0}) of non DEA efficiency is changed into DEA efficiency. Lastly, it can be obtained on the basis of grey relational analysis (GM) that the investment amount of safety management and training of employees has the highest relation on the effective safety benefits of the mining industry. Thus, the investment of safety management and training of employees should be strengthened. This kind of empirical method of comprehensive model provides a direction and theoretical reference for safety investments benefits analysis and optimized investment structure, and a structure for the effective operation of mining industry occupational health and safety management system.**

***Index Terms*—Mining industry, OHSAS18001, safety benefits, DEA, grey relational analysis.**

I. Introduction

OHSAS18001 is an effective way which is recognized by the international organization and proved effective to the occupational health and safety management of the employees. It has put forward the PDCA requirement of system operation planning, personnel management, operational control and so on. Although it has introduced into mining industry for many years, the safety accidents occurring frequently result in great economic loss and passive safety investments which are contrary to the purpose of continuous improvement of OHSAS18001. Feasible DEA model and grey relational analysis method used in this paper supply a reasonable distribution basis for mining industry OHSAS18001. Additionally, the methods provide strong support for the healthy and sustainable development of OHSAS18001.

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II. Safety Investments and Benefits Indicators of Mining Industry OHSAS18001

According to the OHSAS18001standard requirements [1] of 4.4.1 Resources, roles, responsibility, accountability and authority, 4.4.2 Competence, training and awareness, 4.4.6 Operational control, 4.4.7 Emergency preparedness and response and 4.5.1 Performance measurement and monitoring. Additionally, requirements of actual operation of mining industry, four safety investment indicators of mining OHSAS18001are established as shown in the following: safety technical measures, industrial hygiene measures, safety management and training and labor protection products [2].

A. Safety Benefits

Safety benefits refer to realization of safety level, the benefits to the society, the community and the individual [3]. Additionally, they are composed of the sum (decrease loss output and increment output) - total safety investments ratio [4].

B. Safety Technical Measures

Safety technical measures refer to preventing casualty accidents including ventilation system, protection device, insurance device, signal device etc.

C. Industrial Hygiene Measures

Industrial hygiene measures are the technical measures of improving the production environment which do harm to the health of workers and preventing occupational diseases and poisoning, including anti-virus, dust, anti vibration and noise, ventilation, cooling, cold and other equipments etc.

D. Safety Management and Training

Safety management and training cover technical services, training, hardware and software equipments, occupation health examination of employees, three levels of safety education, all kinds of emergency supplies etc.

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E. Labor Protection Products

Labor protection products are the necessary equipments and all labor hygiene protection measures including disinfection room, changing room or clothing room, shower room, women's health room etc.

F. Decrease Loss Output

Decrease loss output means that safety investments activities guarantee the safety production of enterprises, reduce or avoid some safety accidents, reduce the damage to the human society and the environment caused by the accident, protect the wealth of social enterprise effectively and reduce the waste of resources.

G. Increment Output

Increment output is also the increment benefit of safety which means that the benefits are produced by guaranteeing the working conditions of the workers and maintaining the increment process of the enterprise economics.

III. Safety Benefits of Mining Industry OHSAS18001 Based on DEA Model

Data envelopment analysis (DEA) was first introduced by famous operational research experts: A. Charnes, W.W. Cooper and E. Rhodes in 1978 [5]-[6]. It was used to evaluate the relative effectiveness of the same department whose first model was called C^2R model. From the point of view of production function, it is a very good and effective way to study several inputs especially when "production department" are "effective scale" and "technical efficiency" at the same time.

A. The i^{th} Input and the r^{th} Output

The i^{th} input of unit j is explained by x_{ij}, the r^{th} output of unit j is explained by y_{rj} and the input and output is shown as follows:

$$input\begin{cases}1\rightarrow \\ 2\rightarrow \\ \vdots \\ m\rightarrow\end{cases}\begin{bmatrix}x_{11} & x_{12} & \cdots & x_{1n}\\ x_{21} & x_{22} & \cdots & x_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ x_{m1} & x_{m2} & \cdots & x_{mn}\end{bmatrix};$$

$$\left.\begin{bmatrix}y_{11} & y_{12} & \cdots & y_{1n}\\ y_{21} & y_{22} & \cdots & y_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ y_{s1} & y_{s2} & \cdots & y_{sn}\end{bmatrix}\begin{matrix}\rightarrow 1\\ \rightarrow 2\\ \vdots\ \ \vdots\\ \rightarrow s\end{matrix}\right\}output$$

B. The Formula h_j of Input-Output Ratio

Suppose the weight of i^{th} input is expressed by v_i and the weight of r^{th} output is expressed by u_i. Let v_i $(i=1,2,\ldots m)$, u_i $(r=1,2,\ldots s)$, $j=1,2,\ldots n$ and $h_j \leq 1$. Then the optimization model of formula h_j of input-output ratio of j^{th} decision making unit and performance appraisal of j_0 each decision making unit can be summed up as follows:

$${}_{j} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \quad (j=1,2,\ldots n);$$

$$\max h_{j0} = \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_i x_{ij0}};$$

$$s.t = \begin{cases}\dfrac{\sum_{r=1}^{p} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, j=1,2,\ldots n\\ v_i, u_r \geq 0, i=1,2,\ldots m;\ r=1,2,\ldots p\end{cases}.$$

C. The Transformation of the Fractional Programming Problem

This is a fractional programming problem, which can be transformed into an equivalent linear programming problem as shown below:

$$t = \frac{1}{\sum_{i=1}^{m} v_i x_{ij0}} \quad \mu_r = tu_r \ \ w_i = tv_i$$

D. The Linear Programming Model and Vector Form

The linear programming model and vector form are shown as follows:

$$\max h_{j0} = \mu^T Y_0$$

$$s.t = \begin{cases}\mu^T Y_j - \omega^T X_j \leq 0\\ \omega^T X_0 = 1\\ \omega \geq 0, \mu \geq 0\end{cases}$$

$$\max h_{j0} = \sum_{r=1}^{p} u_i Y_{rj0}$$

$$s.t.\begin{cases}\sum_{r=1}^{p} u_i Y_{rj} - \sum_{i=1}^{m} w_i X_{ij} \leq 0, j=1,2,\ldots n\\ \sum_{i=1}^{m} w_i X_{ij0} = 1\\ w_i \geq 0, u_i \geq 0,\ i=1,2,\ldots m; r=1,2,\ldots p\end{cases}$$

E. The Dual Problem and Vector Form

The dual problem and vector form are shown as follows:

$$\min v_D = \theta$$

$$s.t.\begin{cases}\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0}, i=1,2,\ldots m\\ \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, r=1,2,\ldots p\\ \lambda_j \geq 0, \theta \in unconstrained\end{cases}$$

$$DMU \ \min\theta$$

$$s.t.\begin{cases}\sum_{j=1}^{n}\lambda_j x_j + s^- = \theta x_0 \\ \sum_{j=1}^{n}\lambda_j y_j - s^+ = y_0 \\ s^- \geq 0, s^+ \geq 0, \lambda_j \geq 0\end{cases}$$

F. Theorem 1 of Relative Efficiency Evaluation of C^2R Model

Relative efficiency evaluation of C^2R model: (1) Suppose $\theta = 1, s_0^- = 1, s_0^+ = 0$, the decision making unit j_0 is called DEA efficiency. (2) Suppose $\theta < 1, s_0^- \neq 0, s_0^+ \neq 0$, the decision making unit j_0 is called non DEA efficiency.

IV. Grey Relational Analysis of Safety Investments and Benefits of Mining Industry OHSAS18001

The grey system theory was created by Chinese Professor Deng Julong in 1880s [7]. The grey system theory has been successfully introduced to agricultural, industrial, economic and other science fields for over 20 years. Grey system is not fully known with information, that is, some information is known and some other is unknown. Grey relational analysis is an important part of grey system theory whose method is used to analyze the correlation degree of each factor of the system, to calculate the grey relation between the system characteristic variables and the variables of the data sequence and to analyze the advantages results and the evaluation results [8]-[10].

At present, the calculation model about the grey relation between the sequences is the following [11]. Deng Relational Analysis [12], Grey Euclid Relation Grade [13], Absolute correlation degree [14], Generalized Degree of Grey Incidence [15], T's correlation Degree [16], C-Mode Relational Analysis [17], B-Mode Relational Analysis [18]. The method of Deng Relational analysis method is utilized in this paper.

A. Determining the Analysis Sequence

Select reference series and let $X = \{x_0, x_1, \cdots, x_m\}$ be grey relation factor set, x_0 be a reference sequence, x_i be a comparison sequence, and $x_0(k)$, $i = \{1, 2, \cdots, m\}$ $x_i(k)$ be the *k* point number of x_0 and x_i as shown below:

$$x_0 = (x_0(1), x_2(2), \cdots, x_0(n)); x_1 = (x_1(1), x_1(2), \cdots, x_1(n))$$
$$x_2 = (x_2(1), x_2(2), \cdots, x_2(n)) \cdots\cdots,$$
$$x_m = (x_m(1), x_m(2), \cdots, x_m(n))$$

B. Non Dimensional Variables

Each factor in the data of the column may be different because of the dimension, so it is hard to get the correct conclusion when in comparison. The data is generally performed by non dimensional treatment during the grey relational analysis:

$$x_i(k) = \frac{x_i(k)}{x_i(1)}, \mathrm{k} = 1, 2, \ldots \mathrm{n}; \mathrm{i} = 1, 2, \ldots \mathrm{m} \qquad (2)$$

C. Calculating the Relational Coefficient

The relational coefficient of $x_0(k)$ and $x_i(k)$ is shown below:

$$\zeta_i(k) = \frac{\min_i \min_k |X_0(k) - X_i(k)| + \rho \max_i \max_k |X_0(k) - X_i(k)|}{|X_0(k) - X_i(k)| + \rho \max_i \max_k |X_0(k) - X_i(k)|} \qquad (3)$$

$$r(x_0(k), x_i(k)) = \frac{\Delta_{\min} + \rho \ \ \Delta_{\max}}{\Delta_{0i}(k) + \rho \ \ \Delta_{\max}} \qquad (4)$$

In the formula, $\Delta_{0i}(k) = |x_0(k) - x_i(k)|$ is the absolute difference, $\Delta_{\min} = \min_i \min_k \Delta_{0i}(k)$ is the minimum difference between two poles, $\Delta_{\max} = \max_i \max_k \Delta_{0i}(k)$ is the maximum difference between two poles, ρ is the resolution ratio , $\rho \in (0,1)$ (remarks: ρ value normally equals 0.5 in actual calculation.), and ω_k is the weight of *k* point number which satisfies $0 \leq \omega_k \leq 1, \sum_{k=1}^{n}\omega_k = 1$.

D. Calculating Grey Relation

Because the relational coefficient is too scattered to compare overall, normally the average value is expressed as the degree value between comparison sequence and reference sequence, and r_i formula of the relational coefficient is as follows [19]:

$$r_i = \frac{1}{n}\sum_{k=1}^{n} \zeta_i(k) \qquad (5)$$

E. The Relation Ranking

Normally, if $r(x_0, x_i) > r(x_0, x_j)$, the relation of x_i and x_0 is higher than that of x_j and x_0. That is to say, the Influence degree of x_i on x_0 is higher than that of x_j on x_0.

V. Case Study

The mining lies in the Southwest of the Hubei Province, China with nice mining resources. OHSAS18001 has been one of the management methods for many years with a good reputation in the local community as well as the society. Taking the mining industry as an example, this paper evaluates the effective safety investments and safety benefits by methods of DEA and grey relational analysis.

A. Safety Investments and Loss Statistics

As shown in Table 1, the 4 first-grade indicators of the mining industry safety investments including safety technical measures etc. and 23 second-grade indicators including ventilation system etc. are chosen to analyze. Statistical information of safety investments is selected from 2011 to 2015. The accident loss indicators of the comparison sequence of safety investments are selected including the direct accident loss of the first-grade indicator etc. from 2011 to 2015. Common total accident loss algorithm includes the one-to-four direct and indirect ratio method of Heinrich [20] from USA and total loss method of Symonds [21] also from USA which can be calculated by the formula:

$$\begin{aligned} Total\ loss = (&Covered\ losses + A \times Laying-off\ injury\ times \\ &+ B \times Hospitalization\ injury\ times \\ &+ C \times Emergency\ medical\ times \\ &+ D \times No\ accident\ times) \end{aligned}$$

In the formula, A, B, C and D separately refer to the average amount of non insurance cost which stands for varieties of different accidents degree. Per capita direct loss of accidents need to be compared with the loss of previous year, so per capita direct loss of accidents was collected as 0.204 yuan /person of 2010, and the indirect loss of decrease loss output is 4 times of direct loss.

TABLE I: SAFETY INVESTMENTS AND LOSS STATISTICS OF THE MINING INDUSTRY OHSAS18001 (UNIT: TEN THOUSAND)

First-grade indicator	Second-grade indicator	2011	2012	2013	2014	2015
X_1 Safety technical measures	Ventilation system	45.5	47.3	44.3	55.3	57.1
	Protection device	22.4	30.8	28.6	31.2	33.4
	Insurance device	28.5	40.5	41.3	40.2	41.3
	Signal device	31.1	30.9	28.4	56.5	58.1
	Others	5.9	7.7	2.5	6.6	7.5
X_2 Industrial hygiene measures	Dustproof device	3.1	3.4	2.8	2.8	3.2
	Anti noise and vibration	1.4	1.6	1.3	1.4	1.5
	Gas defense	1.1	1.4	1.1	1.5	1.4
	Ventilation, cooling, and cold proof	2.1	2.6	1.5	1.7	1.7
	Others	1.0	0.5	0.6	0.7	1.1
X_3 Safety management and training	OHSAS operating	29.8	33.5	29.7	35.4	36.6
	Specific type of worker training	2.8	2.9	2.6	2.9	2.9
	Three levels of safety education	0.8	0.8	0.8	0.8	0.8
	Occupational health examination	22.0	27.4	24.1	28.1	28.8
	Emergency rescue	21.0	21.9	19.5	22.7	24.3
	Others	2.3	2.6	2.2	2.4	2.4
X_4 Labor protection products	Individual protection	22.4	25.5	24.1	33.2	36.7
	Special protection	37.4	40.2	40.1	51.2	52.2
	Others	7.8	11.1	6.0	4.2	6.2
Direct accident loss	Accident property loss	8.5	8.9	10.8	14.5	10.1
	Accident disposal	65.3	65.7	61.4	67.9	68.9
	Occupational disease Prevention	14.3	14.5	14.2	14.6	14.9
	Others	1.2	1.3	1.1	1.3	1.4
Total safety investments		288	333	302	379	397
Total number of persons		450	459	410	510	534
Gross industrial output value		3689	3864	3216	4237	4789
Total production investment		867	874	770	890	890
Total accident loss		89.3	90.4	87.5	98.3	95.3
Per capita direct loss of accidents		0.2	0.2	0.2	0.19	0.19

B. Calculating the Safety Benefits of the Mining Industry OHSAS18001

The key point of calculating safety benefits is to calculate the safety output as shown below [4]:

B (safety output)= B_1 (decrease loss output) + B_2 (increment output).

In the formula, B_1 (decrease loss output) $=\Sigma$ (decrease loss increment)= early loss(before safety measures)-later loss (after safety measures); B_2 (increment output) = productivity contribution ×total output value.

Y_1 (safety benefits) can be calculated by the data of Table I as shown in Table II.

TABLE II: SAFETY BENEFITS LIST OF THE MINING INDUSTRY OHSAS18001

	2011	2012	2013	2014	2015
Decrease loss output (ten thousand)	13.5	2.3	4.1	5.1	10.7
Increment output (ten thousand)	1226.8	1470.0	1259.7	1803.3	2136.5
Safety benefits (yuan/person)	4.3	4.4	4.2	4.8	5.4

C. Safety Investments and Benefits List of the Mining Industry OHSAS18001

The safety investments and benefits list of the mining industry OHSAS18001 is established according to table1 and 2 as shown in Table III.

TABLE III: SAFETY INVESTMENTS AND BENEFITS LIST OF THE MINING INDUSTRY OHSAS18001

DMU	X_1	X_2	X_3	X_4	X_5
2011	133.4	8.7	78.7	67.6	4.301
2012	157.2	9.5	89.1	76.8	4.427
2013	145.1	7.3	78.9	70.2	4.192
2014	189.8	8.1	92.3	88.6	4.774
2015	197.4	8.9	95.8	95.1	5.406

D. The Safety Benefits Results Calculating

The safety benefits results are calculated by the software MYDEA of DEA as shown in Table IV.

TABLE IV: DEA EVALUATION RESULTS OF SAFETY INVESTMENTS AND BENEFITS OF THE MINING INDUSTRY OHSAS18001

DMU	θ	s_1^-	s_2^-	s_3^-	s_4^-	s_1^+	Efficiency
2011	1.0	0.0	0.0	0.0	0.0	0.0	DEA efficiency
2012	0.9	4.2	0.0	0.3	0.0	0.4	non DEA efficiency
2013	1.0	0.0	0.0	0.0	0.0	0.0	DEA efficiency
2014	1.0	10.1	0.0	5.1	2.0	0.1	non DEA efficiency
2015	1.0	0.0	0.0	0.0	0.0	0.0	DEA efficiency

E. Projection Analysis of C²R Model

The target value of the improvement work can be achieved with the aid of "projection" analysis" when the decision making unit (DMU_{j0}) of non DEA efficiency is changed into DEA efficiency. Reference information for the improvement of production and management efficiency in the future can be provided as well.

Theorem 2: Let $\bar{x}_{ij0} = \theta^0 \cdot x_{ij0} - s_i^{-0}$, $\bar{y}_{rj0} = y_{rj0} + s_r^{+0}$. In the formula, $\theta^0, s_i^{-0} and\ s_r^{+0}$ are the optimal solution for linear programming which corresponds to decision making units (j_0). (x_0, y_0) of the relative efficiency "projection" of DEA which corresponds to $(\bar{x}_{ij0}, \bar{y}_{rj0})$ is determined to be DEA efficiency. According to the above theorem, the before and after adjustment results of the "projection" analysis" are shown in Table V.

TABLE V: BEFORE AND AFTER ADJUSTMENT RESULTS OF SAFETY BENEFITS "PROJECTION" ANALYSIS" OF THE MINING INDUSTRY OHSAS18001

DMU	Before adjustment results					After adjustment results				
	X_1	X_2	X_3	X_4	Y_1	X_1	X_2	X_3	X_4	Y_1
2011	133.4	8.7	78.7	68	4.3	133.4	8.7	78.7	67.6	4.3
2012	157.2	9.5	89.1	77	4.43	140.0	8.7	81.4	70.5	4.5
2013	145.1	7.3	78.9	70	4.19	145.1	7.3	78.9	70.2	4.2
2014	189.8	8.1	92.3	89	4.77	174.0	7.9	84.5	83.9	4.8
2015	197.4	8.9	95.8	95	5.41	197.4	8.9	95.8	95.1	5.4

F. Reference Squence and Comparison Squence Establishing

As shown in Table VI, the results of DEA "projection analysis" of reference sequence and comparison sequence are shown as below: 0 Safety benefits, 01 Safety technical measures, 02 Industrial hygiene measures, 03 Safety management and training, 04 Labor protection products.

TABLE VI: THE ORIGINAL SEQUENCE OF SAFETY BENEFITS AND INVESTMENT STATISTICS OF THE MINING INDUSTRY OHSAS18001 (UNIT: TEN THOUSAND)

Indicators	2011	2012	2013	2014	2015
0 Safety benefits	4.3	4.5	4.2	4.8	5.4
01 Safety technical measures	133.4	140.0	145.1	174.0	197.4
02 Industrial hygiene measures	8.7	8.7	7.3	7.9	8.9
03 Safety management and training	78.7	81.4	78.9	84.5	95.8
04 Labor protection products	67.6	70.5	70.2	83.9	95.1

G. Initialization Squence Establishing

As shown in Table VII, according to the formula (2), the initialization value of safety investments and safety benefits of the mining industry OHSAS18001 from 2011 to 2015.

TABLE VII: THE INITIALIZATION VALUE OF SAFETY INVESTMENTS AND SAFETY BENEFITS OF THE MINING INDUSTRY OHSAS18001 (UNIT: TEN THOUSAND)

Indicators	2011	2012	2013	2014	2015
0 safety benefits	1.0	1.0	1.0	1.1	1.3
01 Safety technical measures	1.0	1.1	1.1	1.3	1.5
02 Industrial hygiene measures	1.0	1.0	0.8	0.9	1.0
03 Safety management and training	1.0	1.0	1.0	1.1	1.2
04 Labor protection products	1.0	1.0	1.0	1.2	1.4

H. Absolute Difference Squence Establishing

According to the formula (4), safety investments absolute difference sequence of OHSAS18001 from 2011 to 2015 can be obtained as follows:

$$\Delta_{01} = (0.000, 0.013, 0.113, 0.193, 0.223);$$
$$\Delta_{02} = (0.000, 0.035, 0.136, 0.208, 0.234);$$
$$\Delta_{03} = (0.000, 0.002, 0.028, 0.038, 0.040);$$
$$\Delta_{04} = (0.000, 0.006, 0.064, 0.130, 0.150).$$

Obviously, $\Delta_{\min} = 0, \Delta_{\max} = 0.234$

I. Relational Coefficient Calculating

According to the formula (3), let $\rho = 0.5$, then the following can be obtained:

$$\xi_{0j(k)} = \frac{0 + 0.5 \times 0.234}{\Delta_{0i} + 0.5 \times 0.234};$$

$$\xi_{01} = \frac{0 + 0.5 \times 0.234}{\Delta_{01} + 0.5 \times 0.234} = (1.000, 0.900, 0.509, 0.377, 0.344);$$

$$\xi_{02} = \frac{0 + 0.5 \times 0.234}{\Delta_{02} + 0.5 \times 0.234} = (1.000, 0.770, 0.463, 0.360, 0.333);$$

$$\xi_{03} = \frac{0+0.5\times 0.234}{\Delta_{03}+0.5\times 0.234} = (1.000, 0.982, 0.808, 0.360, 0.747);$$

$$\xi_{04} = \frac{0+0.5\times 0.234}{\Delta_{04}+0.5\times 0.234} = (1.000, 0.955, 0.647, 0.473, 0.438);$$

J. Relation Analyzing

Let $\omega_1 = \omega_2 = \omega_3 = \omega_4 = \omega_5 = 1/5$, the relation of the comparative indicator x_i and reference indicator x_0 can be obtained as the following:

$$r_{01} = \frac{1}{5}\sum_{k=1}^{5}\xi_{01}(k) = 0.626;\ r_{02} = \frac{1}{5}\sum_{k=1}^{5}\xi_{02}(k) = 0.585;$$

$$r_{03} = \frac{1}{5}\sum_{k=1}^{5}\xi_{03}(k) = 0.779;$$

$$r_{04} = \frac{1}{5}\sum_{k=1}^{5}\xi_{04}(k) = 0.703.$$

Obviously, $r_{03} > r_{04} > r_{01} > r_{02}$.

It can be concluded that safety management and training have the highest relation on effective safety benefits of the mining industry, that is, safety management and training have the greatest impact in the safety investments. The next only to that are labor protection, safety technical measures and industrial hygiene measures. In other words, the investment of safety management and training should be strengthened to increase the safety benefits.

VI. Conclusion

The safety benefits of the mining industry are result of the comprehensive function of the internal and external factors. The relative benefits of mining industry are closely related to the national macro regulation, the market situation, the quality of the products and the state of internal management of the mining industry, which are confirmed by the DEA analysis results. The steel market of Hubei Province falling into an all-time low in 2012 resulted in low relative benefits of that year. Additionally, internal reform of the mining industry in 2014 led to low relative benefits of that year.

Although projection analysis can provide managers with the goal of improving the work, this is only theoretical. In the actual work, some indicators value may not be reduced. Therefore, the improvement measures should be made according to the actual situation to achieve transition to DEA efficiency combined with the increase of output.

The purpose of mining occupational health and safety management system is to continuously improve the performance of the enterprise, to guarantee the employee's occupational health and safety, and to ensure rational scientific investment and maximum economic safety benefits. In this paper, the empirical analysis of the mining industry in Southwest Hubei Province confirmed the importance of the safety management and training impact on safety benefits. It also puts forward the people-oriented management appeal to the managers providing a reference for the sustainable and healthy development of mining industry.

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