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Retraction

Retracted: Emergency Management System for Coal Mine Safety Based on IoT Technology

Mobile Information Systems

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] B. Fang, "Emergency Management System for Coal Mine Safety Based on IoT Technology," *Mobile Information Systems*, vol. 2022, Article ID 9071676, 10 pages, 2022.

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Research Article

Emergency Management System for Coal Mine Safety Based on IoT Technology

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The Internet of Things (IoT) has brought technological innovation to various industries, and it has also brought great impact to coal industry. It is important to study the safety supervision system of coal in the IoT mode to improve effectiveness of safety supervision and make suggestions to improve safety production in coal. In this paper, based on analysis of influence factors and emergency supervision system in the IoT mode, system dynamics modeling theory and method are used to construct a system dynamics model of influence factors and emergency supervision in the IoT mode. The validity and reliability of the model are verified by the system dynamics software to reach more than 98.6%, and the support for the development of coal Internet of things is appropriately increased to support the development of coal Internet of things, ensure the healthy and long-term development of coal Internet of things, improve the level of supervision, and ensure the safe production of coal

1. Introduction

In 2015, China's GDP growth rate was 6.8%, a 25-year low; according to China's National Energy Administration, national energy consumption is expected to be a total of 4.3 billion tons of standard coal in 2015, an increase of 0.9% year-on-year and lowest growth rate since 1998, and energy trend of energy consumption shifting gears and slowing down is obvious [1]. But energy in China's economic growth still occupies an irreplaceable and important position. With comprehensive deepening of reform entering the hardening period, China's energy sector has embarked on a new round of reform, and China's energy development has to achieve structural optimization, total consumption control, security capacity strengthening, and efficiency improvement [2–4]. In the period of "new normal" economy, it is of strategic importance to further enhance effectiveness and relevance of energy regulation to "stabilize growth and adjust structure" [5].

IoT uses local networks or Internet and other communication technologies to link sensors, controllers, machines, people, and things together in a new way to form a network of people and things to achieve informationization, remote management, and control and intelligence. The purpose is to achieve real-time control of real physical world, accurate management, and intelligent decision-making [6]. IoT is an extension of Internet, which includes Internet and all resources on Internet, compatible with all applications of Internet, but elements of IoT, including people, equipment, environment and resources, are real and visible [7]. Therefore, IoT can be organic combination of modern information technology and traditional industries to promote traditional industry productivity and update management model of traditional industries in enterprise. In 2012, the state council requested "12th Five-Year" period to enhance the ability of independent innovation and promote deep integration of information technology and industrialization, transformation, and upgrading of traditional industries [8]. In coal industry as a typical traditional industry, development pressure is huge, and urgent need for technological innovation and use of IoT technology is very necessary [9]. Coal safety production is still not optimistic. Mining itself is also a great damage to natural environment, and there is a need to enhance effectiveness supervision and target. IoT integrates all aspects of safety, production, and management information and collects, stores, and manages all kinds of information in a unified manner, which has a great impact on improving safety, operational efficiency, and informationization level of coals. Therefore, it is necessary to study safety supervision system of coal in the IoT mode to improve safety supervision [10, 11]. Based on the analysis of the influencing factors and emergency supervision system under the Internet of things mode, this paper uses the theory and method of system dynamics modeling and verifies the effectiveness and reliability of the model through the system dynamics software.

2. Related Studies

At present, there are many scholars who have studied rent-seeking behavior in coal safety supervision. In terms of performance of rent-seeking behavior and its influence, many scholars believe that rent-seeking has a great influence on the development of coal industry, an effect of coal regulation. Wang et al. [12] researched how rent-seeking behavior affects effect regulation, suggesting that enterprises may directly influence coal prices through rent-seeking, control lifeline of energy prices, form monopolies and trade barriers, and point out importance of dynamic supervision in regulation. In addition, many scholars have done a lot of research on game between various stakeholders' regulation. Singh et al. [13] pointed out that there is a game between stakeholders' regulation in regulatory activities, which reduces efficiency of regulation. The earliest foreign safety regulation theory began in United States, mainly from the aspect of safety regulation tools to study [14]. From the perspective of internal regulation, it is believed that a highly reliable organization can be established through establishment of a reward and incentive system and effective communication to reduce the occurrence of accidents. It is believed that both external supervision by government and internal management by enterprise are effective ways to regulate. Therefore, a hybrid self-responsive regulatory model is recommended, where government uses more consultative means and makes full use of third-party participation and information services to internalize pressure for safety and environmental protection into economic goals of company [15, 16]. After extensive research on mine safety regulatory legislation and enforcement activities, it was found that mine safety regulations are too numerous and detailed, and many mine owners and miners are unaware of them, with special emphasis on the role of education [17–20].

We used the IoT technology to build a digital mine integration platform, mine automation system, underground precise positioning and navigation system, and intelligent sensing system of mining environment; proposed a 5-layer intelligent mine system architecture scheme based on IoT based on the analysis of current situation of intelligent mine construction; and proposed an intelligent mine application system based on this architecture, pointing out that this. The system can be used to guide coal mining enterprises to build mine IoT system; proposes that core problem of perception mine construction is "3 perceptions": perception of mine disaster risk to achieve early warning forecasting of various accidents and disasters, perception of miners' surrounding safety environment to achieve active safety protection, and perception of mine equipment working health to achieve In sensing layer, developed an intelligent information terminal with miner positioning, surrounding environment information sensing and two-way communication functions; [17] applied IoT technology to realize online real-time monitoring of mine environment by establishing a technology-based wireless sensor network in response to actual needs of mine. In network layer research, Chen and Wang [18] proposed an integrated mine wireless communication and personnel location management system design scheme combining WIFI and RFID (radio frequency identification) for commonly used mine communication system and personnel location system, which all adopt independent network distribution method and have problem of duplicated network distribution. In application layer research, the authors of [19] designed a set of remote online real-time monitoring and fault diagnosis platform for mine electromechanical equipment based on IoT technology, so that it can play an important role in ensuring enterprise safety production [21–26].

Therefore, based on current situation supervision and current situation of development of IoT, this paper uses the theory of system analysis, literature research method, expert interview method, and mind mapping method to determine main factors supervision system and influence of IoT on elements supervision system, construct a model supervision system in IoT mode, and also use system dynamics. The modeling method of system dynamics was used to quantitatively study and establish dynamics model supervision system in the IoT mode, which provides a new idea for study supervision in the IoT mode [27–29].

3. Security Emergency Regulatory Structure

Mine has set up a complete production safety management structure. The specific structure of production safety management organization is shown in Figure 1.

The guiding role of the "three" structure is to fully implement responsibility of enterprises, strictly regulate safety production of enterprises, implement more comprehensive and strict supervision and management of daily production, scientifically carry out emergency rescue work, prevent and reduce occurrence of production safety accidents, and rescue trapped personnel and recover losses to maximum extent when accidents occur. Combined with the current situation and deficiencies of coal production management in target enterprise, the thesis focuses on construction of safety inspection elements around "three," and its element structure is shown in Figure 2.

In this paper, when establishing the evaluation index system, with reference to relevant laws and regulations, combined with opinions of field engineers and technicians, the evaluation index system is established with reference to relevant laws and regulations, combined with opinions of field engineers and technicians, and based on aforementioned principles of index system establishment, corresponding evaluation indexes are selected from following aspects. The coal safety evaluation index system established in this paper is shown in Figure 3.

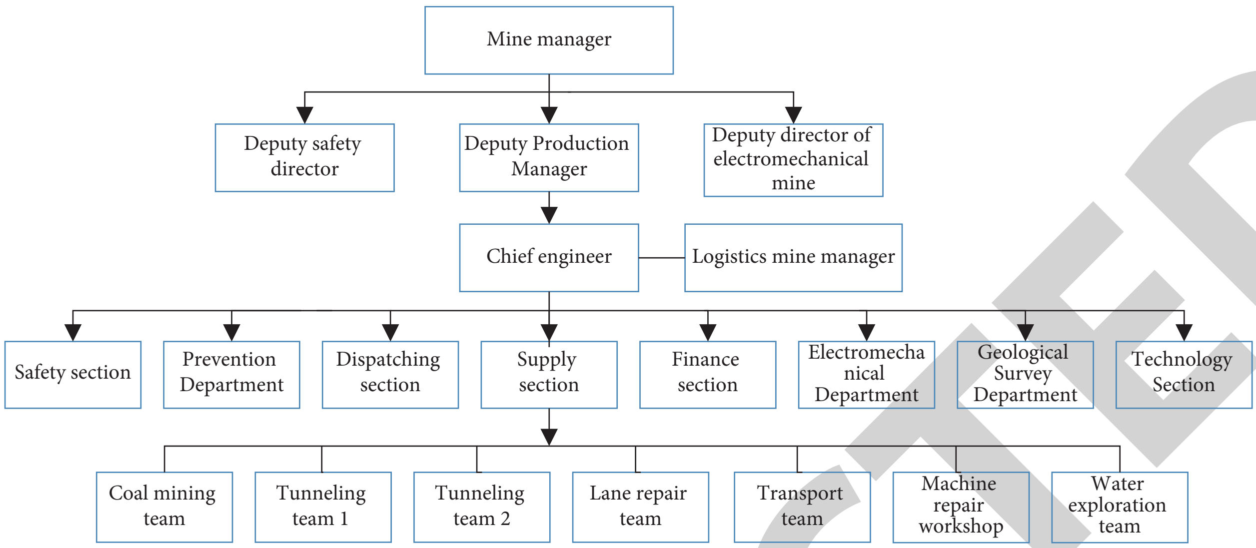

Figure 1: Schematic diagram of mine management system structure.

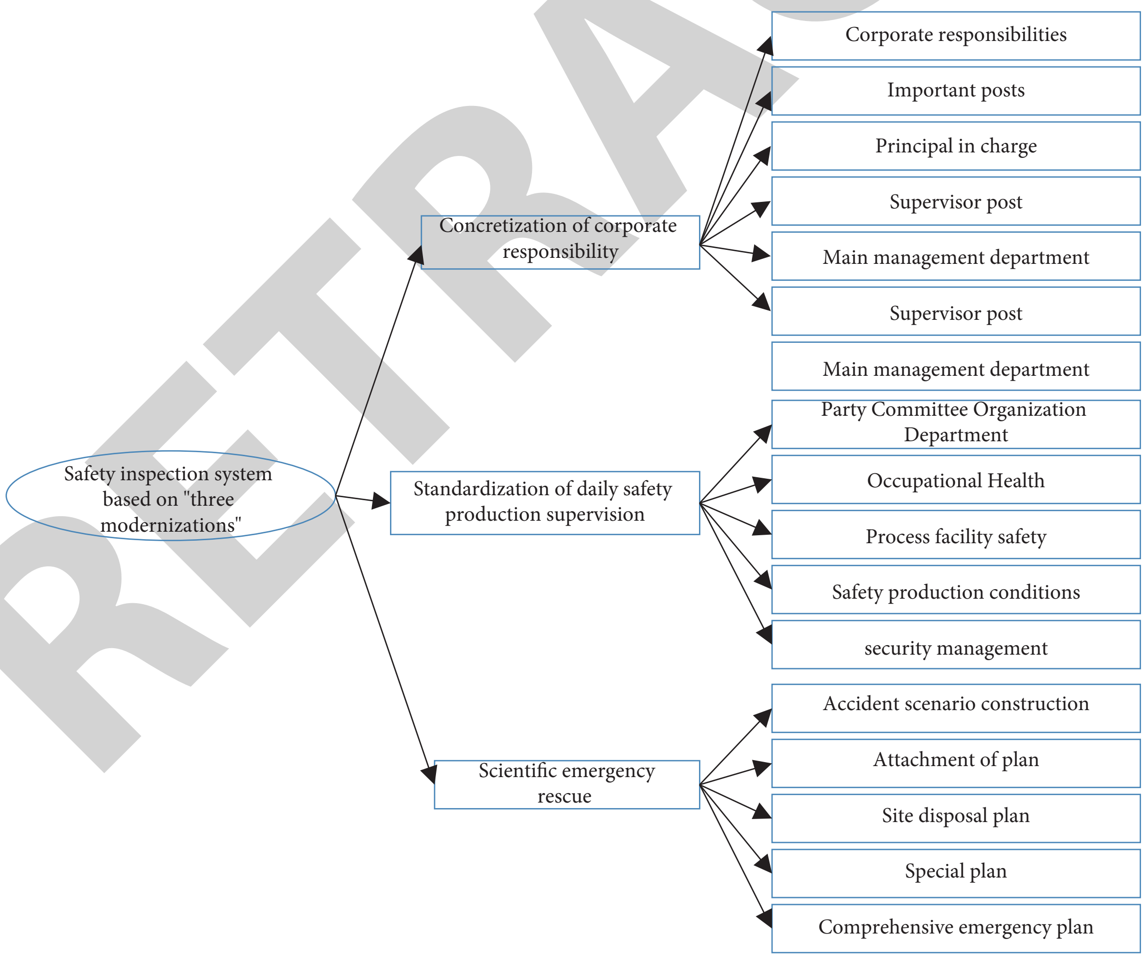

Figure 2: Security inspection architecture based on "three modernizations."

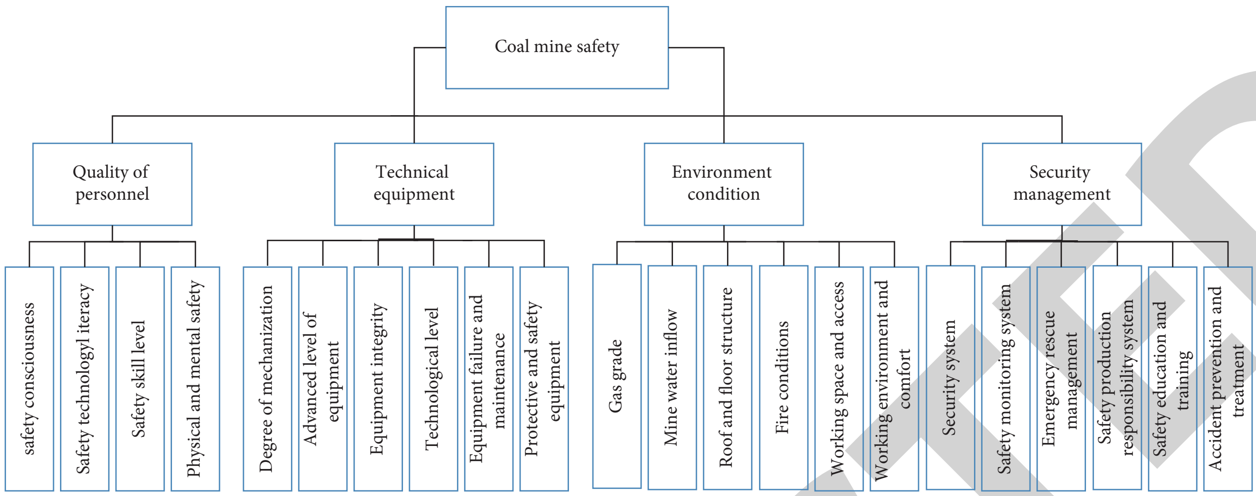

FIGURE 3: Coal mine safety evaluation system.

4. System Dynamics Algorithm

With n samples forming evaluation of composition sample set,

$$D = \{d_1, d_2, \ldots, d_n\}. \quad (1)$$

The set of evaluation attributes of sample set is evaluated by m attributes:

$$P = \{P_1, P_2, \ldots, P_m\}. \quad (2)$$

The matrix of indicator eigenvalues for m attributes for n samples is

$$X = \left(x_{ij}\right), i = 1, 2, \ldots m; \; j = 1, 2, \ldots, n. \quad (3)$$

According to concept of superiority degree in the preference theory, the characteristic matrix of indicators is processed. The relative superiority of efficiency-type indicators is

$$r_{ij} = \frac{x_{ij} - x_{i\min}}{x_{i\max} - x_{i\min}}. \quad (4)$$

Relative superiority of cost-based indicators:

$$r_{ij} = \frac{x_{i\max} x_{ij}}{x_{i\max} x_{i\min}}. \quad (5)$$

Relative superiority of fixed-type indicators:

$$r_{ij} = \begin{cases} 1 - \dfrac{d_i - x_{ij}}{\delta_i}, & x_{ij} < d_i, \\ 1, & x_{ij} \in \left[d_i, d^i\right], \\ 1 - \dfrac{x_{ij} - d^i}{\delta_i}, & x_{ij} > d^i, \end{cases} \quad (6)$$

$$\delta_i = \max\left\{d_i - x_{i\min}, x_{i\max} - d^i\right\}.$$

Relative superiority of interval-type indicators:

$$dr_{ij} = \begin{cases} 1 - \dfrac{d_i - x_{ij}}{\delta_i}, & x_{ij} < d_i, \\ 1, & x_{ij} \in \left[d_i, d^i\right], \\ 1 - \dfrac{x_{ij} - d^i}{\delta_i}, & x_{ij} > d^i, \end{cases} \quad (7)$$

$$\delta_i = \max\left\{d_i - x_{i\min}, x_{i\max} - d^i\right\}.$$

Thus, the attribute relative superiority matrix of m attributes evaluated on n decision objects is obtained:

$$R = \left(r_{ij}\right), i = 1, 2, \ldots m; \; j = 1, 2, \ldots n; \; 0 \le r_{ij} \le 1. \quad (8)$$

Let weight vector of m attributes in system be

$$W = \left(w_1, w_2, \ldots, w_m\right)^T, \quad \sum_{i=1}^{m} w_i = 1, \quad (9)$$

where w_i is the weight of attribute i. By decision relative superiority model,

$$u_j = \frac{1}{1 + \left[\sum_{i=1}^{m}\left[w_i\left(1 - r_{ij}\right)\right]^p / \sum_{i=1}^{m}\left(w_i r_{ij}\right)^p\right]^{2/p}}. \quad (10)$$

Obtain the relative superiority vector of sample set:

$$U = \left(u_1, u_2, \ldots u_n\right)^T, \quad (11)$$

where u_j is the relative superiority of decision j; p denotes the distance parameter: Hemming distance at $p = 1$; Euclidean distance at $p = 2$.

The evaluation decision problem for a set of evaluation objects $a_l \, (l = 1, 2, \ldots M)$ under the set of evaluation indicators $E = \{e_i, i = 1, \ldots, L\}$ can be expressed by

$$S\left(e_i\left(a_l\right)\right) = \left\{\left(H_n, \beta_{n,i}\left(a_l\right), n = 1, 2, \ldots, N\right)\right\}, \quad i = 1, 2, \ldots, L, l = 1, 2, \ldots, M, \quad (12)$$

Table 1: Initial value assignment of the horizontal variable.

Horizontal variable	Data collection and processing	Initial value
Human behavior level $L_1(t)$	According to subindicators of the people's behavior level, including physiological quality, psychological quality, technical quality, and group behavior	72.4
Equipment and facilities level $L_2(t)$	According to subindicators of the equipment and facilities level, including comprehensive evaluation of equipment and facilities use and maintenance, working environment, and equipment and facilities design and purchase	73.2
Environmental safety level $L_3(t)$	According to subindicators of the environmental safety level, including comprehensive evaluation of working space, lighting conditions, and natural environment	69.7
Safety management level $L_4(t)$	According to subindicators of the safety management level, including comprehensive evaluation of safety culture, equipment management, dynamic management, and safety investment	70.5
IoT level of coal $L_5(t)$	According to subindicators of the IoT level of coal, including comprehensive evaluation of key technologies, IoT talents, and IoT investment.	5

Table 2: Simulation results.

Time (year)	2012	2013	2014	2015	2016	2017
IoT level of coal	6	12.34	21.56	30.47	49.57	50.27
Coal safety supervision level	72.89	74.58	79.58	85.62	87.57	92.58

Table 3: Evaluation results.

Time (year)	2012	2013	2014	2015	2016	2017
IoT level of coal	6	11.24	19.56	30.17	39.57	49.27
Coal safety supervision level	71.29	74.9	80.21	83.32	88.57	91.48

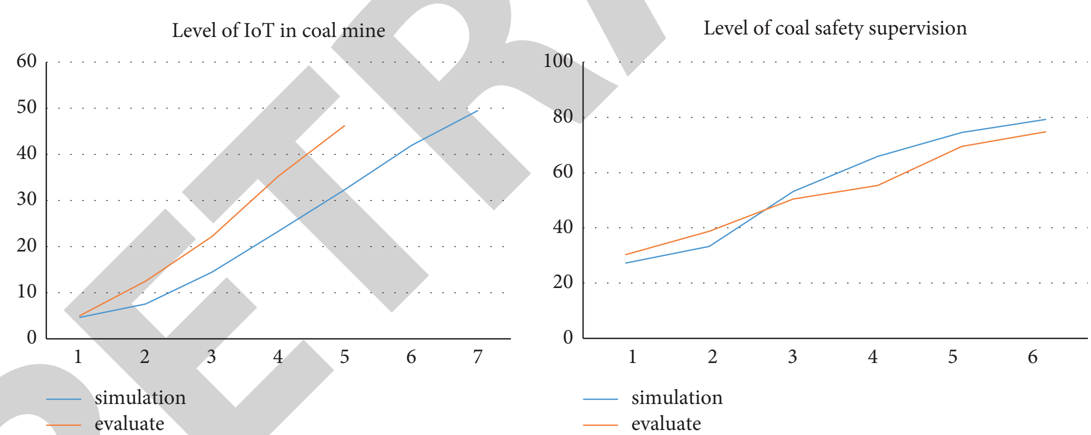

Figure 4: Comparison between model simulation results and historical evaluation results.

where $\beta_{n,i}(a_l) \geq 0 \sum_{n=1}^{N} \beta_{n,i}, (a_l) \leq 1.\beta_{n,i}(a_l)$ is the reliability of decision maker, indicating that, for the evaluation index e_i,the reliability of evaluation object a_l evaluated as evaluation level $H_n (n = 1, 2, \ldots, N)$ is $\beta_{n,i}$, and then the corresponding decision matrix D_g is

$$D_g = (S(e_i(a_l)))_{L\times M}. \tag{13}$$

The system dynamics algorithm provides a systematic and rational way to produce an overall evaluation by aggregating individual judgments. Based on the evidence theory, when evaluating the safety condition of a coal, evaluation of different indicators is used as evidence, and a set of evaluation terms is used as a framework for identification.

5. Results

In May 2013, mine was reapproved to have a production capacity of 4.11 million tons/year. The total thickness of coal-bearing strata is 233.46 m, divided into 5 coal group sections, containing 22 layers of coal; total thickness of coal seams is 12.43 m; coal-bearing coefficient is 4.60%; and coal-bearing area of well field II is 45.88 km^2, with total resource reserves of 378 million tons and recoverable reserves of 164 million tons [13]. The mine is designed as a vertical shaft with horizontal pan area development, the location of the shaft head is in the deep part of the shaft field, elevation of the shaft head is 83.4 m, elevation of the car park level is −557 m, and depth of the shaft is 612.3 m. The coal quality of mine is

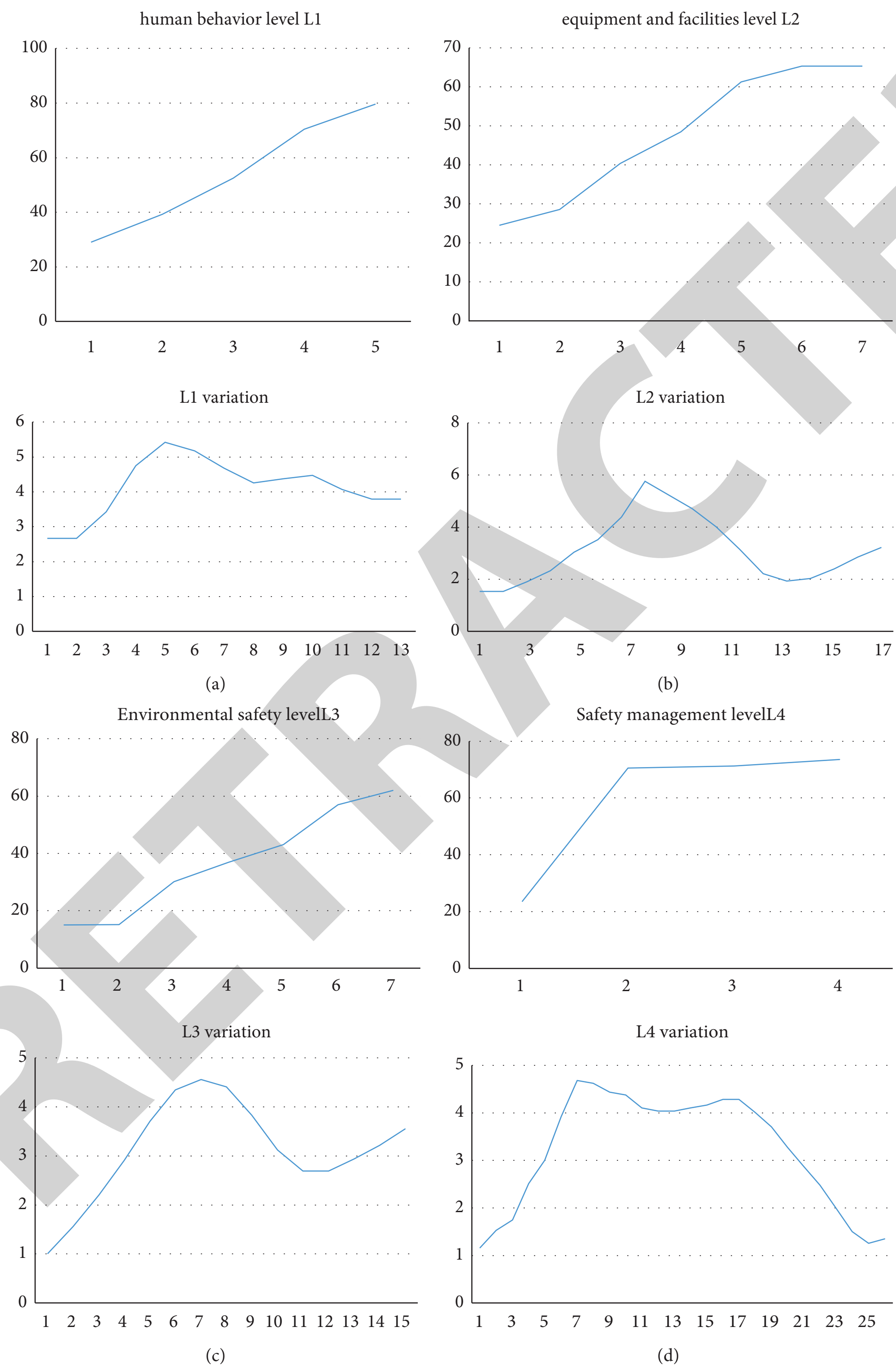

FIGURE 5: Change trend of four elements. (a) Change trend chart of the human behavior level. (b) Change trend chart of the equipment and facilities level. (c) Change trend of the environmental safety level. (d) Change trend chart of the safety management level.

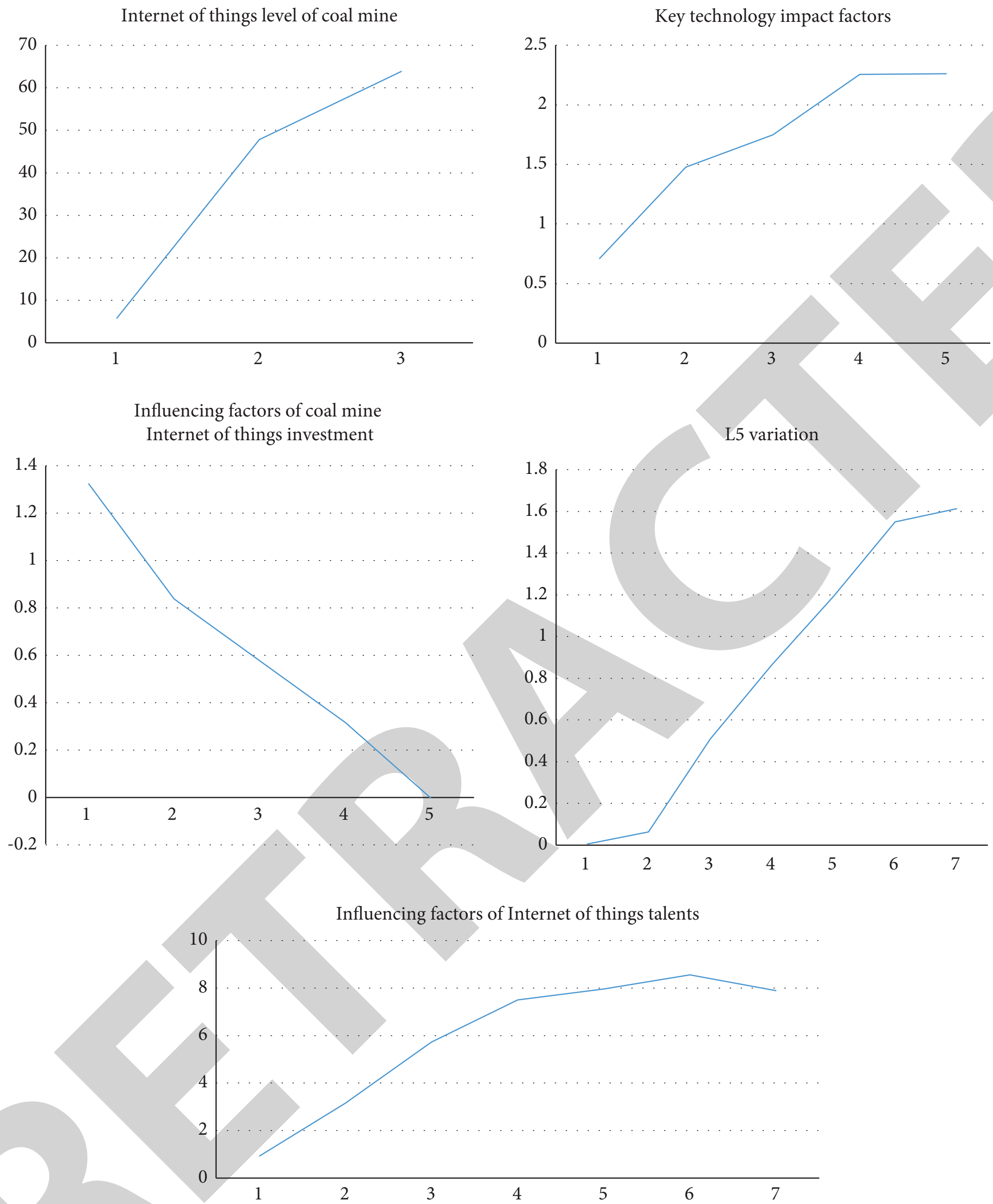

Figure 6: Variation trend of coal networking level and its influencing factors.

extra low sulfur, low phosphorus, high caloric quality anthracite coal, is a low gas mine, and safety production status is good. The simulation is based on implementation of coal informationization and coal IoT projects from 2012 to 2017. The simulation time of system is set from 2012 to 2017, with a total time of 6 years and a step size of 0.25 years. Table 1 is obtained from the evaluation of the human behavior level, equipment and facilities level, environmental safety level, safety management level, and IoT level of mine by relevant experts 1.

All equations of variables and initial values and parameter settings were entered into the constructed system dynamics model, and results of model run were obtained by running simulation software Vensim (Table 2) and comparing them with historical data (Table 3) to obtain Figure 4, where historical data were obtained by questionnaire evaluation.

Table 4: Different investment strategies.

Strategy	Different input ratio (safety input : coal IoT input)
Initial	1 : 0.3
Strategy 1	0.8 : 0.5
Strategy 2	0.5 : 0.9

As shown in Figure 5, from 2010–2015, the development trend of coal IoT level and coal safety supervision level obtained from simulation is similar to the development trend of actual evaluation, which indicates that the system simulation model has strong adaptability. From simulation results, it can be seen that the level of IoT grows rapidly, from 5 in 2012 to 48.13 in 2017; level supervision also shows an overall growth trend, with a slow growth between 2012 and 2014, a rapid increase from 2012 to 2015, and a slow growth rate from 2014 to 2017. With the application of IoT technology, after about one year of adaptation, the level supervision grows rapidly at the beginning and slows down at the end. This is similar to actual situation and is consistent with the impact of application of new technologies on industry.

From feedback loop analysis of the system, change in level monitoring is the combined result of change in the level of human behavior, equipment and facilities, and environmental safety. As the level of IoT grows, the level of personnel monitoring, equipment and facilities monitoring and management, gas monitoring, workspace monitoring, and safety management monitoring grow, and level of human behavior, equipment and facilities, environmental safety, and safety management all grow. As level supervision is improved, the gap between expectation and reality of safety supervision is narrowed, and coal enterprises invest less in safety, so investment in human behavior level, equipment and facilities level, and environmental and safety management level is reduced. The trend of four factors R, R2, R3, and R4 are all decreasing, which inhibits the growth of each level and leads to slow growth supervision level.

As different government policies and management measures have different impacts on coal safety supervision system in the IoT mode, the analysis found that development of IoT in coal has a significant contribution to the improvement supervision level, and main influencing factors of IoT level in coal are coal IoT input, government policy, and IoT development. Under initial conditions, the trend of level of IoT and its influencing factors are shown in Figure 6.

As can be seen from Figure 6, at this time, the government policy factor is set to 1. The change in the level of IoT, Rs, is changed under te combined effect of key technology, IoT talent, and IoT input, which first increased and then slightly decreased from 2010 to 2015. From Figure 6, it can be seen that strength and trend of different factors are different, and influence of key technology and IoT talent are gradually increasing, while influence of IoT technology input is strong at beginning and slowly decreases with time. This indicates that, in the initial stage of IoT development, reliance on IoT inputs is greater, and then in the development stage of IoT, reliance on IoT talents and key technologies will become greater. Moreover, there are some limitations to the growth of IoT level due to impact of declining IoT inputs.

In initial case, IoT investment was set at ten times gap between expectation and reality of safety supervision, which is only about 30% of investment in improving the level of human behavior, equipment and facilities, environmental safety, and safety management of basic safety, i.e., the ratio of safety investment in improving basic safety to IoT investment is 1 : 0.3. Now, 20% of safety investment in improving basic safety is used for IoT. The ratio of safety input for

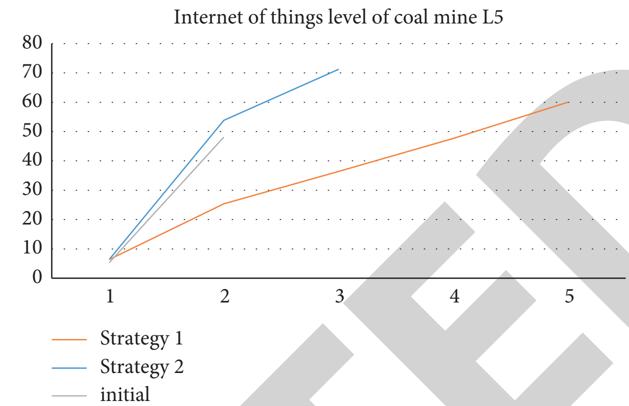

Figure 7: Comparison of the change trend of coal networking level (input).

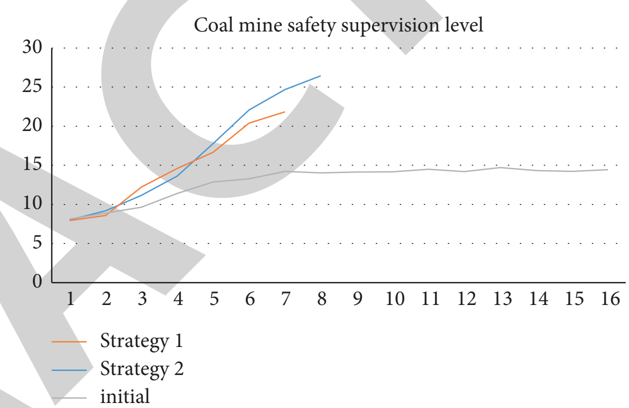

Figure 8: Comparison chart of the change trend supervision level (input).

Table 5: Comparison of coal networking level (input).

Time (year)	2012	2013	2014	2015	2016	2017
Strategy 2	5	18.2	32.9	48.25	61.93	73.58
Strategy 1	5	16.84	29.67	41.87	52.08	61.98
Initial	5	12.23	21.51	30.07	39.71	49.25

Table 6: Comparison supervision level (input).

Time (year)	2012	2013	2014	2015	2016	2017
Strategy 2	71.2	72.8	75.49	79.50	77.88	80.41
Strategy 1	71.2	74.65	81.47	84.57	98.52	94.07
Initial	71.2	74.21	78.59	85.27	87.56	90.58

improving basic safety and coal IoT is 0.8 : 0.5, which is strategy 1; 50% of safety input for improving basic safety is used for coal IoT, which is 0.5 : 0.8, which is strategy 2, as shown in Table 4 for different input strategies. The simulation results of model are shown in Figures 7 and 8 and Tables 5 and 6.

From the comparison of Figure 7 and Table 5 on the change of IoT level, it can be seen that the value of the IoT level is significantly higher in strategy 1 context than in the initial context and significantly higher in strategy 2 context than in strategy 1 context. Therefore, upon increasing the

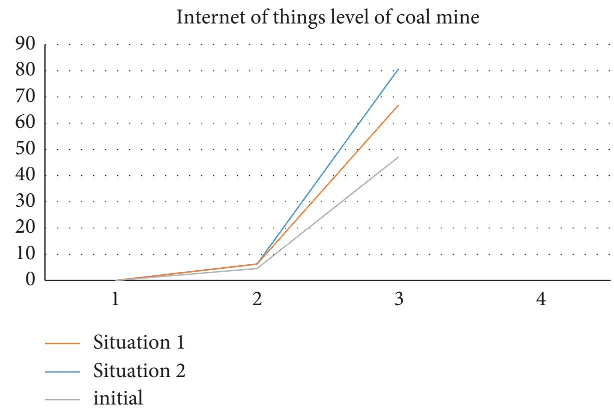

FIGURE 9: Comparison of the change trend of coal networking level (policy).

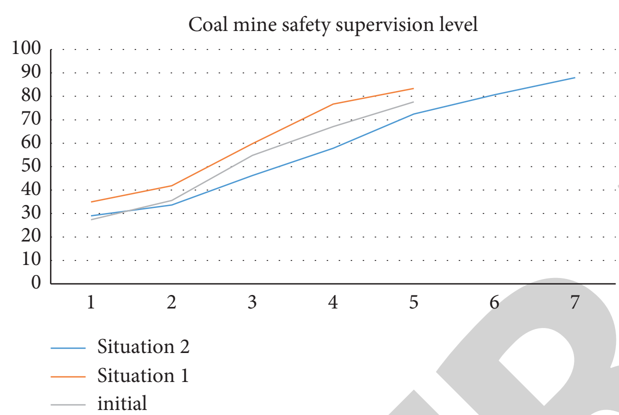

FIGURE 10: Comparison of the change trend supervision level (policy).

proportion of coal IoT input, the level of coal IoT increases significantly, and there is more input faster growth.

From the comparison supervision level in Figure 8 and Table 6, it can be seen that the change supervision level in first three years is not obvious in strategy 1 compared with the initial scenario, and after 2015, the level supervision has a more obvious increase, which indicates that appropriate increase of coal IoT input to increase the level of coal IoT is not obvious in the early stage for the improvement supervision level, and it works slowly in the later stage. There is a certain delay. In strategy 2, compared with the initial situation, level supervision is significantly lower than the initial situation, which indicates that too much of safety investment for improving basic safety is used for construction of IoT instead of making level supervision grow effectively.

The government proposes to combine it with traditional industries to enhance development of traditional industries. As a typical traditional industry, coal industry has also made corresponding policy adjustments. Therefore, it is necessary to simulate the impact of policy adjustment on the development level of IoT technology and level supervision. In the initial model, the government policy factor is set to 1. The following simulations show changes in system when government policy support is increased by 50% and 80% from the original one. The government policy factor is set to 1.5 and 1.8, and the simulation model is run to simulate the level of IoT and level of safety supervision, and simulation comparison graphs are obtained (Figures 9 and 10).

A comparative analysis of vertical changes in the level of IoT and level supervision in three different scenarios with government policy factors of 1, 1.5, and 1.8 in Figures 9 and 10 shows that span between scenario 1 and initial is larger, i.e., the level of IoT changes significantly when the government policy factor increases from 1 to 1.5, while span between scenario 2 and scenario 1 is smaller, i.e., change from 1.5 to 1.8 is relatively small when increasing from 1.5 to 1.8. The change in level regulation is similar to the change in the level of IoT. Comparing cross-sectional changes in the level of coal IoT and level supervision in three different scenarios with government policy factors of 1, 1.5, and 1.8, we can see that the level of coal IoT increases significantly with the increase of government policy factors, while for level supervision, the value of level supervision is similar between 2012 and 2015 and gradually increases in 2016 and 2017. The gap gradually widens. This shows that the level of government policy support directly affects the development of IoT, and for level supervision, the effect of government policy is not obvious in short term, but plays a crucial role in the long-term development process.

6. Conclusions

With the development and application of IoT in coal, it has a great impact on coal safety supervision. This paper uses the system dynamics theory and method to analyze and study the coal safety supervision system in the IoT mode, establishes the cause-effect diagram supervision system in the IoT mode, verifies validity and reliability of the model through empirical analysis and model testing to reach more than 98.6%, and proposes that support for the development of IoT in coal should be increased appropriately. It is proposed that support for development of IoT should be increased appropriately, and a good environment and atmosphere for IoT research should be created to ensure healthy and long-term development of IoT, so as to improve level supervision and ensure safe production of coals.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares no conflicts of interest.

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