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Visualization Method on The Cognition and Decision-Making of Core Personnel in Coal Mines: Basis for Strategic Plan

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Abstract. This research analyzed the application of visualization methods and systems in core positions in four coal mining enterprises with a long history, as well as their impact on the cognitive load and decision-making behavior performance of core employees. It explored their achievements in process reengineering and system optimization, analyzed their impact on safety production, production costs, and profitability, and shaped core business and competitive advantages to achieve corporate strategy.

The research recognized that, firstly, the scope of visualization methods and systems was clear, the structure was orderly, and the implementation was appropriate, laying the foundation for subsequent research. Secondly, the visualization methods have a positive impact on employee cognitive load, decision-making behavior, and performance, and can promote information and knowledge dissemination. Visualization methods transmit the impact on core employees to process optimization and system transformation, thereby achieving visual control of risk sources and reducing safety accident rates. Thirdly, coal mining enterprises face challenges in high-dimensional visualization research and development, system integration, privacy protection, data security, as well as adapting to future business development and talent teams. And proposed a strategic plan to address these challenges. At the end of the paper, suggestions were made for the application of visualization methods in coal mining enterprises.

Keywords: coal mining enterprises, technology integration, visualization management, visualization method

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1. Introduction

The exploration of coal mine visualization methods and information technology based on cognition and decision-making stems from the complexity, safety, and challenges experienced in the coal mining process. In the past, due to the large differences between the north and south of coal mines in China, complex geological conditions, relatively poor mining conditions, and high development pressure intensity, safety accidents occurred frequently, resulting in low production efficiency and enterprise benefits. Currently, China's coal mines have entered a stage of high-quality development for smart mines, and coal mining enterprises are facing problems such as massive and heterogeneous data, information redundancy, information load and interference, and a single visualization method. In this environment, core personnel find it difficult to recognize and make decisions in a timely manner, team collaboration is poor, production processes are difficult to optimize, and management costs further increase. So, the visualization and utilization of information has become a huge challenge in the safety production of coal mining enterprises.

Cognitive psychology theories and experiments have shown that 70% -80% of human perceptual information comes from vision, about 50% of human brain functions are related to visual image processing, and 65% of people belong to visual learners. Human beings have high efficiency and speed in processing image information, and have advantages in transmitting and controlling production between teams (Yan & Chen, 2021). The visual technology provides an ideal space for breaking through bottlenecks. Under the current employee capabilities and production technology conditions, coal mining enterprises need to find breakthroughs in visual technology and management methods, transforming traditional text and numbers into clear, precise, and focused graphics in order to maintain the optimal cognitive load. In mining production, the exploration of visualization methods has an impact on maintaining optimal cognitive load and behavioral decision-making, as well as on operational safety, process optimization, production efficiency improvement, and enterprise benefits.

The existing literature has laid the foundation for utilizing visualization methods and information resource development to enhance the understanding and decision-making of information resources. Sweller (2016) believes that human cognitive resources are limited and self-depleted, and the allocation of cognitive resources requires information visualization and efficient schema

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matching to improve cognitive efficiency and learning ability. Sweller has found through extensive research that information visualization methods, levels, and structures have a significant impact on people's cognitive load, often affecting learning and behavioral outcomes.

In the study of the impact of visualization on thinking and decision-making, Yan Wei (2022) found that Piaget's schema is an individual's perceptual understanding and way of thinking about the world. They proposed the formula "S → (AT) → R", which means that a certain stimulus (S) is assimilated by the individual (A) into the cognitive structure (T) before it can react (R). Piaget's Double Constructions theory suggests that external activities are internalized through internal logical operations and schematically externalized from the edge of the object to the essential process, and this complex process is explained by the concepts of schema, assimilation, adaptation, and balance. In visual cognition and schema theory, emphasis is placed on the structure of low-level and higher-order vision in visualization and visual cognition. In production management research, emphasis should be placed not only on visualizing the physical properties of things, but also on visualizing the internal connections and laws of things, in order to help employees understand the essence of things and stimulate more efficient decision-making behavior.

In addition, Ming et al. (2015) and Li (2017) found that in a visual work environment, excessive cognitive load can cause rapid fatigue, reduced flexibility, stress reactions, increased personal practice, and frustration, leading to errors in information acquisition and analysis and decision-making errors. It can also lead to decreased job performance, human accidents, and safety risks; However, a low cognitive load can lead to waste of human resources and cause aversion, as well as a decrease in homework performance. Therefore, the cognitive load in visualized work not only affects individual decision-making and performance, but also has a negative impact on production processes, team collaboration, etc., resulting in adverse effects on enterprise production efficiency and profits.

In this way, research on the visualization methods of core employees will provide positive and beneficial effects on their information cognition and decision-making, and explore the mechanisms by which visualization methods affect employee cognition and decision-making, further exploring the impact of visualization methods on optimizing production processes, improving the quality of underground decision-making, and reducing safety risks. In addition, research

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on the impact of visualization methods will promote coal mines to attach importance to the application of visualization methods, which will be helpful in reducing safety risks and production costs, improving production efficiency, and enhancing visualization literacy.

2. Methodology

This study adopted a quantitative descriptive research design and conducted an in-depth investigation into the visual management practices of coal mining companies. This method places great emphasis on numerical data and statistical analysis, aiming to objectively describe observed phenomena. By prioritizing the collection of digital data, this study objectively measured and analyzed various aspects related to visual management. Through statistical analysis, this study identified patterns and trends, providing clear and concise descriptive results for different aspects of visual management. This method also minimizes bias among researchers, contributing to the objectivity and reliability of the insights provided. Overall, the adoption of quantitative descriptive research design promotes systematic and structured exploration, providing valuable and objective insights for coal mining companies.

2.1. Sampling Procedure

The sampling technique used in this study is stratified sampling, which was chosen because it can provide a more accurate and representative understanding of the population. The surveyed population includes core employees of four coal companies. To ensure a comprehensive inspection, the researchers communicated with the human resources departments of the four coal companies. The stratified sampling process involves dividing the population into different job groups and then selecting participants from each group. The sample includes approximately 222 personnel who have been carefully selected to represent the core job roles within these companies. This choice has been carefully considered and aims to obtain comprehensive perspectives and insights. The willingness and accessibility of respondents played a crucial role, streamlining the process and effectiveness of data gathering (Domingo, 2023a; Domingo, 2023b; Domingo, 2023c).

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2.2. Respondents

The respondents of this study were the representatives from subordinate coal mines such as Anhui Huainan Coal Mine Group Co., Ltd., Shanxi Fenxi Coal Mine Group Co., Ltd., Datong Coal Mine Group Co., Ltd., Shandong Yanzhou Coal Mine Group Co., Ltd.

Table 1

Distribution of Respondents

Coalmine Enterprises	Coalmine leaders	Manager	Administrator	Core employees	Total	Percentage
Huainan Coal Mine Group Co., Ltd	7	24	7	12	50	22.5%
\Fenxi Coal Mine Group Co., Ltd	11	23	7	17	58	26.1%
Datong Coal Mine Group Co., Ltd	13	24	8	14	59	26.6%
Yanzhou Coal Mine Group Co., Ltd	9	22	8	16	55	24.8%
Total	**40**	**93**	**30**	**59**	**222**	**100%**

Specifically, the distribution of respondents among 40 coal mine leaders, 93 managers, 30 security administrators, and 59 core employees is shown in Table 1. Among them, the core employees are key personnel in the five major systems of coal mining machine transportation, and are selected due to their different job roles and professional knowledge, ensuring that the research can comprehensively understand the impact of visualization methods on employee cognition and decision-making, as well as the optimization of production processes and the profitability of enterprises.

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2.3 Research Site

This study selected subordinate coal mines such as Anhui Huainan Coal Mine Group Co., Ltd., Fenxi Coal Mine Group Co., Ltd., Datong Coal Mine Group Co., Ltd., and Yanzhou Coal Mine Group Co., Ltd., which are distributed in the main coal production areas of China, as shown in Figure 3 of the China Coal Mine Resource Distribution Map. This provides an ideal opportunity for researching and exploring visualization methods and applications in Chinese coal mines. Datong Coal Mine is located in Datong, the coal capital of China, and is one of the three major coal mining groups in China. It has been established for 74 years and has 73 subordinate mines with a production capacity of 200 million tons. Fenxi Coal Mine is under the jurisdiction of Shanxi Coking Coal Group. It has been established for 67 years and has 20 subordinate mines with a production capacity of 70 million tons. Yanzhou Coal Mine is located in Shandong Province. It has been built for 57 years and has 23 pairs of mines under its jurisdiction. Four pairs of mines are under construction, with a production capacity of 160 million tons. Huainan Coal Mine is located in Anhui Province, with a history of 120 years. It has 13 pairs of mines and a production capacity of 100 million tons.

The case study companies own multiple mines and have rich experience in safety risk prevention and control in various aspects such as raw coal production, commercial operation, and safety management. The mining operations are relatively complex and require high-precision and efficient production processes. By jointly exploring visualization methods and technological applications, this study aims to provide improved visualization planning solutions for coal mines to further improve production efficiency and product quality.

3. Results and Discussion

3.1 Profile of the Respondents in Coal mines

The respondents in coalmines were profiled based on age, sex, years in service, position, and unit or department. In terms of age, most respondents fell into the 26-35, 36-45, and 46-55 age groups, with the highest concentration in the 26-35 range. Regarding sex, there were slightly more male respondents than female, attributed to labor laws barring women from certain coal mining roles. Years in service were distributed relative to retirement ages, with a decline in

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personnel as service length increased. Positions were categorized into nine aspects, with technical roles comprising the majority, followed by administrative and managerial positions. Lastly, core employees were dispersed across various departments, reflecting their impact and application of visualization methods within the coal mining enterprises.

3.2 Visualization Methods on the Cognition and Decision-making of Core Personnel in Coalmines

3.2.1 Scope

A detailed assessment of the current scope of visualization methods across four coal companies reveals a general consensus among respondents. The first indicator, scoring 3.52, denotes "strong agreement" that visualization methods cover all core positions, crucial for achieving organizational objectives. The second indicator, scoring 3.24, signifies "agreement" that visualization methods are applied to core job contents, enhancing collaboration and work performance. Similarly, the third and fourth indicators, scoring 3.14 and 3.16 respectively, affirm "agreement" that business information and processes are efficiently visualized, fostering process optimization and collaborative efficiency. The fifth indicator, scoring 2.93, denotes "agreement" that visualization methods encompass personnel, equipment, networks, and software, facilitating human-machine integration crucial for decision-making and management performance. Overall, with a grand mean of 3.20, classified as "agree," respondents concur that the scope of visualization applications aligns with enterprise goals across the four coal companies. This grand mean signifies that respondents unanimously agree that the scope of visualization applications in the four coal mining enterprises are the same and consistent with the strategic goals of the enterprises (Knaflic, 2017).

3.2.2 Structure

The evaluation of the structure of visualization methods reveals a well-organized system across five indicators. The first indicator, scoring 3.23, indicates "agreement" on the reasonable spatial distribution of hardware systems, enhancing core employees' cognitive abilities. Similarly, the second

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indicator, scoring 3.10, shows "agreement" on the reasonable combination of functions, aiding in decision-making. The third indicator, scoring 2.78, suggests "agreement" on the reasonable setting of data structure, enhancing processing efficiency. The fourth indicator, scoring 2.61, signifies "agreement" on the completeness of knowledge, model, and method bases, supporting effective decision-making. Finally, the fifth indicator, scoring 3.03, denotes "agreement" on the scientific overall structure, contributing to operational efficiency. With a grand mean of 2.95, classified as "agree," respondents unanimously believe in the reasonable structure of visualization methods, supporting core employee performance and corporate strategic goals.

3.2.3 Implementation

The evaluation of visualization method implementation highlights its significance across five key aspects. The first indicator, scoring 3.50, signifies "strong agreement" that enterprise leaders strongly support visualization method promotion, recognizing its role in enhancing cognitive abilities and optimizing processes. Similarly, the second indicator, scoring 3.42, denotes "strong agreement" that personnel training for visualization technology has yielded positive outcomes, emphasizing the need for continuous training to enhance core personnel cognition. The third indicator, scoring 3.26, indicates "strong agreement" that companies prioritize funding for visualization projects, reflecting their commitment to system construction and implementation. Moreover, the fourth and fifth indicators, also scoring 3.26, highlight "strong agreement" regarding systematic promotion, research, and evaluation of visualization methods, showcasing enterprises' dedication to enhancing safety and profitability. With a grand mean of 3.36, classified as "strongly agree," respondents unanimously emphasize the importance of strong leadership and enterprise support in achieving safety and economic benefits through visualization implementation.

3.2.4 Results

The evaluation of visualization method results encompasses core employee satisfaction, work efficiency, safety, stability, and scalability, across five indicators. The first indicator, scoring 3.55, indicates "strong agreement" that core employee operational needs are met, underscoring the alignment of visualization methods with core employee requirements and enterprise

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strategies. Similarly, the second indicator, scoring 3.52, denotes "strong agreement" that visualization methods exhibit good safety and reliability in harsh environments, enhancing work efficiency and performance. The third indicator, scoring 3.46, emphasizes the role of visualization methods in improving resource utilization efficiency and reducing cognitive load, aiding decision-making and human resource development. Furthermore, the fourth indicator, scoring 3.26, highlights the strong maintainability of visualization methods, ensuring continuity of work and adaptability to complex environments. Lastly, the fifth indicator, scoring 3.22, suggests "agreement" that visualization methods possess scalability, maintaining system flexibility and adaptability to future work needs. With a grand mean of 3.40, classified as "strongly agree," respondents unanimously affirm the scientific nature of visualization method results, emphasizing safety, reliability, and scalability, which contribute to process optimization, business development, and long-term enterprise strategy alignment (Murata & Katayama, 2016)

3.3 Impact of the Visualization Methods on the Cognition and Decision-making of Core Personnel in Coalmines

3.3.1 Benefit

The evaluation of visualization methods' benefits for core employees highlights their impact on attention, cognition, and decision-making. The first indicator, scoring 3.60, strongly agrees that visualization methods effectively attract visual attention and boost employee happiness, thus optimizing work efficiency. Similarly, the second indicator, scoring 3.64, emphasizes the clarity provided by visualization methods, aiding in quickly identifying key content and improving safety levels. Additionally, the third indicator, scoring 3.51, underscores the reduction of cognitive and learning pressure on staff through visualization methods, promoting knowledge innovation and learning ability. Moreover, the fourth indicator, scoring 3.43, emphasizes enhancing information comprehensibility and reducing cognitive load, leading to improved decision-making and work performance. Furthermore, the fifth to eighth indicators collectively affirm the positive impact of visualization methods on decision-making awareness, feasibility assessment, progressive decision-making, and overall cognition of core employees. With a grand mean of 3.47, classified as "strongly agree," respondents unanimously advocate for the utility of

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visualization methods in reducing cognitive load, enhancing memory ability, and improving decision-making quality, thereby promoting safety management and knowledge innovation within the enterprise (Sweller, 2017)

3.3.2 Innovation

Evaluation of the impact of visualization methods on process improvement reveals strong agreement among respondents regarding benefits such as operational optimization and collaboration. The highest mean score, 3.60, indicates that information display enhances job performance. Other indicators, scoring between 3.46 and 3.55, emphasize improved safety and quality through visual simulation. Overall, with a grand mean of 3.47, respondents unanimously advocate for the positive impact of visualization methods on enterprise process improvement, promoting safety, innovation, and cost-effectiveness.

The benefits of visualization methods for system improvement are highlighted, indicating strong agreement among respondents regarding improved perception and time-saving. Mean scores ranging from 3.21 to 3.64 underscore the effectiveness of visualization methods in enhancing system operations, reducing costs, and enhancing safety. The grand mean of 3.46 emphasizes the comprehensive benefits of visualization methods for system enhancement, including improved safety awareness and decision-making efficiency. Meanwhile, the survey data also demonstrates that visualization can optimize production processes, improve enterprise safety production levels, and promote knowledge innovation (Nancy, 2021).

3.4 Challenges

The challenges of visualization methods are highlighted, revealing significant obstacles in their development. Respondents agree that high-dimensional visualization technology presents a challenge due to technical limitations and a scarcity of specialized talent. Integration issues between visualization methods and production systems also pose challenges, with difficulties in bridging information silos and handling diverse data. Adapting visualization methods to evolving business needs and ensuring privacy protection amid big data proliferation are new challenges. Data security and talent cultivation in high-tech fields are also pressing concerns. The

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comprehensive evaluation indicates agreement among respondents regarding these challenges, emphasizing the need for coal mining enterprises to invest in research, talent development, and data security to address them and foster future advancements. coal mining enterprises must reasonably regulate the application of information technology and visualization technology, protect personal privacy and data security (Zhang, 2022).

3.5. Proposed a Strategic Plan as a Result of the Study

The proposed strategic plan for coal mining enterprises is meticulously crafted after analyzing the prevalent challenges faced by these entities. Addressing these hurdles is vital for ensuring robust security, transparent management practices, and adept utilization of visual technology methods. Firstly, the plan prioritizes overcoming challenges posed by high-dimensional visualization technology by leveraging its potential to minimize negative impacts on coal mining operations. Strategies involve introducing external expertise and fostering in-house research and development teams. Secondly, it focuses on integrating visualization methods with production systems, aiming to mitigate technical challenges through talent acquisition, standardization, and increased investment in research and development. Additionally, the plan emphasizes adapting visualization methods to meet evolving business needs, enhancing privacy protection measures, and ensuring robust data backup and security protocols. Moreover, it underscores the importance of nurturing talents proficient in high-tech and intelligent manufacturing technologies to drive innovation and enhance safety levels. Overall, the strategic plan not only addresses current utility challenges but also aims to amplify the value of data and human resources, ultimately transforming coal mining enterprises into innovative entities driven by visualization, safety, and intelligence.

4. Conclusion

In conclusion, the widespread adoption of visualization methods across the four coal mining enterprises signifies a high level of application within the industry. These methods have revolutionized the interpretation of vast business data, simplifying complex information into easily digestible graphics that enhance decision-making and transparency in enterprise management. Moreover, visualization techniques have proven instrumental in driving process

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reengineering and system enhancement, empowering employees to grasp process dynamics, identify safety risks, and address critical operational issues effectively. Moving forward, the proposed strategic plan underscores the importance of talent cultivation, technological integration, and robust security measures to further leverage visualization methods in coal mining enterprises. By investing in talent development, establishing integrated technological standards, implementing encryption technologies, and deploying early warning systems, the plan aims to advance the application of visualization methods and elevate the level of visualization management across coal mining enterprises, fostering innovation, safety, and efficiency in the industry.

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