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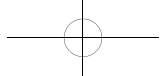
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# Utilizing Microwave Technology in Radio and Television Transmitters

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**Abstract:** In order to improve the performance and reliability of the radio and television transmission system and provide users with a better audiovisual experience, this paper first analyzes the advantages of microwave in radio and television transmitters, and further elaborates the radio and television transmission system. Through the reasonable configuration and application of microwave equipment, the performance and reliability of radio and television transmission system can be improved, and the stable transmission of radio and television signals can be ensured.

**Keywords:** Microwave; Launch pad; Television broadcast

**Online publication:** August 29, 2023

## 1. Introduction

Due to the rapid advancement of information technology, radio and television have become crucial means of disseminating information, leading to increased demands for transmission quality and reliability. As an advanced medium of communication, microwave technology plays an increasingly important role in the radio and television transmission system. Microwave refers to electromagnetic waves with a frequency of 300 MHz to 300 GHz, which has high frequency, short wavelength, and strong penetration. Microwave can realize long-distance transmission and wireless reception of signals in radios and television, thereby improving the coverage and transmission quality of signals<sup>[1]</sup>. Microwave has many advantages, such as improving the quality of the transmitted signal, reducing the production and maintenance costs of the transmitter, facilitating the switching of multiple transmission methods, and improving the security and confidentiality of the signals. Through the rational use of microwave technology, efficient transmission, remote monitoring, equipment debugging, and emergency communication of radio and television signals can be achieved<sup>[2-3]</sup>. Moreover, microwave technology is continually evolving and innovating, and it is poised to play an even more extensive and vital role in the realm of broadcast and television in the future.

## 2. Advantages of microwave in radio and television transmitters

### 2.1. Improves the quality of the transmitted signal

Microwave technology can effectively improve the transmission quality of radio and television signals. Compared to the traditional radio wave transmission method, microwave technology has higher signal

stability and anti-interference ability, which can effectively reduce the bit error rate and noise of the signal. This helps to improve the broadcast quality and clarity of broadcast and television, and provide users with a better audiovisual experience.

## **2. 2. Reduces the construction and maintenance costs of the launch pad**

Microwave can reduce the construction and maintenance costs of radio and television transmitters. Primarily, it is worth noting that microwave equipment demonstrates superior signal transmission efficiency and significantly reduced transmission loss in comparison to conventional radio wave transmission equipment. Microwave equipment can reduce the energy consumption and transmission power requirements of the transmitting equipment, thereby reducing the operating costs of the transmitter. Secondly, microwave can reduce the number and scale of antennas of the transmitter, the construction area of the transmitter, and thus the production cost of the transmitter.

## **2. 3. Makes switching of multiple transmission modes more convenient**

Microwave makes switching between multiple transmission modes easier, which helps improve the reliability and flexibility of broadcast and television systems. For instance, in the event of a natural disaster or emergencies, microwave technology can be utilized by seamlessly switching between different microwave stations. Microwave technology allows stable transmission of signals and emergency communication and ensures that radio and television can still function under special circumstances.

## **2. 4. Improve the security and confidentiality of signals**

Microwave technology can improve the security and confidentiality of broadcast television signals. Microwave signals can be encrypted during transmission to safeguard the confidentiality and security of the signal. In addition, microwave technology can also realize the digital encryption of signals to them from being eavesdropped or tampered with during transmission.

# **3. Application of microwave in radio and television transmitters**

## **3. 1. Radio and television transmission system**

Radio and television transmission systems are mainly composed of the following parts (Figures 1 & 2):

### **(1) Radio and television transmitter**

As the core of a radio and television transmission system, the transmitter is responsible for converting signals and transmitting them through antennas. The transmitter generally includes a signal source, a transmitting equipment, an antenna feeder system, cooling system, and other components.

#### **(i) Signal source**

The signal source is the starting point of the radio and television transmission system and is responsible for generating signals. The signal source can be from a program production center, satellite, etc.

#### **(ii) Transmitting equipment**

Transmitting equipment is the key equipment for converting radio and television signals into radio waves. Transmitting equipment includes modulators, power amplifiers, transmitting antennas, etc. The modulator modulates the broadcast television signal to a specified frequency band, the amplifier amplifies the signal, and the transmitting antenna converts the signals into radio waves and sends them out.

#### **(iii) Antenna feed system**

The antenna feeder system is an important part of the radio and television transmission system that is responsible for sending the transmitted radio waves to the receiving end. The antenna feed system includes

an antenna and a feeder, the antenna converts the radio waves into a wireless signal, and the feeder transmits the signal received by the antenna to the receiving end.

(iv) Cooling system

The cooling system is responsible for reducing the temperature and ensuring the normal operation of the transmitting equipment. The cooling system includes components such as radiators and air conditioners, which can effectively reduce the temperature of the transmitting equipment and ensure the stability of the transmission system.

(2) Receiving port

The receiving port is the terminal of the radio and television transmission system, which is responsible for receiving and restoring radio and television signals. The receiving end includes receiving antennas, feeders, demodulators, and other equipment, which converts the radio waves to radio and television signals for users to listen and watch.

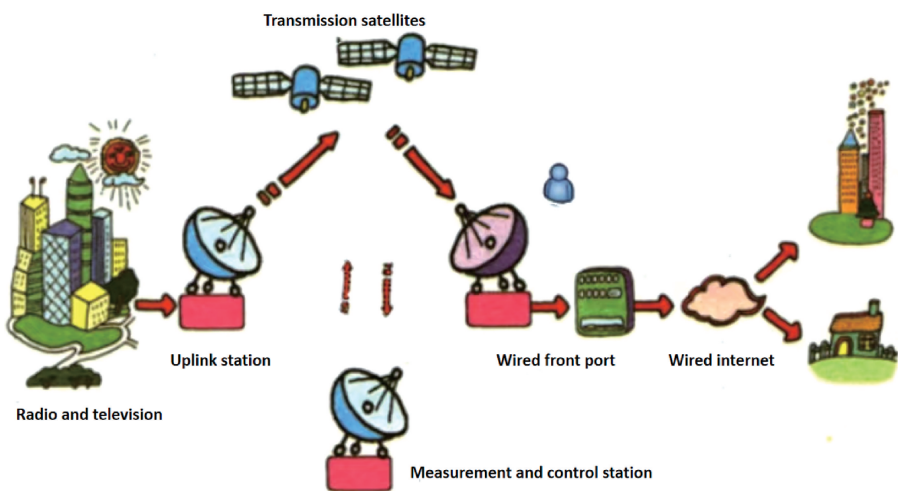


Figure. 1 Radio and television satellite transmission system

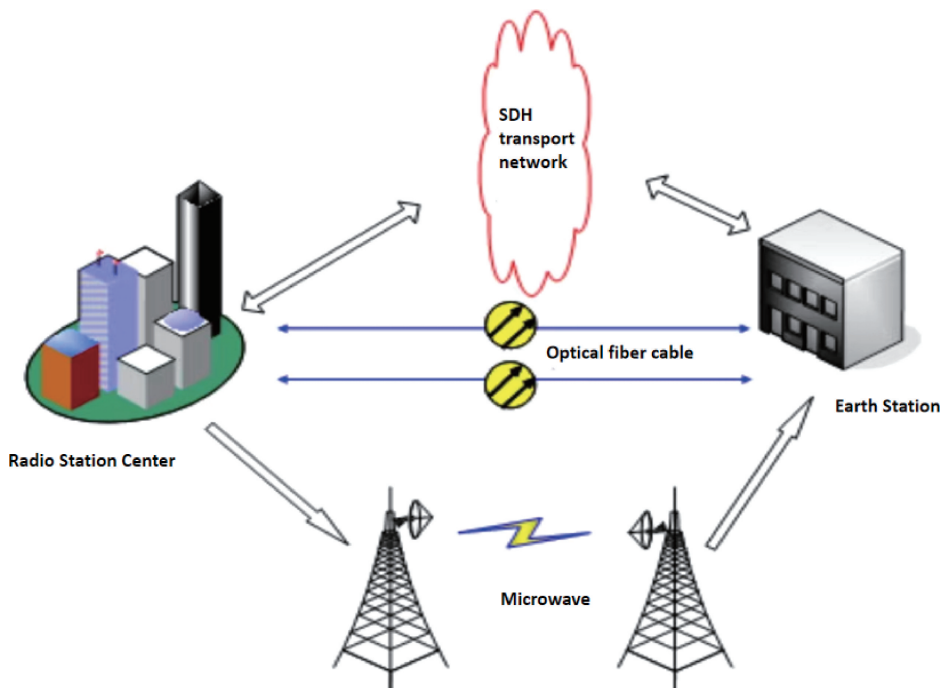


Figure. 2 Basic structure of radio and television transmission system

3. 2. Specific application

3. 2. 1. Signal transmission

Microwave can be used for the transmission of radio and television signals. Microwave transmitting equipment converts radio and television signals into microwaves and transmits them through antennas. The receiving port restores the received microwave signal to radio and television signals, which will be received by the users (Figure 3).

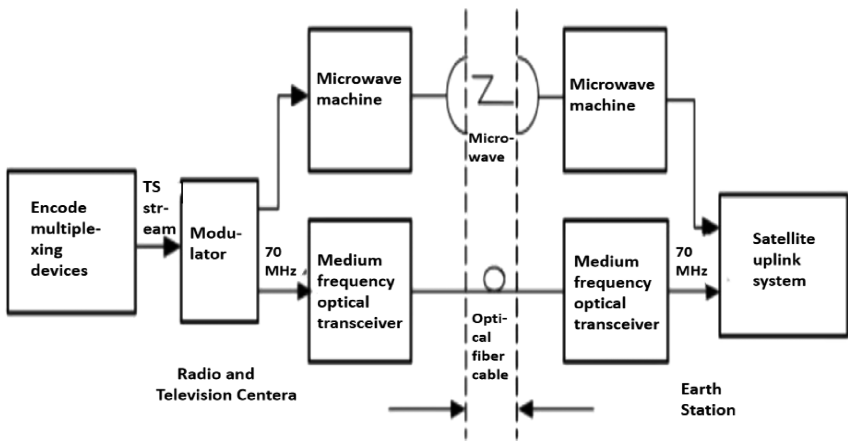


Figure. 3 Intermediate frequency transmission mode

3. 2. 2. Remote monitoring

Microwave can be used for remote monitoring of radio and television transmitters. The parameters and status of the transmitter can be transmitted to the remote monitoring center through a microwave transmission equipment. Then, the working status of the transmitter can be monitored and adjusted at the monitoring center in real time to ensure the stable transmission of radio and television signals (Figure 4).

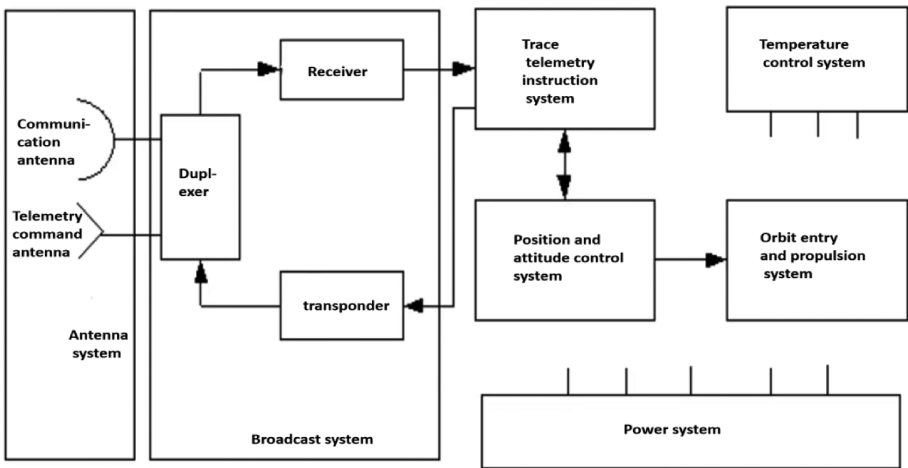


Figure. 4 System monitoring

3. 2. 3. Equipment debugging

Microwave technology finds application in the equipment commissioning of radio and television transmitters. With microwave test equipment, various devices can be commissioned and tested on the launch pad site. For example, parameter adjustment of microwave transmitting equipment, calibration of

antenna systems, etc.

### **3.2.4. Emergency communications**

Microwave technology can be used for emergency communication on radio and television transmitters. In the event of natural disasters or other emergencies, microwave technology can provide a reliable means of communication. The use of microwaves allows signal transmission and communication during emergencies, and the normal function of radio and television in special circumstances can be guaranteed.

### **3.3. Optimization strategies**

#### **(1) Choosing the right microwave equipment**

The microwave equipment should be chosen according to the actual needs of the radio and television transmitter, including the transmitter, the receiver, the antenna, etc. Besides, the quality and performance of the selected equipment should meet the relevant standards and technical requirements.

#### **(2) Determining the microwave transmission scheme**

A suitable microwave transmission scheme, including the frequency, bandwidth, route, etc. of microwave transmission should be designed according to the specifications of the radio and television transmitter. At the same time, the influence of topography, climate, electromagnetic environment and other factors on microwave transmission should be considered to ensure the feasibility and reliability of the scheme.

#### **(3) Constructing the microwave network**

According to the microwave transmission plan, we build microwave network, including: microwave transmission tower, microwave receiving station, microwave signal relay station, etc. At the same time, we must consider the security, reliability and scalability of the network to ensure the normal operation and management and maintenance of the network.

#### **(4) Optimizing microwave network management**

Aspects of microwave network management should include monitoring network operation status, collecting user feedback, and handling faults and abnormalities in a timely manner. Moreover, the network should be adjusted and optimized according to the actual situation to improve the performance and efficiency of the network.

#### **(5) Strengthening technical training**

To enhance the technical expertise and operational proficiency of radio and television staff, it is essential to provide them with specialized training in microwave technology. Our training includes basics of microwave, equipment operation, maintenance skills, network management, optimization skills, and more. Through training, proficiency in the application and management of microwave technology can be ensured among the staff, thus ensuring the stable operation of radio and television transmitters.

#### **(6) Establishing an emergency plan**

A comprehensive emergency plan should be developed to address microwave transmission failures, enabling timely implementation of effective measures to restore signal transmission in case of any failure. The emergency plan should include equipment backup, routing backup, emergency repair, etc., to improve the stability and reliability of the radio and television transmitter.

#### **(7) Joint other means of communication**

In radio and television transmitters, limited means of communication may be risky. Therefore, we can consider combining microwaves with other communication methods (such as optical fiber, satellite, etc.) to form a multi-channel, multi-backup signal transmission system. By doing so, we can enhance the safety and reliability of the entire system while ensuring the stability of signal transmission.

#### 4. Summary

In summary, the application of microwave technology in radio and television transmitters offers numerous advantages and holds significant practical significance. Microwave technology in radio and television transmitters allows signal transmission, remote monitoring, equipment debugging, and emergency communication. By utilizing microwave technology effectively, we can enhance the quality and reliability of broadcast television transmissions. This ensures the stable transmission of broadcast and television signals, providing users with a high-quality audiovisual experience. Through the selection of suitable equipment, designing appropriate solutions, building well-structured networks, optimizing management, and reinforcing technical training, we can ensure the effective utilization of microwave technology in radio and television transmitters, thus delivering high-quality radio and television services to audiences. At the same time, microwave technology is constantly developing, and it will play a more extensive and important role in the field of radio and television in the future.

#### Disclosure statement

The author declares no conflict of interest.

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# Analysis on the Configuration Path of Improving the Quality and Efficiency of County-Level Libraries in China

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**Abstract:** County-level libraries have an inescapable responsibility for cultivating local cultural identity and realizing rural revitalization. Therefore, we analyzed factors that affect the service efficiency of grass-roots libraries in Henan Province through a field investigation and qualitative comparative analysis (QCA), and proposed a high-efficiency configuration. In addition, we put forward the strategy of improving the quality and efficiency of our country's county-level libraries in the electronic information age.

**Keywords:** County libraries; Henan county-level libraries; Resource allocation efficiency; Qualitative comparative analysis

**Online publication:** August 29, 2023

## 1. Introduction

Since the 18th National Congress of the Communist Party of China, our country has built public libraries and cultural centers in counties and comprehensive cultural stations in townships, and the framework and pillars of the modern public cultural service system has been basically established<sup>[1]</sup>. However, due to the impact of the urban-rural dual structure, there are still many problems of unbalanced and insufficient urban-rural development in China's library undertakings. County-level libraries, especially those in the central and western regions, are not well-constructed, lack resources, and have low utilization rates. In the age of electronic information, it is necessary to overcome the general shortage of government financial, human, and material resources, and outline a new development path for county-level libraries. In fact, insufficient is not the only factor that affects the service effectiveness of county-level libraries. "Configuration" in this context refers to the organization and alignment of resources or modules with distinct functions, similar to assembling "building blocks" to create a specific arrangement that accomplishes the necessary functions. This study aims to investigate the factors influencing the service efficiency of county-level libraries and identify the configuration paths utilized to enhance service effectiveness.

## 2. Research methods and case selection

### 2.1. Methods for evaluating resource allocation efficiency

Data envelopment analysis (DEA) is a quantitative analysis method suitable for quantitative evaluation of the cultural industry, based on multiple input indicators (i. e., resources) and multiple output indicators

(i. e., services), relatively effective evaluation of comparable units of the same type<sup>[2]</sup>. DEA is a linear programming model that calculates the input-output ratio and finds ways to reduce inefficiency by comparing inefficient and efficient units<sup>[3]</sup>.

## **2. 2. Methods of studying factors affecting service effectiveness**

The ineffectiveness of county-level library services can be attributed to various factors, including resource factors, environmental factors, and subject factors. Traditional quantitative methods such as multiple regression analysis and structural equation modeling focus on the unique “net effect” of a single variable, while ignoring that the causes or conditions of social phenomena are mostly interdependent rather than independent<sup>[4]</sup>. The qualitative comparative analysis method of fuzzy sets (fsQCA) was adopted in this study, which integrates both qualitative and quantitative approaches. By incorporating “configuration comparison” and “set theory,” fsQCA allows for the examination of intricate asymmetric causality and potential interdependencies among variables through multi-case comparisons. Moreover, it uncovers multiple equivalent paths leading to the same outcome<sup>[5]</sup>, enabling a more detailed and comprehensive analysis.

## **2. 3. Case selection**

Henan Province has jurisdiction over 18 cities, 83 counties, and 1, 791 townships. According to statistics, in 2021, there will be 169 public libraries, 2, 412 township (street) cultural stations, more than 50, 000 comprehensive cultural service centers in villages (communities), and more than 46, 000 rural bookstores<sup>[6]</sup>. During the “Thirteenth Five-Year Plan” period, most of the county-level libraries in Henan Province built new buildings, “urban study rooms,” and “24–hour self-service libraries,” and generally carried out the mode of branch libraries. However, according to statistics, the average area of the county-level libraries in Henan Province, the book purchase funds per capita and the total number of books in the collection are all at the middle and lower levels in the country<sup>[7]</sup>. There are not many professional and technical personnel in the library, and many township libraries do not have full-time staff, services are usually provided by volunteers. In April 2018, the Henan provincial digital public cultural service platform “People’s Culture Cloud” was officially launched. In 2020, a province-wide public cultural service distribution and management platform “Wenhua Yuyue” was built, and a closed-loop service structure of “the people order, professional organizations receive orders, and the government pays” was established<sup>[8]</sup>.

## **2. 4. DEA method to calculate resource allocation efficiency**

We used the development of county-level libraries in 18 regions of Henan Province in 2020 as panel data, and the data was divided into primary data and second-hand data. However, the conditions are limited and some data are not particularly accurate. The procedure that we adopted for this research is as follows: First, a scientific and reasonable evaluation index system was established to ensure efficient library resource allocation, where the output index (Y) was the service effectiveness, and the input index was the book-borrowing rate, the number of visitors, and the rate of reviews. From the perspective of resource-based theory, physical resources such as financial resources, material resources, and human resources invested in the service process were selected. These resources are directly influenced by intangible factors, such as management, system, cultural activities, etc. There are also some indirect influencing factors, such as external environmental variables, GDP per capita, degree of informatization, and culture of residents.

On the basis of determining the data of input indicators (investment funds, number of books, area of



county-level library buildings) and output indicators (borrowing rate, number of visitors), DEAP 2.1 software was used to calculate the efficiency of county-level libraries in 18 regions of Henan Province, and the input-oriented BCC model was used for analysis. The estimated results are shown in Table 1.

**Table 1** Efficiency of county-level libraries in 18 regions of Henan Province

Region	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	State
Zhengzhou	0.34	0.713	0.477	drs
Xinyang	0.401	1	0.401	drs
Xinxiang	0.24	0.505	0.476	drs
Anyang	0.411	1	0.411	drs
Kaifeng	0.393	0.653	0.601	drs
Xuchang	0.413	0.59	0.701	drs
Jiyuan	1	1	1	–
Zhumadian	0.314	1	0.314	drs
Pingdingshan	0.345	0.547	0.630	drs
Puyang	0.14	0.14	0.993	irs
Luohe	1	1	1	–
Sanmenxia	0.288	0.297	0.970	irs
Luoyang	0.289	0.610	0.474	drs
Nanyang	0.228	1	0.228	drs
Zhoukou	0.222	0.932	0.239	drs
Shangqiu	0.183	0.62	0.295	drs
Hebi	0.96	0.97	0.989	irs
Jiaozuo	0.56	0.56	1	–
Average	0.429	0.73	0.622	

Note: “drs” means decreasing scale efficiency, “irs” means increasing scale efficiency, “–” means constant scale efficiency

Table 1 shows that the overall efficiency of county-level libraries in Henan Province was not high, with an average comprehensive technical efficiency of 0.429, and the efficiency of most areas was below average. These results indicate that there is still much room for improvement in the efficiency of county-level libraries in Henan Province; secondly, there are large differences in the efficiency of the 18 regions. Therefore, the reasons for uneven development needs to be analyzed.

**3. Configuration analysis of influencing factors and efficient paths with QCA method**

The fsQCA method was used to identify the influencing factors and efficient paths, with the comprehensive technical efficiency of 18 regions as the outcome variable, and four variables including book resources, human resources, external environment (GDP per capita), and cultural activities as the antecedent conditions. Because there is a minimum sample size for fsQCA analysis, in which the number of cases needs to be greater than  $2k$  ( $k$  is the number of explanatory variables). This study selected data from 18 regions, so four explanatory variables were chosen.

**3.1. Variable assignment and calibration**

When performing fsQCA analysis, it is first necessary to assign values to the explanatory variables. Variable assignment is the process of judging whether or to what extent a case belongs to a certain set. The data of the variables in the fsQCA method is also called the degree of membership. According to the characteristics of the data of each variable, a direct calibration method was used to convert the data of 18

regions into a four-valued fuzzy set (0, 0.33, 0.67, 1) membership scores. Among them, “0” means no membership at all, “0.33” means that the degree of no membership is greater than that of membership, “0.67” means that the degree of membership is greater than that of no membership, and “1” means complete membership.

3.2. Analysis of necessity of single condition variable

A truth table with  $2k$  rows was first constructed, where  $k$  was the number of antecedent conditions, and each row represented a possible combination of conditions. A single conditional variable and a non-state necessary conditional analysis of each conditional variable were then performed. The analysis of necessity of fsQCA is simply the extent to which the result set is included in a certain condition set. Only when the consistency level of a condition variable exceeds 0.9 can the condition variable be considered a necessary condition for the outcome variable.

Table 2 Necessity test of single conditional variable

Variable	Consistency	Coverage
Book resources	0.826	0.783455
Book resources	0.456	0.940035
Human resources	0.741	0.962222
Human resources	0.683	0.886667
External environment	0.624	0.812918
External environment	0.743	0.962306
Cultural activities	0.713	0.926
Cultural activities	0.626	0.813

Table 2 shows that the consistency levels of the four conditional variables (including non-state) were all less than 0.9, which means that none of the individual conditions alone can affect the efficiency of resource allocation. indicating that the conditional variable of library resources is a sufficient condition for high efficiency. However, the explanatory power of a single conditional variable for high efficiency is limited, meaning that the high efficiency of county-level libraries is not solely determined by one condition but is the outcome of multiple conditional configurations.

3.3. Conditional configuration analysis

Conditional configuration analysis measures the impact of different combinations of antecedent condition variables on outcome variables, and it is the core of fsQCA research methods. In this study, the case frequency was set at 1, the consistency was greater than 0.8, and the PRI consistency was greater than 0.75. A standard analysis was performed to output complex solutions, parsimonious solutions, and intermediate solutions. Since there were only 4 explanatory variables in this study, the conclusions were not many, so the analysis of high-efficiency configuration through complex solutions was chosen (Table 3).

As shown in Table 3, there were 3 groups of high-efficiency condition combination paths, and the consistency indexes of these 3 groups of configurations were 1, 0.939, and 1 respectively, indicating that the 3 groups of configurations were all necessary conditions for high efficiency. The total consistency was 0.89, indicating that these three configurations are also sufficient conditions for improving service efficiency. The total coverage was 88.7%, indicating that these 3 combinations can explain the vast majority of cases. Further analysis showed that these three groups of configurations can be summarized into the following two high-efficiency paths:

**Table 3** Configurations with high resource allocation efficiency

Explanatory variables	Condition combination		
	1	2	3
Book resources	●	●	⊗
Human resources	●		●
External environment GDP		●	⊗
Cultural activities		⊗	●
Consistency	1	0.939	1
Original coverage	0.524	0.496	0.497
Unique coverage	0.059	0.033	0.056
Total consistency		0.89	
Total coverage		0.887	

Note: ● indicates that the core resource is a core condition; ⊗ indicates that the resource is lacking; blank indicates that the resource is dispensable

(i) Resource support type

Corresponding to configuration 1 (book resources \* human resources) and configuration 2 (book resources \* external environment \* cultural activities). Configuration 1: ample library resources and human resources. The combination of these two resources can produce high quality service. A typical example of this configuration is the Mengjin District Library of Luoyang City, which has abundant funds, resources, and facilities. The library also contains the center of the “National Cultural Information Resource Sharing Project” and 120 village-level grassroots service points. The library and its branches have a collection of more than 485,000 volumes, with 13 professional librarians. It was rated as a national first-class museum. Configuration 2 means that the economically developed areas have rich book resources, and although the cultural propaganda activities are less prominent, the residents are still relatively civilized, which can also lead to high quality service. For example, the Yuzhou Library under the jurisdiction of Xuchang City has an area of 8,000 square meters and a collection of more than 400,000 books. Besides, a total of 140,000 books were borrowed from that library in 2022. Therefore, it has been rated as a national first-class museum for many times.

(ii) Management-driven

Configuration 3 (book resources \* external environment \* human resources \* cultural activities) means that although the area is economically backward and lack book resources, but the management personnel are highly professional, and cultural promotion and publicity activities are carried out relatively well, which can also bring about the improvement of service effectiveness. For example, Zhoukou City’s GDP per capita ranks relatively low in Henan, and its Huaiyang District (County) library was built earlier, but there are not many collections in the library. However, many activities have been carried out to promote reading, such as lectures and parent-child reading class of Chinese classics. These initiatives have led to the library receiving multiple awards. It was rated as a national first-class library in the sixth national evaluation of public libraries above the county level. During the pandemic, the library was closed but online services were provided, which served more than 100,000 people.

**3.4. Further conclusions**

The service efficiency will not be affected by one factor alone, except for book resources. From this, it can be concluded that county-level libraries should pay attention to the allocation of book resources, because excellent book resources are crucial for the development of county-level libraries. Besides, a prerequisite for county-level libraries to excel in their services is the establishment of a document resource system that meets the needs of grassroots residents. However, in many areas of our country, there is still an

inadequate supply of public cultural service resources, coupled the issue of “suspension” in terms of supply and “weak participation” in terms of consumption. It is necessary to form mechanisms and policies that promote the allocation and function of resource elements through government leadership. Moreover, enhancing the service efficiency of county-level libraries necessitates the collective influence of multiple factors, with the combination and allocation of resources being more critical than the improvement of individual resource capabilities<sup>[9]</sup>. Therefore, we should also pay attention to other aspects, so as to effectively improve the effectiveness of public cultural services in county-level libraries.

#### **4. Strategies for improving the quality and efficiency of county-level libraries in our country in the electronic information age**

##### **4.1. Shaping service brand strategy with characteristic culture**

Shaping a service brand strategy with characteristic culture involves proactive and distinctive cultural integration, breaking through various limitations, and innovating around elements such as resources, services, space, and personnel. The provincial government should protect and develop key areas of with excellent culture by gathering experts to interpret classic documents, excavating and protecting intangible cultural heritage, building digital platforms for ancient books, and developing cultural and creative products. Besides, the government needs to improve their leadership and coordination, and do a good job in terms of top-level management and organization. Provincial and municipal libraries should do a good job in industry leadership and service training. Improving competitiveness at the county-level libraries can only be achieved when the construction of local characteristic culture and the development a distinct cultural service brand system is emphasized.

##### **4.2. Innovating and building a resource system based on demand**

To achieve high-quality service and create an optimum information environment, it is necessary to dig deep into the potential of internal resources and carefully analyze the advantages of external resources. It is also important to encourage the participation of social forces and improve the multi-subject joint construction input system through project-driven, “government + organization + library,” and other models, and enhance the supply of resources. Under the multi-supply structure, it is also necessary to actively seek the perfect balance between the supply and demand. On one hand, this system should allow grassroots residents to express their needs. On the other hand, the system should be able to predict the cultural information needs of the masses through accurate data collection and analysis<sup>[10]</sup>.

##### **4.3. Seeking breakthroughs in sustainable development led by digital intelligence technology**

Leveraging modern digital intelligence technology to effectively explore the cultural essence of literature resources allows for the creation of a diverse virtual service environment in the digital library. This transformation positions the library as the focal point for the cultural experience and atmosphere of the masses<sup>[11]</sup>. It is important to predict the needs of the masses and provide personalized and refined services. Internal and external resources of the organization should be integrated, and resource allocation and spatial layout should be optimized. Moreover, the flow of talents, resources, information, and other elements between urban and rural areas should be promoted. In addition, the equalization of public cultural services should also be improved. County-level libraries should actively participate in the construction of national public digital cultural projects and actively participate in the construction of the national smart library system. The “order-based,” “menu-based,” and “reservation-based” service mechanisms should be gradually promoted and enhanced to foster self-improvement and functional

expansion of county-level libraries.

**Disclosure statement**

The author declares no conflict of interest.

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# Intelligent Road Safety System Based on Multi-Function Warning Device

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**Abstract:** A warning device for car driving is proposed in this paper, which includes support rods and warning plates. In this device, several display screens are installed on one side of the warning panel. Indicator lights are set on the display screen. A warning board is mounted on the top box. Several radar detectors are mounted on one side of the top box, and the radar detectors correspond to the display screens. Several warning lights are installed on the top box, and the warning lights correspond to several radar detectors. The sliding side of the support rod cleans the unit. The change of positions of the indicator lights based on the radar detectors will be reflected on the display screens, which allows drivers to understand the situation of the road. Therefore, they can prepare for changing lanes and overtaking, and understand the position and speed of all vehicles in this road section in advance.

**Keywords:** Traffic safety; Intelligent traffic; Warning device

**Online publication:** August 29, 2023

## 1. Background technology

Road safety is something that every driver should understand and master. Adhering to traffic regulations is essential for ensuring road safety. While driving, drivers must possess a comprehensive understanding of various traffic signs and signals, and adhere to traffic rules. This includes adhering to speed limits and refraining from overspeeding, as well as respecting road markings and avoiding haphazard lane changes. Drivers should first observe the surrounding vehicles before changing lanes or turning. However, in some cases, the driver did not look at the rearview mirror before changing lanes, resulting in sudden lane changes. This behavior increases the risk of collisions with trailing vehicles, potentially causing harm to both drivers and their vehicles<sup>[1]</sup>.

Intelligent transportation system uses advanced sensor and algorithm technology to provide real-time traffic information through vehicle detection, traffic flow monitoring, and traffic condition analysis to help drivers make better decisions while driving. Driver behavior research is dedicated to detecting and analyzing the behavior of drivers, so as to improve safety awareness and driving literacy, and reduce traffic accidents. Intelligent driver assistance system uses advanced sensors and algorithm to provide drivers with real-time information and warning to make driving safer and more convenient. Cleaning and maintenance technology refer to the use of advanced cleaning equipment<sup>[2]</sup> to reduce the need for manual cleaning and maintenance. The integrated traffic safety system integrates different traffic safety systems to form



comprehensive traffic safety solutions to achieve more efficient and safe traffic management. This paper proposes an intelligent road safety system based on a multi-function warning device.

## 2. System survey

This study introduces a road driving warning device, with its surface structure illustrated in Figure 1. The device is designed to enhance the warning system for lane changes in vehicles. The warning board is equipped with multiple display screens on its side, featuring warning lights. A connection box is fixed on top of the warning board. This box is equipped with several radar detectors, which correspond to a display screen. Additionally, several warning lights are mounted on the top of the box, and they correspond one-to-one with the radar detectors. The support rod on the side is connected using a sliding mechanism to facilitate the removal of the device.

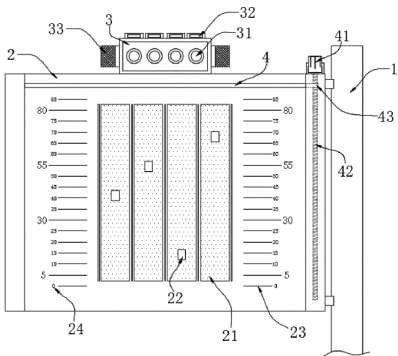


Figure. 1 Schematic diagram of road driving warning device. Description for each number: 1, support rod; 2, warning board; 21, display screen; 22, indicator light; 23, scale line; 24, distance identification; 3, top box; 31, radar detector; 32, warning lights; 33, voice alarm; 4, cleaning rod; 41, drive motor; 42, wire rod; 43, thread plate.

There are two scale lines on one side of the warning board, which are symmetrically distributed. The scale lines correspond to the size of the display screen. On the side of the warning board, the two distance signs correspond to the positions of the two scale lines. Alarms are installed on both sides of the top box, which cooperate with several warning light functions. The top of the warning board is equipped with a motor that drives the cleaning rod. The output end of the drive motor is firmly connected with the wire rod, and the one end of the cleaning rod is fixed with the thread plate is connected to the side wall of the wire rod. The cleaning rod is attached to the side of the warning board and the side walls of several display screens.

The intelligent road safety system utilizes multiple radar detectors to control the position of the warning lights that are displayed. This allows drivers to observe specific driving conditions on the display screen and while changing lanes and overtaking. The system provides advanced information about vehicle location and speed, enhancing road safety for both drivers and pedestrians. Additionally, the warning board is designed with dust-cleaning functions to prevent impurities from obstructing the driver’s view of the device and the road conditions.

## 3. Device implementation

This paper presents the following technical solutions, including a support rod and a warning board. The side of the warning board is equipped with several screens, each screen featuring an indicator light. The warning board is firmly connected to the top box. Several radar detectors are positioned on the side of the top box, corresponding to the number of display screens. The top box also accommodates several warning

lights, matching the number of radar detectors. The support rod is affixed on the side and enables the device to be easily slid for cleaning purposes (Figure 2).

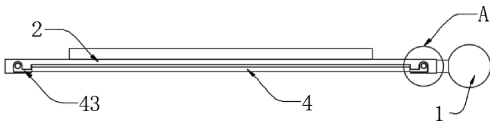


Figure. 2 Schematic diagram of the top-view profile structure

The support rod supports the warning panel. The support pole is installed on the edge of the road, so that the warning sign can be hung above the road for the driver to see. The warning signs correspond to different lanes on the road. Vehicles are scanned and recorded by multiple radar detectors as they move. The display is controlled by data scanned by the radar detector. In this way, the lane that the vehicle is in can be observed through the warning lights. The driver can observe multiple screens and understand the conditions of the road section, be prepared to change lanes and overtake, and grasp the position and speed of all vehicles on the road section in advance. The top box protects and supports radar detectors and warning lights. Warning lights and displays are controlled and triggered by radar detectors. When a tendency of a vehicle turning or a turning signal is detected, the radar detectors will detect whether there are vehicles that pose a safety hazard to the vehicle in multiple lanes. When it is detected that vehicles in other lanes conflict or pose a risk to the vehicles, the radar detector controls the warning lights to issue warnings to vehicles in the corresponding lanes in time. By doing so, the driver would be aware of the safety hazards when changing lanes, and traffic accidents can be avoided. When the equipment is in use, it is easy to be contaminated with impurities and dust Therefore, the warning device is equipped with a cleaning rod that would slide up and down to wipe away the dust on the display screens, so that drivers are able to see the information displayed clearly.

There are two scale lines on one side of the warning sign, the two scale lines are symmetrically distributed, the scale lines correspond to the size of the display screen, and there are two distance marks on one side of the warning sign; the two scale lines are located on multiple display screens on both sides of the area, so that drivers in each lane can analyze and judge the scale marks and indicator lights. By observing the positional relationship between the indicator lines, the driver can judge the distance and driving speed of the surrounding vehicles, which is will be helpful in creating a better driving experience.

Alarms are installed on both sides of the top box, and are matched with multiple warning lights. The alarm can remind the driver to observe the device in time, and remind the surrounding drivers when a driver decides to change lanes, so that the surrounding drivers can slow down or change lanes in time, thus reducing the occurrence of accidents. A driving motor is installed on the top of the warning board, which connects the screw rod at the output end of the driving motor and the threaded plate at the end of the cleaning rod; the driving motor moves the screws up and down to move the cleaning rods (Figure 3).

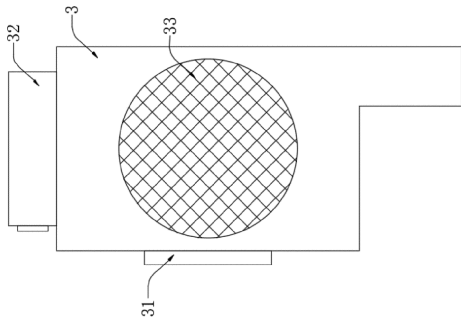


Figure. 3 Schematic diagram of the lateral view structure of each component on the top box



The cleaning rod is attached to the side of the warning sign, where the warning signs and several display panels are located. As the cleaning rod is moved vertically, it acts as support and propels the wiping board to clean the display screen. This mechanism enhances the cleaning effectiveness while preventing any potential damage to both the warning sign and the display screen (Figure 4).

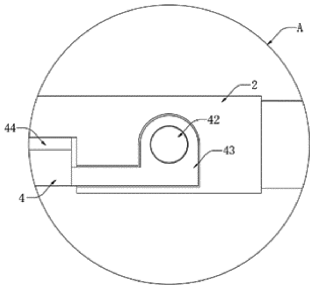


Figure. 4 Enlarged schematic diagram of the structure

## 4. Technology implementation process

### 4. 1. Design phase

The functions and requirements of the equipment should be defined, such as vehicle speed detection, warning information display, sound alarm, etc. The components and modules such as radar detectors, display screens, sound modules, etc should also be determined.

### 4. 2. Radar detection technology

A suitable radar detector should be selected and connected to the control board<sup>[3]</sup>. Algorithms for radar signal processing should be developed to handle returned radar signals and to extract information about vehicle position and speed. Antenna systems should be designed, encompassing the arrangement and adjustment of antennas to achieve optimal reception of vehicle detection signals.

### 4. 3. Display technology

The right type of display screen should be used, such as LED display. The display would be connected to the control circuit board, and a control program would be written to control the display content. Then, vehicle information and warning will be displayed on the screen through programming, and suitable appropriate fonts, icons and animation should be used.

### 4. 4. Alarm sound

A suitable alarm sound should be selected and connected to the control circuit board<sup>[4]</sup>. Using sound synthesis technology, the warning message is converted into speech and played through the speaker. This requires a control program to trigger the voice playback of the corresponding alarm information.

### 4. 5. Cleanup mechanism

The structure and driving method of cleaning rod and wiping cotton should be determined, which will be driven by a suitable motor and transmission device. Sensors should be installed to realize automatic detection of dust and impurities, and trigger the cleaning mechanism to work. A control program should be written to coordinate the work of the cleaning mechanism and other modules.

### 4. 6. Control and algorithms

Embedded systems need to be developed along with control programs to facilitate the coordination of

different modules' functions. Algorithms, such as those for vehicle detection and early warning judgments, should also be developed. These algorithms would initiate relevant early warning actions based on the results of the detection process. Furthermore, the integration of the system is essential; this involves connecting and testing the different modules to ensure their effective collaboration and overall stability.

#### **4. 7. Testing and debugging**

Functional testing should be carried out to make sure that the device performs its functions. Performance tests, such as vehicle detection accuracy, display effect, sound playback clarity, etc. should also be carried out. Stability and reliability tests should be carried out, including long-term operation and operation in various environments. Besides, the system should be further optimized and debugged, and some improvements should be made.

### **5. Innovation**

#### **5. 1. Multifunctional design**

The device is fully functional and cleverly integrates display screens, indicator lights, radar detectors and warning lights to build a multi-functional system, thereby significantly improving the ability of vehicle lane warning.

#### **5. 2. Visual cues and voice alerts**

The device uses the built-in photosphere on the display screen, the top warning light and the voice alarms on both sides to provide the driver with a full range of visual prompts and different levels of alarms in a multi-sensory manner, effectively enhancing the driver's intuitive perception and awareness of the vehicle's conditions.

#### **5. 3. Cleaning function**

The cleaning unit consists of rods and wipes to remove dust and debris on the warning signs and displays quickly and efficiently. This innovative design plays a vital role in providing accurate and reliable visual information by ensuring that drivers have a clear view of the display screens at all times.

### **6. Conclusion**

The device uniquely integrates smart technology with a multifunctional design, providing drivers with detailed vehicle driving information through the synergy of radar detectors and displays, so that they can better prepare for lane changes and overtaking. In addition, the ingeniously designed cleaning function removes dust and impurities in time to ensure that the device is always visually clear. Overall, the innovative design of the device greatly improves the safety of road driving and the driver's perception, making a significant contribution to road traffic safety.

### **Disclosure statement**

The authors declare no conflict of interest.

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# Research on the Development of Global New-Energy Vehicle Industry Under the Goal of Carbon Neutrality

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**Abstract:** As a pioneer in energy conservation and environmental protection, new energy vehicles also play an important role in reducing carbon dioxide emissions. Carbon neutrality will become a long-term measure to reduce greenhouse gas emissions in the future, and the new-energy vehicle industry should develop a path that is more in line with the goal of carbon neutrality

**Keywords:** New-energy vehicles; Development path

**Online publication:** August 29, 2023

## 1. Introduction

Carbon neutrality involves assessing and quantifying the carbon dioxide emissions produced by organizations, individuals, and businesses during their operations. This is followed by implementing energy-saving measures, emission reductions, and tree planting over a specific timeframe to offset these emissions, thereby decreasing overall carbon dioxide emissions. The concept of carbon neutrality advocacy has been gaining support from many countries. From January 29 to February 2, 2007, the United Nations Intergovernmental Panel on Climate Change (IPCC) held meetings in Paris. After the meetings, global climate change assessment reports pointed out that about 90% of the climate change in the past 50 years may be caused by human activities. In July 2013, the International Air Transport Association introduced the “2020 Carbon Neutrality” initiative for the aviation sector, which requires airlines worldwide to cover emissions exceeding the set quota post-2020. Furthermore, in October 2018, the United Nations Intergovernmental Panel on Climate Change urged all nations to proactively combat global warming, aiming to restrict it to a 1.5 °C rise<sup>[1]</sup>.

Carbon neutrality is the main component of the United Nations Climate Change Conference and the environmental protection implementation measures of various countries in recent years, and it is the main means for human to reduce carbon dioxide emissions. As a pioneer of energy conservation and environmental protection, new-energy vehicles also play an important role in reducing carbon dioxide emissions. Carbon neutrality will become a long-term measure to reduce greenhouse gas emissions in the future. The global new-energy vehicle industry must formulate a path that is more in line with the goal of carbon neutrality<sup>[2]</sup>, which involves five aspects.

## **2. Adhering to the development line with innovation as the core**

Innovation is the fundamental driving force for the sustainable development of the industry and an important way to realize the leapfrog development of the new-energy automobile industry. The fact that global sales of new-energy vehicles have soared in 2020 proves that technological innovation is the driving force behind industrial development<sup>[3]</sup>. Therefore, this means that continuous innovation and development of new technologies can ensure the overall development of the new-energy automobile industry

### **2.1. Technological innovation**

The early stages of the new-energy vehicle industry saw rapid development, with sales surging since 2015. These sales figures have notably outpaced the growth rate of overall vehicle sales. However, this growth is largely attributed to robust industrial support policies playing a pivotal role. Notably, post-subsidy vehicle prices hold a significant advantage over traditional fuel vehicles, delivering exceptional cost-effectiveness and attracting consumer interest. Due to excessive reliance on subsidies, companies generally lack the motivation for technological innovation. The core technologies for new-energy vehicles are still in an immature stage, particularly in areas such as range, electronic control management, and safety protection. These aspects are yet to reach advanced technical levels. Manufacturers have relied heavily on pricing advantages to compensate for these technological gaps. However, starting from 2017, major global new-energy vehicle producing countries have progressively reduced subsidies. As a result, new-energy vehicle companies are now compelled to hasten the upgrading of their products. Before 2017, the mileage of pure electric vehicles was generally around 300 km, which was far from the mileage of fuel vehicles. After 2017, the energy density of power batteries began to increase rapidly, and the level of electronic control continued to be optimized. In 2018, the battery life of pure electric vehicles has generally reached 400–500 km, and some models can even reach 550 km. Facing challenges such as bottlenecks, innovation gaps, and a slowdown in advancements, the range and acceleration performance of new-energy vehicles have remained stagnant. Simultaneously, there has been a sharp reduction in subsidies for new energy vehicles. The combined effect of these two factors has significantly impacted global new energy vehicle sales. In 2019, the annual growth rate of global new energy vehicle sales was only 9.5%, falling below 10% for the first time, far lower than the previous growth rate, and was at the lowest point in recent years. As a result, new-energy vehicle companies have learned from the experience and started prioritizing technological innovation. In 2020, the technology of new-energy vehicles showed significant improvements, with the maximum range generally reaching 600 km, and the Xpeng P7 model had a range of more than 700 km<sup>[4]</sup>. Acceleration levels have also seen significant improvements. For instance, the BYD Han EV has achieved a 0–100 km/h acceleration time of under 4 seconds for commercially available pure electric family cars. Despite the global decline in car sales due to the COVID–19 pandemic in 2020, new energy vehicles remained unaffected, experiencing a sales increase of 46.6%. This marked the first time that sales exceeded 1 million units. Returning to a high-growth era amid decreasing subsidies is a challenge. Technology advancements have emerged as a crucial factor driving this progress.

#### **2.1.1. Power battery**

The development trend of battery technology determines the overall development trend of the new-energy vehicle industry as it is the core technology of new energy vehicles. In recent years, the energy density of power batteries has achieved new breakthroughs. Companies such as BYD, Ningde Times, AVIC Lithium Battery, and Panasonic have been actively developing batteries with high energy density. The American luxury pure electric car Lucid Air was launched in October 2021, with a battery life of 832 km. GAC

AION LX Plus pure electric SUV had a range of 1 008 km in the catalog of recommended models for the promotion and application of new-energy vehicles announced by the Ministry of Industry and Information Technology of China in November 2021, and was the world's first pure electric vehicle with an energy density exceeding  $200 \text{ Wh} \cdot \text{kg}^{-1}$  car at that time<sup>[5]</sup>.

Car battery manufacturers have been improving battery performance and battery safety. In March 2020, sales of BYD Han had been rising steadily since its launch, and their blade battery passed the acupuncture test. In March 2021, GAC Aian's magazine battery system achieved a breakthrough in safety technology. The power battery pack demonstrated resistance to catching fire upon being needled, successfully passing the acupuncture thermal diffusion test. In September 2021, Great Wall Motors introduced the Dayu battery, which exhibits exceptional safety features. It remains non-explosive and non-flammable even if single or multiple batteries experience thermal runaway at any position. Additionally, this battery technology provides comprehensive coverage of the battery's chemical system<sup>[6]</sup>. In the future, cars will provide users with a safer driving environment, and the safety of power batteries will be significantly improved.

The charging and swapping technology has also been improving and developing. Brands like Xpeng, Tesla, and NIO can charge up to 80% capacity in 30 minutes with charging power of 180–250kW. Porsche achieves 80% charge within 15 minutes, utilizing charging power up to 350kW. Although not as swift as refueling for conventional vehicles, innovations such as BAIC New Energy and NIO's battery replacement stations can replace a car battery in just 5 minutes. This trend indicates a potential solution for insufficient mileage in the future<sup>[7]</sup>.

### **2. 1. 2. Electric control system**

The electronic control system is control center of new-energy vehicles. Electronic control technology has also been developing rapidly in terms of using new materials. Silicon carbide power modules have begun to be used in pure electric vehicles. BYD, Tesla, Weilai, Infineon, Mitsubishi, "CRRC Times" and Hitachi are developing new Silicon carbide power module system for energy vehicles. The use of silicon carbide power modules is the future development trend of electronic control technology. Silicon carbide power modules can significantly improve the overall efficiency and service life of electronic control systems.

As a transitional model for pure electric vehicles to replace fuel vehicles, hybrid vehicles can effectively solve the problem of range anxiety. However, their energy consumption during power-feeding often surpasses that of equivalent fuel vehicles, leading to lower long-term sales. New breakthroughs have been made in recent years. The January 2021 release of BYD DMI's super hybrid technology achieved remarkably low fuel consumption during power-feeding, effectively addressing the previous issue of high fuel consumption<sup>[8]</sup>. DMI models immediately became the best-selling models in the market, and the backlog of orders and the short supply had boosted the overall sales of hybrid vehicles.

### **2. 1. 3. Drive motor**

The drive motor is also the core component of the new-energy vehicle. It directly drives the vehicle. During the initial phase, it delivers maximum torque, resulting in strong acceleration performance that surpasses similar-grade fuel vehicles. Nevertheless, the motor's torque diminishes rapidly during high-speed operation. In recent years, drive motor output power has steadily risen, driven by ongoing innovation in materials, performance, and systems. For instance, the 2019 Porsche Taycan pure electric coupe features a rear drive motor with an impressive power of up to 476PS, a substantial increase from the 150PS rear drive motor that come out in 2018<sup>[9]</sup>.



The early drive motors used round-wire materials. After 2015, flat wire motors began to replace traditional round-wire motors, becoming the development trend of drive motors. Most of the new-energy models on sale generally use single/dual motor configurations. Some models are even equipped with three or four drive motors, which further improved the power and performance of the vehicles, and offered products at different price range<sup>[8]</sup>. Asynchronous motor and permanent magnet synchronous motor both come with their own advantages and disadvantages, and the combination of the two drive motors optimizes the overall performance. Companies such as Weilai and Tesla have launched models equipped with permanent magnet synchronous motors and asynchronous motors, and the overall performance has been significantly improved compared with the previous models.

#### **2. 1. 4. Auxiliary technology**

In addition to the core technology of new-energy vehicles, auxiliary technologies have also advanced by leaps and bounds. Low drag coefficient, lightweight body, concealed exterior decoration, heat-pump air conditioner are all auxiliary technologies that have been widely used in the field of new-energy vehicles. The reduction in vibration and noise of the drive motor, combined with the integration of intelligent network technology, has enhanced the competitive edge of auxiliary technology's core products. This has led to significant enhancements in functionality, efficiency, handling, safety, environmental friendliness, and comfort. As a result, the overall competitiveness of energy vehicles has seen substantial improvement.

### **2. 2. Model innovation**

Technological innovation is the driving force leading the development of the new-energy automobile industry, but technology alone is not enough, and marketing strategies are also important. In recent years, many new business models have emerged in the new energy vehicle industry.

#### **2. 2. 1. Direct sales model**

In the era of traditional fuel vehicles, the 4 S store sales model integrating sales, service, spare parts (as per industry norms), and survey occupies the mainstream, and consumers generally purchase vehicles on the spot. However, since 4 S stores are generally operated by intermediary agents, it is difficult for production companies to supervise, so they have been criticized for problems such as arbitrary charges, mandatory configuration, bundled sales, and defrauding consumers. In recent years, with the rapid growth of Internet technology, mobile payment methods have gained widespread acceptance. Given the high level of intelligent network connectivity in pure electric vehicles, their compatibility with online services is remarkable. Manufacturers such as Ideal, Xpeng, Tesla, NIO, and WM Motor have embraced online sales models that are centered on direct sales (online purchases). This approach facilitates the entire process, including ordering, payment, delivery, and after-sales service, effectively eliminating intermediary 4 S store agent involvement. This shift ensures complete transparency and openness in pricing. In this mode, consumers can freely choose configurations on the basic model to achieve exclusive personalized customization. Besides, major companies have also set up showrooms in the central business district of the city for display and test drive only, so as to increase their popularity and attract potential customers. The direct sales model has effectively solved the long-standing problems of traditional 4 S stores. However, since it is a new thing, it will take time to gain public acceptance. In the short term, it will have limited impact on the 4 S store model that has existed for many years. However, due to the Covid-19 pandemic 2020, strict anti-pandemic measures have led to the closure of many 4 S stores, making it impossible for consumers to purchase products. However, the direct sales model can realize complete contactless online purchases, and new cars can be sold even during the pandemic prevention and

control period. As a result, Tesla achieved remarkable global sales of 499,500 vehicles in 2020, marking a 35.8% year-on-year increase. Following suit, traditional fuel vehicle manufacturers began to emulate the direct sales approach, establishing premium pure electric vehicle sub-brands that adopted the same model. Notably, SAIC Motor's R Automobile and Geely Group's Jifan Automobile Company were established, signifying a transformative shift in the sales model within the new energy automobile industry<sup>[9]</sup>.

### **2.2.2. "Vehicle-electricity separation" business model**

In the early days, the battery of a new-energy vehicle was fixed on the chassis of the car, which made it difficult to replace, and the batteries were expensive, with a limited range and poor appearance. The present battery replacement technology enables the rapid disconnection of vehicles from power batteries, giving rise to a new business model known as "vehicle-battery separation." This concept first emerged in 2010 when State Grid introduced the "vehicle-electricity separation" model, initiating pilot projects with battery-swapping taxis from Haima and Zotye. NIO introduced a battery rental program for ES8 in late 2017. Subsequently, in July 2018, BAIC New Energy launched the "vehicle-electricity separation" solution. Weilai followed suit, introducing an upgrade plan in September 2019 allowing users to switch from a 70 kW-h to an 84 kW-h battery pack. In 2020, Weilai launched the WOkW-h battery pack. By December 2021, Weilai unveiled a flexible battery upgrade system, permitting users to enhance battery packs on a monthly, annual, or permanent basis, effectively augmenting the range of new energy vehicles.

### **2.2.3. Customization of operating vehicles**

The operating costs of operating vehicles need to be strictly controlled. In recent years, the rising oil price has caused the transportation cost to rise year after year, making the operation of commercial vehicles difficult. Pure electric vehicles typically offer a slightly shorter range compared to equivalent fuel vehicles. However, their usage costs are considerably lower than gasoline, diesel, or natural gas vehicles, resulting in significant reductions in operational expenses. The operation mode of fixed locations enables it to plan routes in advance, conveniently replenish energy, and avoid mileage anxiety, making pure electric vehicles a better alternative. In recent years, many countries and regions around the world have begun to gradually convert commercial vehicles into pure electric vehicles. Taiyuan City, Shanxi Province, China replaced all 8,292 taxis in the main urban area with pure electric vehicles (BYD e6) at the end of 2016, becoming the first city in the world to achieve 100% electrification of taxis. Dubai, UAE took the lead in replacing taxis with Tesla pure electric vehicles in 2017, and received good feedback. The proportion of electric taxis in Shenzhen City, Guangdong Province, China have reached 98.57% in January 2019, which is more than 21,000 pure electric taxis. A world-renowned taxi-hailing application developer, Uber, began to popularize pure electric vehicles globally in 2017 by cooperating with automobile companies and subsidizing drivers. The United States, Norway, the United Kingdom, France, Canada, Germany, Japan and other countries has also begun to gradually replace fuel buses with pure electric buses. The rapid promotion of new-energy vehicles has led more and more companies to devote themselves to this promising field. Historically, automobile manufacturers and operating companies functioned as separate buyers and sellers, operating in isolation. The rise of intelligent network connectivity in new energy vehicles has empowered manufacturers to autonomously establish remote network systems for vehicle operation and management. E-hailing services have connected the two aspects of automobile production and operation. In recent years, original equipment manufacturers have independently established e-hailing companies. For example, CAO CAO Travel by Geely, Shouqi Car-hailing by BAIC, Xiangdao Travel by SAIC and other e-hailing brands. E-hailing platforms have broken the monopoly of taxis and benefited



consumers. In addition to that, vehicle manufacturers also cooperate deeply with car-hailing companies. In June 2018, 500 dolphin buses customized by Yinlong New Energy for Zhuhai were officially put into operation, where sales were only open to Didi-registered online car-hailing operators. In addition, BYD also produces customized pure electric buses for Japan, the United Kingdom, Israel, and other countries. In the future, more customized new-energy commercial vehicles will be put into the market. Technological and model innovations have propelled the new energy vehicle industry into a qualitative leap. This internal enhancement is crucial, especially in the era of carbon neutrality. Currently, the majority of global new energy vehicle companies have set up independent research and development systems for their products. It is imperative to remain committed to the path of innovation and drive the sustainable growth of the new energy vehicle sector.

### **3. Expanding the industrial scale, which is guided by with the market demand**

In the early stage of the development of the new-energy vehicle industry, due to immature technology and insufficient market research, some traditional fuel vehicle companies directly transformed existing fuel vehicles into new-energy vehicles in order to save costs and energy, and obtain subsidies at the same time. The most typical model is the “oil-to-electricity” model released by Volkswagen. Volkswagen has launched pure electric versions of fuel vehicles such as LaVida, Golf, and Bora. Fuel vehicles are typically designed considering the dimensions and features of their engines, including factors like volume, structure, and intake/exhaust systems. Consequently, they often feature a ventilated front face, a shorter wheelbase, and limited internal space. However, due to these constraints, accommodating a shorter wheelbase becomes challenging. The large-capacity battery and the ventilation intake grille affect the drag coefficient, both of which affect the range of pure electric vehicles to varying degrees, and the irregular arrangement will lead to unequal weight distribution at the front and rear of the vehicle and an imbalance in the center of gravity, which will affect driving experience. Moreover, unreasonable motor and battery layout will also cause safety problems. As a result, Volkswagen’s electric vehicles frequently encounter issues related to limited power output and short battery life. Other major automakers such as Toyota, Mercedes-Benz, BMW, and SAIC have introduced similar models, which all led to the same challenges and outcomes. The “oil-to-electricity” approach reflects traditional fuel vehicle manufacturers’ attempts to address the new energy vehicle market, which led to unsuccessful results. In contrast to the speculative “oil-to-electricity” approach favored by traditional fuel vehicle manufacturers, new energy vehicle companies are more inclined to adopt platform-based strategies, establishing dedicated platforms for their electric vehicles. Notably, companies like BYD, Great Wall, Geely, and Mercedes-Benz from the fuel vehicle sector have introduced their own exclusive platforms for new energy vehicles. This trend is also evident in pure electric vehicle manufacturers such as Tesla, NIO, Xpeng, and Ideal. As a trailblazer in the global new energy vehicle landscape, BYD has developed a comprehensive platform system, featuring the BNA architecture encompassing two key platforms: the DM platform and the e-platform. The DM (Dual Mode) platform is dedicated to hybrid models, forming the foundation for popular hybrid models like Tang DM, Song DM, and Qin DM. At the beginning of 2021, BYD launched a new DMI model, subdividing the DM platform into DMP models focusing on performance and DMI models focusing on energy saving; the e platform focuses on pure electric models, Tang EV, Song EV, Qin EV, Yuan EV, etc. The hot-selling pure electric models of the Dynasty series and e-network models such as e1 and e2 all come from this platform. At present, both DM platform and e-platform have developed to the third generation, namely DM 3.0 and e-platform 3.0, and BYD’s platform system has been gradually improving. In addition, NIO’s NT platform, Xpeng’s SEPA platform, Geely’s SEA’s vast architecture, Great Wall’s ME platform, and Mercedes-Benz’s EVA platform are all exclusively pure electric vehicle

platforms. Platform-based models typically exhibit characteristics such as a streamlined front face and an extended wheelbase for vehicles of the same category. These traits maximize the inherent benefits of pure electric vehicles, resulting in compelling products that are both market-competitive and well-aligned with consumer preferences. Notably, platform products have become the driving force behind the substantial sales of new energy vehicles in recent years. Looking ahead, adopting a platform-based approach is poised to become the primary strategy for new energy vehicle companies, enabling them to consistently broaden the industrial scope of new energy vehicles.

#### **4. Improving the industrial security system and the construction of related supporting facilities**

Since the development of the new-energy vehicle industry, the technical level and production quality of the product itself have been significantly improved, which is almost at par with fuel vehicles. New-energy vehicles even has great advantages in terms of acceleration performance, intelligent network connection, and noise, vibration, and harshness. This resulted in a rapid growth in the sales of new-energy vehicles. However, the development of modern industries is often a systematic chain development where all links are an indispensable part of the development system. Problems in any link will affect the development of the industry as a whole. Supporting industries are often ignored because its development generally has limited impact on the overall industry. One major hurdle is the lack of adequate charging and swapping facilities, which hampers the industry's growth. As global sales of new energy vehicles continue to rise, it is essential to tackle these challenges by considering several approaches.

##### **4. 1. Formulating relevant targeted plans and policies**

During the initial phase of the new energy automobile industry's development, various countries with major production and sales have implemented their own industrial plans and supportive policies. The industry's sales have surged due to a combination of these plans, policies, and its inherent growth. However, the lack of attention to supporting infrastructure by both governments and enterprises has also created potential challenges for the industry. The current situation of lagging development of charging and swapping facilities has made the governments of major producing and selling countries begin to pay attention to and formulate relevant plans and policies. In terms of infrastructure development, it's evident that supporting facilities hold the same significance as the vehicles themselves. While countries like the United Kingdom, Norway, and Japan have introduced plans for charging facilities, there's a notable absence of targeted plans or policies for new energy vehicle supporting infrastructure in many nations. As a result, the progress in constructing and enhancing charging and swapping networks remains quite constrained. The main production and sales countries of new energy vehicles should introduce plans and policies for supporting facilities as soon as possible, to solve problems such as parking difficulties, property difficulties, and fuel vehicles occupying charging spaces, and promote the construction of charging and swapping networks.

##### **4. 2. Speeding up the construction of charging and swapping networks**

Global public charging piles have grown rapidly in recent years. As of the end of 2020, the number of public charging piles in the world has exceeded 1 million, and the compound annual growth rate in the past seven years has reached 32%, far exceeding the growth rate of gas stations. The main reason is that the development of the fuel vehicle industry has been highly mature. The demand is currently close to saturation, but the increase in number of charging piles is still significantly lower than the annual growth rate of new energy vehicle sales. The vehicle-to-pile ratio of new energy vehicles has remained high in recent years. The current vehicle-to-pile ratio in major production and sales countries exceeds 5 : 1,

which has begun to restrict the popularization of new energy vehicles. Primarily, new energy vehicle companies are focusing on developing their own networks. Tesla, as a pioneer in charging infrastructure, stands at the forefront of global progress in network expansion. By the conclusion of 2020, Tesla had deployed over 20,000 supercharging stations worldwide, spanning across six continents. It is currently the world's largest single manufacturer charging network. BAIC, NIO, Xpeng, BMW, Porsche, and other companies are actively developing their own charging and swapping networks. BAIC and NIO, as enterprises mastering the technology of battery swapping, are also laying out the construction of swapping stations. In addition, power equipment companies such as State Grid and Telecom are also vigorously building a network of public charging piles. With the joint efforts of vehicle and power equipment manufacturers, the construction of the charging network has made great progress, but it still lags behind the sales growth of new energy vehicles<sup>[10]</sup>. In October 2021, the Ministry of Industry and Information Technology of China issued the "Notice on Launching the Pilot Program of the Application of New Energy Vehicle Battery Swap Mode" and decided to start the pilot work of the new-energy vehicle battery swap mode. The support of relevant policies will further accelerate the construction of the battery swap network.

#### **4.3. Improve the scrapping and recycling of power batteries**

After long-term use, the electrolyte activity of the power battery will weaken. The lifespan of an electric car battery is 4 – 6 years, and the lifespan of electric commercial vehicle is even lower, at only about 3 years. As the number of vehicles increases year by year, the number of scrapped power batteries for new energy vehicles will also increase sharply.

Toyota is the first company in the world to produce hybrid vehicles and has been in this field for a long time. Its nickel metal hydride battery recycling and processing system has been established as early as 1998. In 2009, Toyota began to establish recycling guidelines in countries selling hybrid vehicles. In 2010, Toyota extended the battery recycling agreement to ensure the hundred 100% recycling. In 2012, Toyota began to recycle rare earth materials for motors. In 2013, Toyota began to try the cascade utilization of Ni-MH batteries. Toyota's first established a recycling network, followed by evaluating recycled batteries to ascertain their characteristics. Subsequently, the processing methods were categorized into three types: cascade utilization, integration into the maintenance system, and dismantling. This approach refines batteries based on their specific situations, leading to a significant enhancement in battery utilization rates<sup>[11]</sup>. In recent times, companies such as Volkswagen, BMW, and GM have also initiated efforts to set up systems for recycling used batteries.

Reprocessing and re-selling scrapped batteries can not only save production costs, but also increase income. At the same time, it also solves the problem of unused scrapped power batteries in society, and realizes the recycling and sustainable utilization of resources in the entire industrial chain.

#### **5. Determining a suitable development path**

New energy vehicles have been promoted and popularized in more than 40 countries around the world, covering six continents. Nonetheless, the new energy vehicle industry's development scale, level, and trajectory vary, resulting in distinct strategies and paths. China, for instance, boasts an advanced new energy vehicle research and development prowess, coupled with relatively abundant domestic raw material resources catering to the needs of these vehicles. Plug-in electric vehicles and hydrogen fuel cell vehicles have been developing rapidly, covering a relatively complete range of models. The United States and Germany have developed new-energy vehicle technology, but there has been no development in the field of battery and hydrogen fuel cell vehicles, and the development of plug-in electric vehicles is the main focus. France is also yet to develop batteries and hydrogen fuel cell vehicles, with pure electric being the main

trend for development. Japan's battery industry is well developed, but due to the country's special terrain conditions and long-term insufficient power supply, only ordinary hybrid vehicles and hydrogen fuel cell vehicles have been developed, along with plug-in vehicles. South Korea's vehicle battery industry is also well-developed, but they entered the plug-in electric vehicle sector later. Consequently, Korea predominantly focuses on hydrogen fuel cell vehicles, with some pure electric vehicles. In contrast, countries like Norway, the United Kingdom, Sweden, the Netherlands, and others have relatively less robust new energy automobile manufacturing sectors. However, their emphasis lies in promoting and popularizing these vehicles, yielding impressive outcomes. On the other hand, emerging countries in the new energy automobile industry, such as Malaysia, Thailand, Singapore, Mexico, Australia, South Africa, and Brazil, have yet to formulate distinct development paths according to their own attributes, leading to slower industry growth<sup>[12]</sup>. The main production countries should continue to maintain and maximize their respective advantages, and develop sustainably according to their own characteristics; while emerging countries should find their own positions as soon as possible and formulate targeted development routes to achieve rapid development.

## **6. Strengthen coordination and cooperation to promote the common development of global industries**

Today's industrial collaboration includes not only collaboration with other external industries, but also intra-industry collaboration; only by optimizing the collaborative development mechanism within the industry can the internal development efficiency of the industry be improved. The current development among regions and industrial chains is uncoordinated, which need to be solved from two aspects.

### **6.1. Regional coordinated development**

The new-energy vehicle industry has experienced rapid growth in recent years, yet it still lacks a cohesive and unified development model. Even though large regional cooperation organizations such as the European Union and ASEAN have issued relevant plans and policies to promote the joint development of the new-energy vehicle industry, due to great differences in politics, economy, and culture in various countries, the level of industrial development is still not the same. Furthermore, the level of industrial specialization within integrated cooperation organizations is relatively low, leading to challenges in formulating specific measures for driving industrial development. As a result, the implementation of plans and policies often faces limitations and lacks impactful outcomes. Although major production countries such as China-Germany, the United States-EU, and Japan-South Korea have established new-energy vehicle industry development alliances, the scope of influence is small, and in the end they still cannot effectively promote the sustained and rapid development of the global industry<sup>[13]</sup>.

The new energy vehicle industry should actively respond to this situation. There has been no professional new-energy vehicle industry cooperation organization in the world. The main production and sales countries should take the lead in planning and establishing global industrial cooperation organizations such as industry alliances and cooperation forums to strengthen international cooperation and promote the common development of new-energy automobile industries in all countries. New-energy vehicle production and sales countries such as China, the United States, Germany and other countries should play a leading role in their respective continents, take the lead in establishing inter-regional new energy vehicle industry integration cooperation organizations, and promote the development of regional new energy vehicle industries.

### **6.2. Coordinated development of industry chain**

The disconnection and fragmentation of the industrial chain has continued to hinder the development of the



global new-energy automobile industry in recent years, and there have even been serious consequences in which upstream and downstream supply problems have led to the suspension of production of related companies. The reason is that all parties in the industrial chain develop independently and lack coordination, and one party may benefit temporarily, but in the long run, it is the industry as a whole that is ultimately damaged. In recent years, new-energy vehicle industries around the world have begun to realize this problem, and various companies have gradually strengthened their collaborative development through industrial chain cooperation, shareholding, and acquisitions: CATL, LG, Panasonic, and other battery companies have established a solid cooperative relationship with a number of new-energy vehicle companies to break through the industrial chain barriers between autopart companies and vehicle companies. The deep cooperation between German Volkswagen, BMW, Mercedes-Benz and other vehicle companies and Bosch, ZF, Continental, and other autopart companies in the field of new-energy vehicles has promoted the rapid development of the country's new energy vehicle industry. BYD has become the world's first enterprise that integrated battery with new-energy vehicle manufacturing<sup>[14]</sup>. Lithium product giants such as Tianqi Lithium Industry and Ganfeng Lithium Industry have successively acquired large lithium mines around the world and started to independently develop batteries. The global new energy automobile industry is gradually maturing through the coordinated development of the industrial chain, and an integrated model of the entire industrial chain might appear in the near future.

## Disclosure statement

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# Application and Research of 5G Communication Technology in Intelligent Coal Mine

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**Abstract:** In recent years, science and technology in China has been developing rapidly, and various industries have begun to undergo changes due to the development. Coal mining is a highly dangerous industry. Therefore, proper technology is needed to improve the quality and safety of coal mining. The application of 5G communication technology allowed for the development of intelligent coal mines, with broad application prospects and research value. This article aims to thoroughly analyze the application of 5G communication technology in intelligent coal mines, considering the practical context. The goal is to offer insights and guidance for future endeavors in this domain.

**Keywords:** 5G communication technology; Intelligent coal mine; Application

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## 1. General introduction

After the “Guiding Opinions on Accelerating the Intelligent Development of Coal Mine” was put forward in 2020, the domestic coal mining industry has actively developed new technologies to build intelligent coal mines. As one of the important industries in China, coal mining can provide sufficient power for social production. In order to improve the quality and efficiency of mining, coal mining enterprises must make full use of 5G communication technology. Therefore, it is necessary to analyze the application of 5G communication technology in intelligent coal mines.

## 2. Introduction to 5G communication technology

5G is the fifth-generation mobile communication technology, featuring high speed, low latency, and wide connection. The International Telecommunication Union has defined three major applications of 5G: enhanced mobile broadband, ultra-high reliability and low-latency communication, and massive machine-type communication<sup>[1]</sup>. Among these, enhanced mobile broadband addresses the significant surge in mobile internet traffic, ensuring a seamless user experience. Ultra-high reliability and low-latency communication are crucial for applications like industrial control, telemedicine, and autonomous driving, where reliability and minimal delays are critical. Mass machine communication targets smart city development, environmental monitoring, and smart home systems, catering to the needs of data sensing and acquisition. The three aforementioned application scenarios collectively constitute the realm of 5G communication technology. Given the prevailing societal trends, 5G technology has been extensively

adopted across various sectors, showcasing strong application value and promising developmental opportunities.

### **3. The necessity of applying 5G technology in the intelligentization of coal mines**

The application of 5G communication technology marks that our society has entered a new stage. The intelligent construction of coal mines is in line with the development trend of the times and the objective needs of industry development. Its necessity is mainly reflected in several aspects: firstly, the application of 5G communication technology is in line with the construction of intelligent coal mines. This technology facilitates the realization of Internet of Things (IoT) sensing, information integration, smart control, and comprehensive management, significantly enhancing the safety and efficiency of coal mining operations. Moreover, it mitigates the hazards associated with manual labor, thereby reducing the potential risks incurred during mining activities. With 5G technology, the degree of intelligence of coal mines will be greatly improved, and the process of intelligent development will be accelerated<sup>[2]</sup>. Second, it can effectively control the cost of the enterprise. The application of 5G technology can to replace manual operations by integrating different equipment and machinery, thus improving mining efficiency and quality. Unlike manual operations, mechanical equipment and the application of advanced technology can realize 24 h operation, and only requires monitoring staff, thus reducing manpower and overall cost, and improving production efficiency. Third, the application of 5G technology can greatly improve the safety of coal mining. Since coal mining is usually done underground, mining personnel often need to face a more complex environment, making them prone to safety accidents. In view of this, 5G technology can realize the effective monitoring of the mining environment of underground coal mines. Once a problem occurs, an alarm can be issued in time, thereby avoiding risks, improving mining safety, reducing economic losses of coal mining enterprises, and generating more profit.

### **4. The application strategy of 5G technology in the intelligentization of coal mines**

#### **4.1. Virtual interaction based on 5G technology**

In 3 D modeling, the application of 5G technology can be used for virtual presentation, which improves the intelligence of coal mines. In the past, human-computer interaction was the main mode. This mode has certain limitations. Managers cannot directly obtain relevant data information, which affects the effectiveness of coal mining operations<sup>[3]</sup>. 5G technology can realize 3 D modeling and virtual presentation. Based on the visual design, managers can understand various information and equipment locations under the mine more intuitively, and various processes such as cloud real-time rendering and hybrid implementation can also be performed, improving the effectiveness of human-computer interaction. This ensures streamlined, accurate, and efficient information transmission, greatly benefiting operators. Precise positioning and data enable systematic management and control of mechanical equipment, thereby promoting standardized operations and optimizing mining efficiency.

#### **4.2. Precise positioning**

Traditional coal mine underground positioning is performed using ultra-bandwidth transmission and Bluetooth, but it is difficult to achieve accurate positioning through these methods. When the infrastructure is not well positioned, the effectiveness of coal mining will be affected<sup>[4]</sup>. The application of 5G technology can greatly improve positioning accuracy and avoid the above problems. It involves the comprehensive collection of diverse data produced during coal mining and production via extensive network coverage. Subsequently, this information is relayed to the control center, ensuring both timeliness and



efficacy while delivering more precise and comprehensive data support. Evidently, 5G's low latency emerges as a primary developmental focal point. This attribute facilitates improved network positioning and the expansion of application services. Accurate and autonomous positioning of mechanical equipment not only enhances its operation but also facilitates dynamic data feedback, which, in turn, supports informed decision-making for effective deployment planning. This contributes to the overall scientific efficiency of deployment strategies.

#### **4. 3. Collaborative operation & maintenance based on 5G technology**

Through the analysis of the application of 5G technology, it is not difficult to see that the remote collaborative operation and maintenance of mines belongs to the scenario of mobile network communication technology<sup>[5]</sup>. Since coal mining is usually carried out in an underground environment, the mining space is small and unique. In view of the continuous shrinking of the mine space, it is necessary to upgrade, install, and transform the intelligent system. Traditional manual maintenance methods alone will not be sufficient. The establishment of a dedicated remote system is crucial to facilitate seamless collaboration between manual and remote commands, thereby enhancing the overall efficiency of operation and maintenance processes. Leveraging 5G technology for comprehensive data collection from the mine, encompassing audio, video, parameters, and more, allows for real-time data transmission. This data can then be utilized by intelligent equipment to ensure the development of robust virtual operation models or systems, providing a solid foundation for effective implementation. With virtual reality, coal miners and managers can cooperate better, and the need for manual maintenance will be reduced, thus reducing personnel cost investment and reducing the safety risks of miners<sup>[6]</sup>.

#### **4. 4. Mobile edge computing based on 5G technology**

Mobile edge technology's advancement predominantly relies on the utilization of IT service environments and computational capabilities to cater to end-user needs. These dual functions will serve as efficient tools to facilitate user engagement with mobile nodes, resulting in reduced latency and an elevated user experience<sup>[7]</sup>. By applying 5G network mobile edge computing science to the construction of intelligent mines, it can be reflected in various scenarios of the IoT, and then according to the needs of intelligent management and control, it will be analyzed with reference to mine scenarios to optimize the design of the scheme to ensure the application effectiveness of the technology<sup>[8]</sup>. The construction of mines needs to be analyzed based on the actual needs of intelligent coal mine construction. Cloud-edge collaboration technology should be used to improve mobile edge computing, so that the overall scientific research can be greatly improved. In addition, 5G technology can also be applied in the construction of a multi-layer intelligent framework, which can effectively promote the integrated development of cloud computing and edge computing, and the effectiveness of collaborative processing has been greatly improved. It is necessary to ensure all-round coverage, scientifically use artificial intelligence and deep-learning algorithms, cooperate with 5G technology, strengthen the operating environment perception of multiple types and multiple devices, ensure the accuracy of data collection, and speed up the process of information transmission. With the effective application of 5G technology, delays in the calculation process can be reduced. In case of an emergency or unforeseen situation during the underground coal mining process, the equipment hosting system can be initiated promptly to gather and analyze data. Subsequently, algorithms can be enhanced based on the situation, effectively elevating the level of intelligence.

#### **4. 5. Monitoring technology based on 5G technology**

5G technology is essential for safety monitoring in the construction of intelligent coal mines. Using 5G

technology, some dangerous areas can be better detected. In order to improve the effectiveness of environmental monitoring, it is necessary to install a large number of sensors on underground mining vehicles and equipment. While undertaking the installation process, it is crucial to focus on achieving low cost, solid stability, and minimal energy consumption. Besides, maintaining strong connectivity with the communication transmission network is essential to enhance transmission speed and ensure real-time performance. The 5G wireless communication system's low power consumption and large connection scenario can control the terminal delay within 1 ms, and the connection density can reach  $10^6/\text{km}^2$ , fully meeting the needs of the mine safety monitoring information collection<sup>[9]</sup>.

#### **4. 6. Safe driving of mine vehicles**

Under 5G technology and IoT, trackless auxiliary vehicle long-distance data communication and mobile base station layout technology have achieved better application, making full use of the existing dispatch management platform, while integrating high-performance, low-cost sensors and wireless communication equipment. This integrated approach significantly enhances the platform's performance, enabling more efficient execution of scheduling, identification, and management tasks.<sup>[10]</sup> With the support of many technologies, the communication needs of underground vehicles in coal mines can be greatly met. Together with the wide area network terminal, the operating data of all vehicles can be collected and uploaded to the cloud, providing accurate data support for coal mining and vehicle driving<sup>[11]</sup>. In addition, 5G technology, edge computing, and self-driving technology can improve the automation of personnel and material transportation, reduce the number of human resources required for underground operations, improve the effectiveness of auxiliary transportation, and realize automatic operations. Besides, the dispatching system will also be more efficient. Intelligentization and automation of transportation equipment makes coal mining easier, ensuring that the entire operation is realized under effective supervision to achieve automated operations and production.

#### **4. 7. Remote real-time control**

Remote real-time control is also a technique that emerged under 5G technology, which meets the needs of intelligent mine construction. Production control is especially important for the development of coal mining enterprises. Moreover, coal mining itself is a dynamic process, which requires dynamic control of underground conditions and monitoring. Therefore, real-time control is required to ensure mining efficiency and safety, which necessitates the application of this technology. In the traditional mode, remote control is done through routers, network protocols, and sensors. Although this method achieves its purpose, it actually has low transmission efficiency and limited real-time transmission, along with other problems, which greatly limit the effectiveness of coal mining<sup>[12]</sup>. Using 5G technology, combined with the specific coal mine space structure and operation needs, etc., set up a real-time remote monitoring system and organizational structure, complete the comprehensive and dynamic monitoring of the mine, and develop a professional control module to ensure the effectiveness of remote control. All control tasks will be presented in the form of menus to provide adequate protection for underground operators<sup>[13]</sup>.

### **5. The development prospect of 5G technology in the intelligentization of coal mines**

On the whole, there are still some limitations in the application of 5G communication technology in the construction of intelligent mines. It is believed that with the development of science and technology, its application will be more extensive in the future, making coal mining easier<sup>[14]</sup>. Specifically, its future development trend includes the following aspects: first, the network is fully covered. Within the scope of intelligent mines, all skeleton networks will be covered in the form of 5G, which improves transmission

efficiency while ensuring normal underground communication and eliminate the limitations of traditional optical fiber network. Secondly, it can be arranged according to the actual working conditions in the mine, and the 5G micro base station can be scientifically adjusted to improve the utilization of resources, help coal mining enterprises save resources, reduce costs, and create higher economic value. Third, on-site analysis should be carried out according to the needs of underground coal mining to realize personalized development and ensure scientific and reasonable technology application. The existing transmission platform can serve as the foundation for establishing an integrated platform mechanism that aligns various scenarios with platforms. This approach not only facilitates real-time transmission but also enhances perception capabilities. This trend represents a significant trajectory for future 5G technology applications. Its application in mining construction contributes to achieving true visualized and intelligent mining operations, thus underpinning the enhancement of coal mining's quality and efficiency.<sup>[15]</sup>.

## 6. Conclusion

To sum up, in order to better meet the needs of social production, the quality, efficiency and safety of coal mining must be improved. The construction of intelligent coal mines has been increasingly highlighted after the state promulgated relevant policies, and the application of 5G technology has accelerated its construction. The application of 5G technology will be more extensive in the future. While achieving full coverage, it can also analyze the scene under the mine, and realize the integration of various technologies. The problems of transmission and perception can also be improved, which in turn promotes the development of the mining industry. The degree of intelligence lays the foundation for the continuous operation of coal mining.

## Disclosure statement

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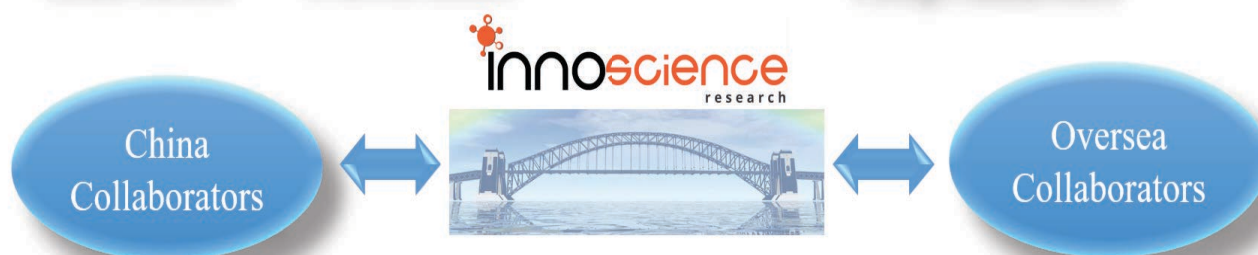
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