Computer Communications 149 (2020) 332–342

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

Research on the application of block chain big data platform in the construction of new smart city for low carbon emission and green environment

Minglin Sun [a], Jian Zhang [b,c,*]

[a] School of Management, Jilin University, China
[b] School of Economics and Management, Chongqing University of Arts and Sciences, China
[c] Chongqing Vocational College of Transportation, China

A R T I C L E I N F O

Keywords:
Block chain
PKI/CA
New smart city
Government information

A B S T R A C T

The sharing of government information resources is significant for improving the level of governance and social information. However, due to the existence of cross-domain security and trust islands, government departments are hindering the sharing of government information resources with other organizations and the public. To this end, the blockchain technology is used to construct a decentralized distributed peer-to-peer trust service system, which is integrated with the existing PKI/CA security system to establish a new trust model that supports multi-CA coexistence. Based on this, the structural composition and functional data flow of the blockchain smart city information resource sharing and exchange model designed in this paper. This paper launched a study on the role of the smart big data platform, and selected the development of smart cities in Hefei as an empirical analysis. From the connotation of smart city, block chain and big data technology combined, and the positive effects of relevant information technology summarized on the construction of smart city big data platform. Based on this, the smart city development level evaluation model of TOPSIS method constructed. The evaluation model constructed to make a vertical comparison from 2012 to 2017, the scale of smart cities is growing at an average annual rate of more than 30%, saving 20% of urban resource allocation and becoming a new pillar industry. Therefore, Hefei City should further increase environmental supervision and promote the use of low-carbon environmental protection new energy. The improvement of government management level has a positive effect on the construction of smart Hefei.

1. Introduction

The smart city was first proposed by the United States in 1990. Urban construction is labeled as the new theme of the “Sapiential Cities”. People want to use wisdom to find the best solution for urban planning. Smart city uses data technology to improve people’s livelihood issues such as transportation, housing, government public services, education and medical care through smart response. Nearly 300 cities in China have successively launched pilot projects for smart city construction. This effectively improved the level of public services, improved management capabilities, and promoted urban economic development [1–5]. This promotes the evolution of cities in the traditional sense to smart cities. Under the background of the “Thirteenth Five-Year Plan”, the development of smart cities has entered a new stage and has been raised to the height of national strategy. It has been given a heavy historical mission in the context of the rapid development of urbanization. Smart cities have become a new direction for future urban development. Smart cities have made achievements in e-government, green ecology, and smart transportation.

At present, scholars at home and abroad have carried out in-depth research and combining on the existing security and trust issues, security assurance mechanisms, sharing models, technical methods and models around the sharing of government information resources in smart cities [5–9], and proposed a unified information resource for smart cities. Library model [10], collaborative model of information resource sharing subsystem and business subsystem [11], ERP integrated government information resource integration model [12], e-government information resource integration model [13], government information resources based on network knowledge Integration framework model [14] and cloud government information sharing model [15]. These models have different characteristics, advantages and disadvantages, and also have different application scenarios. However, in the practice of sharing and publicizing information resources in smart cities, mutual trust difficulties, weak privacy protection, high

* Corresponding author at: School of Economics and Management, Chongqing University of Arts and Sciences, China.
E-mail address: m18686527660zj@163.com (J. Zhang).

https://doi.org/10.1016/j.comcom.2019.10.031
Received 28 August 2019; Received in revised form 24 October 2019; Accepted 26 October 2019
Available online 31 October 2019

data security risks, low efficiency, untimely exchange, inconsistent data, difficult business collaboration, poor data traceability and information sharing still exist. The difficulty of wide-ranging and other difficulties has made the sharing of information resources in smart cities face enormous challenges and risks. It has become the key to urgently need to be solved in the current research and application of government information resources sharing and openness. The main construction goal of smart cities is to use information technology to sense, transmit, integrate and analyze key information of the core system of urban operation, to realize urban intelligence. In terms of urban governance, big data can realize efficient, secure, and shared exchange of various types of data, and block chain technology can provide a better solution. Big data technology and block chain technology serve as two separate Internet technologies. Block chain is a form of informationless interaction [6,7]. It packages and stores various types of data in the form of blocks. This essentially enables information to be provided and shared data. The block chain has the characteristics of decentralization, trust mechanism, shared ledger and information traceability characteristics, which can effectively help new city data sharing. In addition, data openness is not only conducive to the construction of transparent government and service-oriented government, but also encourages innovation and creates new business value and employment opportunities.

Through open data, the government can increase public participation in public management and improve its public management and service levels. Therefore, the role of the block chain big data platform in the construction of new smart cities is irreplaceable. This paper will analyze the role of the platform in the construction of smart cities and conduct empirical analysis. Therefore, based on the blockchain technology, this paper has the advantages and characteristics of decentralization, security, trustworthiness, tamper resistance and traceability [16]. At home and abroad, relevant scholars discuss the application of blockchain technology in the field of e-government. A framework model for the sharing of government information resources based on blockchain is constructed. This paper includes the following parts: Firstly, through the combining of the literature, the domestic and foreign research status and theoretical application value of blockchain technology applied to smart city information resource sharing are expounded. Secondly, the smart city information resource sharing based on blockchain technology is discussed. Finally, the blockchain ecosystem of smart city information sharing is expounded to further solve the trust island, data ownership and peer management, standards existing in smart city information sharing and exchange. Issues such as consistency control and non-real-time exchange provide new implementation paths.

2. Related theoretical research and work

2.1. The role of block chain in the construction of smart cities

Block chain technology is a new form of data and service organization that has emerged in recent years. The safe operation of the block chain itself supports the operation of many fields, which forms a hyperactive scale ecosystem. Block chain technology encrypts and directly trades all types of data, creating a new data credit system [11]. More and more scholars are devoted to exploring how to apply the principle of block chain technology to the construction of government big data platform to build a modern smart city. It uses its decentralized approach to distribute the government big data platform in a distributed manner, and the centrally deployed servers and storage devices are distributed to the service nodes. In this way, the block chain architecture in Fig. 1 can be basically divided into three layers: the base layer, the driver layer, and the application layer.

The purpose of building a smart city is to use the new technology and new organizational forms to create greater value for the society, and to promote government efficiency, community autonomy, and social collaboration. From this perspective, the application of block chain technology in the construction of smart cities is the inevitable development of technology. The application of intelligent contracts based on block chain technology has further liberated the creativity of the big data open platform. Big data is the technical foundation of a smart city [12]. In addition, large-scale data collection, data storage, and data computing are the foundation of big data. Big data realizes the disclosure, sharing and reuse of smart city data information in cyberspace. The smart data city's big data platform involves all aspects of the system, as shown in Fig. 2.

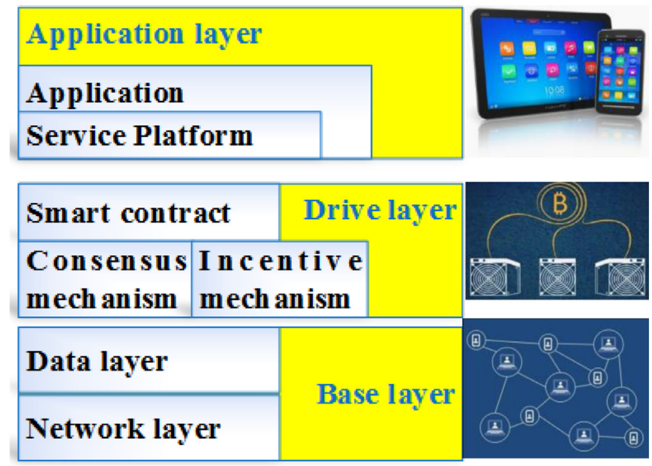

Fig. 1. Block chain hierarchy.

The data concentration and opening of smart cities has long been due to the opening of government data. The government has proactively disclosed all kinds of databases it has to all the public to promote the transparency of government work. The openness of data is not only conducive to the construction of transparent government and service-oriented government, but also encourages innovation and creates new business value and employment opportunities [13,14]. This can increase public participation in public management, thereby improving public management and service levels. The organic integration of such data and services promotes the healthy and sustainable development of smart cities.

2.2. The convergence of blockchain technology and big data

The application of block chain technology can solve various problems of existing big data centers on the smart city big data open platform. The block city-based smart city open big data platform consists of a block chain network, a regulatory access service, a data participant service, a data source, and an operator. Among them, the block chain node network adopts the alliance chain technology. The alliance chain is a special form of block chain network [15]. It is characterized by node admission and privilege grading, and adopts consensus algorithms such as DPOS (delegated proof of stake) or PBFT (practical Byzantine fault-tolerance algorithm). Different from the public chain and POW consensus mechanism, the participating nodes of the alliance chain are strictly controlled by the supervisory server. Only block-accepted nodes can get block chain data. The benefits of doing so are twofold [17,18]. On the one hand, it is better to maintain system privacy. On the other hand, an efficient data synchronization algorithm has significantly improved the throughput and storage efficiency of the system.

The providers and users of the data include government agencies, enterprises, individuals, and the like. Take the smart transportation service as an example. An excellent smart transportation service needs to use road congestion information, vehicle distribution information,

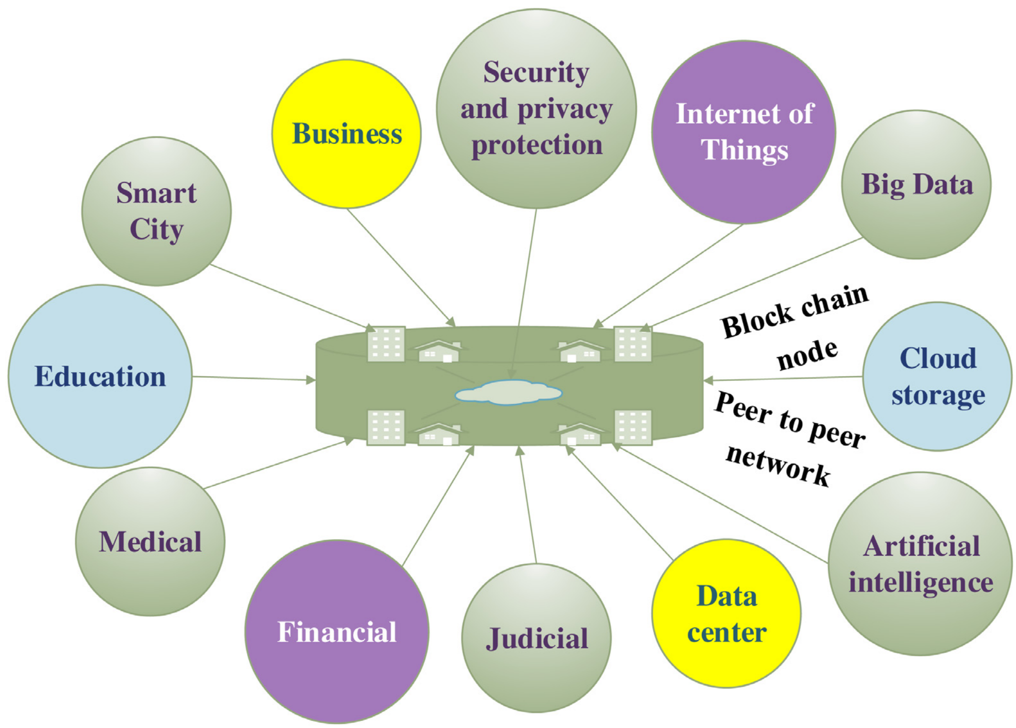

Fig. 2. Block chain ecology.

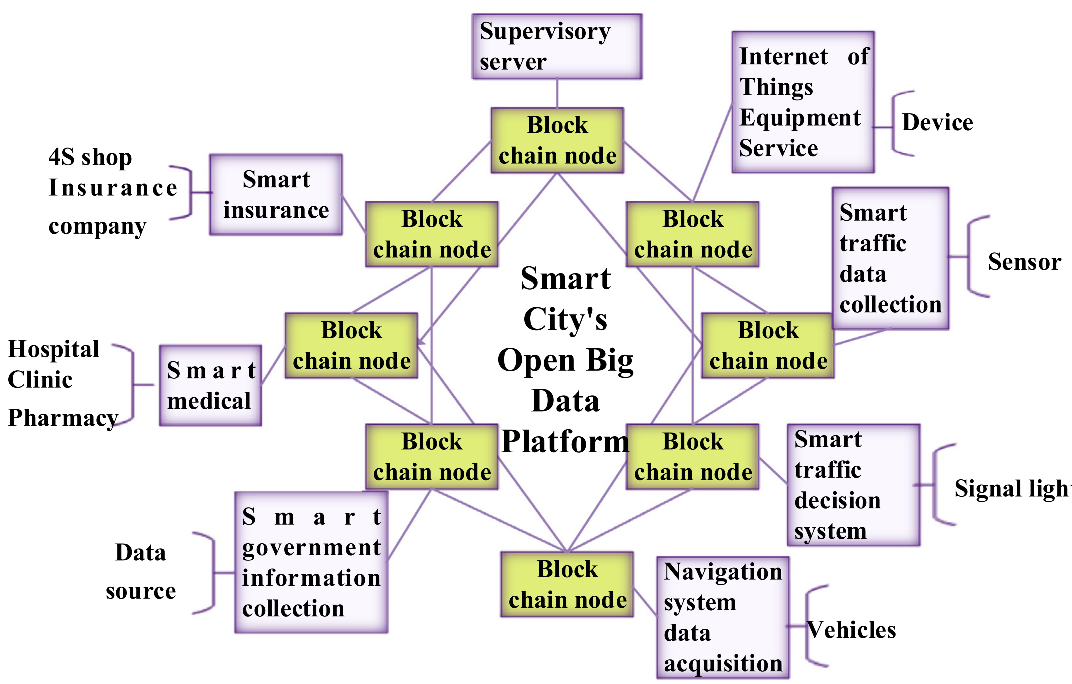

Fig. 3. Open big data platform structure constructed by block-chain.

weather information, road control information, and so on. (In Fig. 3) So much information is scattered among the many participants. These information data are processed by each service provider. The platform submitted through the block chain node. The necessary data provided for the system [19]. The actuator is the part of the operation after comprehensive analysis of the data. They include specific or abstract operations such as signal lights, insurance approvals, and loan credits. It can be seen that there are not many parts of the entire system responsible for the government. This includes only a single block chain node and a regulatory access department. The former is used to define rules and the latter is used to limit access and regulation. The various parties provide the rest. This increases the efficiency of the system and saves costs.

2.3. Block chain data junction

(1) Block chain pole

A block is all information packed by a blockchain network within a fixed time period. Each block on the chain contains two parts, the

Table 1
Block field details.

	Section	Description	Size
Part 1	Block size	The block size of this field	4
Part 2	Version	Software and protocol updates	4
	Time	Time average of each node	4
	Bit	Difficult target time	4
	Nonce	Counter	4
	Hashblock	Hash value	64
Part 3	Number of transactions	Total number of transactions	10
	Record of transactions	Transaction details	To be determined

block loss, and the block body. The block misses the version number, the hash value of the previous block, the root value of the Merkle tree, the difficulty value, and the random number. The field descriptions of the body are shown in Table 1. The block body is sealed with all transaction data for a period of time. These transaction data organized by the Merkle tree. The leaves of a Merkle tree are the hash values of data blocks (for example, a collection of files or files). A non-leaf node is a hash of its corresponding child node concatenated string. See Fig. 4 for details.

(2) Merkle tree

The Merkle tree was proposed by Ralph Merkle, which uses data hashing to create a recursive tree-shaped knot. In Bitcoin, each transaction is converted into a hash value by hashing as the leaf node of the Merkle tree, and the parent node of the Merkle tree is hashed by the hash values of two or more child nodes. The Proof of work algorithm refers to the "Hash Now" proposed by Adam Back. The purpose is to pay a certain amount of power to suppress the spam problem when sending mail. What is not uncommon is that in Bitcoin, PoW combines the receipt of electronic money with the consensus of each node. The principle of PoW is mainly that each node in the distributed system solves a problem through its own computing power. The first node that calculates the answer to the problem and obtains the system reward through the node verified by the military node (that is, the system receives the electronic money) [16]. Each node continuously tries to use the random number Nonce, so that the block hash value is less than or equal to the target hash value. If you are unable to get a qualifying Nonce for a long time, change the block time until you find the appropriate Nonce. The algorithmic flow of the body is shown in Fig. 5.

3. The construction of a smart city construction model

3.1. The requirements for smart city based on blockchain technology

As a distributed data storage platform, the block chain system is only the primary application of block chain technology, which can meet the basic needs of smart cities. Smart cities also need to use big data platforms to combine these collected data to create new value. As the rule maker and executive supervisor, the government provides a platform for smart city participants to play the role and value of big data. On the one hand, each participant can obtain a large amount of data to reduce costs and improve service quality [20]. On the other hand, they also have enough motivation to share their data to serve smart cities. Based on the TOPSIS method, we constructed a model to verify the development level of smart cities. We obtained data on smart cities in Hefei through literature review, and analyzed the role of big data platforms in the smart city process in Hefei. The entropy method objectively gives weight to the evaluation indicators. It determines the weight of each indicator by the magnitude of the indicator observations [21]. The standardization of this paper is processed by the extreme value method, which is divided into positive index and reverse index. The specific methods are as follows:

Positive indicator

$$X'_{ij} = \frac{X_{ij} - \min(X_{1j}, X_{2j}, \dots, X_{nj})}{\max(X_{1j}, X_{2j}, \dots, X_{nj}) - \min(X_{1j}, X_{2j}, \dots, X_{nj})} + 1,$$
$$i = 1, 2, \dots, n;\ j = 1, 2, \dots, m \tag{1}$$

Reverse index

$$X'_{ij} = \frac{\max(X_{1j}, X_{2j}, \dots, X_{nj}) - X_{ij}}{\max(X_{1j}, X_{2j}, \dots, X_{nj}) - \min(X_{1j}, X_{2j}, \dots, X_{nj})} + 1,$$
$$i = 1, 2, \dots, n;\ j = 1, 2, \dots, m \tag{2}$$

The calculation formula for calculating the proportion of the indicator-I in the area-J is as follows

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \qquad (i = 1, 2 \dots \mathrm{n},\ j = 1, 2, \dots, m) \tag{3}$$

$$E_{ij} = {}^{1}/_{\ln m} * \left(\sum_{i=1}^{m} P_{ij} \ln P_{ij}\right), \quad i = 1, 2 \dots \mathrm{n}, \quad j = 1, 2 \dots m \tag{4}$$

$$D_{ij} = 1 - E_{ij}, i = 1, 2 \dots \mathrm{n}, \quad j = 1, 2 \dots m \tag{5}$$

$$W_{ij} = \frac{D_{ij}}{\sum_{j=1}^{m} D_{ij}}, \quad i = 1, 2 \dots \mathrm{n}, \quad j = 1, 2 \dots m \tag{6}$$

TOPSIS is a multi-attribute decision making method. It mainly conducts multi-objective evaluation and decision analysis for limited programs. Hwang and Yoon proposed it in 1981, which can also be called the sorting method that approximates the ideal solution. This evaluation method ranks the schemes according to the closeness of the evaluation scheme with the positive and negative ideal solutions.

Determine the formula for positive and negative ideal solutions.

$$V_j^* = \max_i(V_{ij}) \tag{7}$$

$$V_j^{\nabla} = \min_i(V_{ij}) \tag{8}$$

Calculate the Euclidean distance.

$$S_{\mathrm{i}}^* = \sqrt{\sum_{j-1}^{\mathrm{m}} (V_{ij} - V_j^*)^2}, i = 1, 2, \dots, n, j = 1, 2, \dots, m \tag{9}$$

$$S_{\mathrm{j}}^{\nabla} = \sqrt{\sum_{j-1}^{m} (V_{ij} - V_j^{\nabla})^2}, i = 1, 2, \dots \mathrm{n}, j = 1, 2, \dots \mathrm{m} \tag{10}$$

Calculate the closeness C value of each object to the ideal solution.

$$\mathrm{C_i} = \frac{\mathrm{S_i}^{\nabla}}{\mathrm{S_i}^* + \mathrm{S_i}^{\nabla}} \tag{11}$$

C_{i} is between 0 and 1, and the larger the value, the higher the level of development of smart cities in the year. The smaller the C value, the lower the level of development of smart cities in the year.

3.2. Block architecture-based smart city overall architecture model

The collaborative sharing of smart city basic information breaks the segmentation and realizes the effective cooperation and sharing of the bar data between the bar departments. At the same time, it needs to realize the peer management of different stakeholders and promote the flattening of the organizational structure of government departments. Government governance and public services are transparent, efficient and intelligent, while ensuring the security of government data, thus shaping a new social credit system. The blockchain establishes mutual trust relationship through P2P distributed peer-to-peer network, time-insensitive cryptographic books and distributed consensus mechanism, and uses intelligent scripts composed of automated scripts to program and manipulate data, ultimately achieving information connectivity to value. The evolution of the Internet. Therefore, relying on multiple

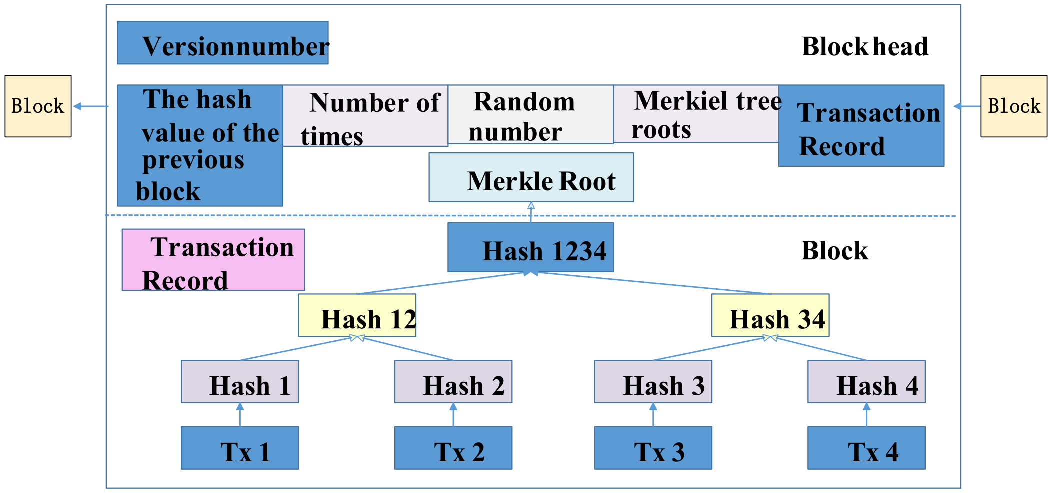

Fig. 4. Open big data platform structure constructed by block-chain.

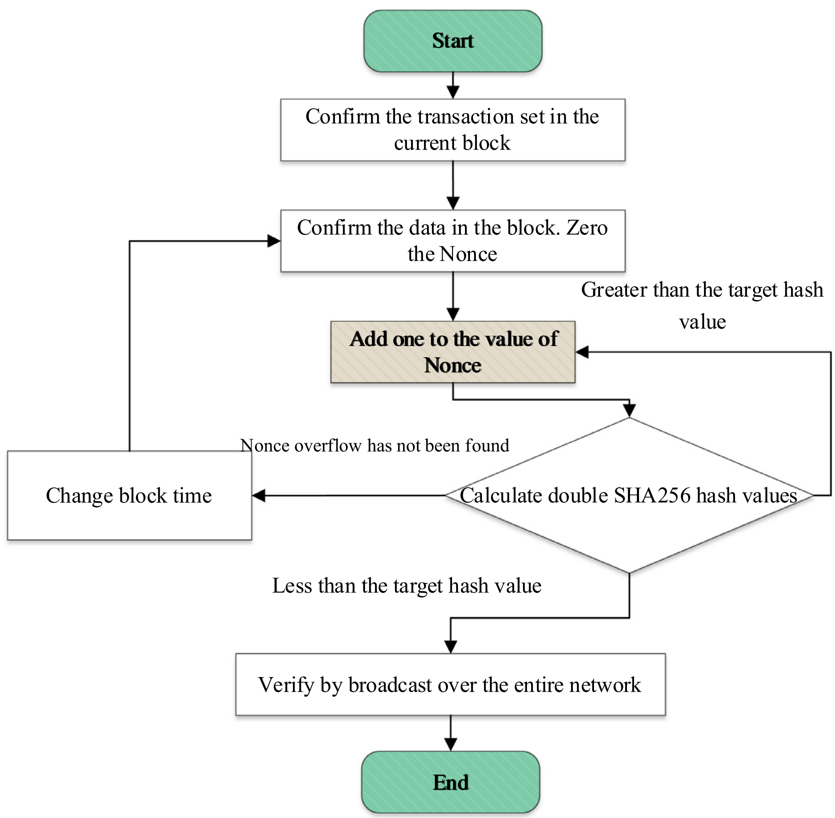

Fig. 5. Open big data platform structure constructed by block-chain.

value chains (public chain, private chain, alliance chain), a blockchain government information sharing model that can be dynamically expanded, managed, controlled, and open services is constructed (see Fig. 6).

In the blockchain smart city resource sharing and exchange model, there are two main roles: data producers and data consumers, including business centers of various government departments such as finance, taxation, civil affairs, health, education, public security, etc. Institutions, businesses, the public, and non-profit organizations. Logically, data producers and consumers form a blockchain network of multiple types of chains. Each chain consists of different nodes that maintain various types of entity information, such as data generated by ordinary citizens, enterprises, government agencies, etc., and the data of different chains are isolated from each other [22]. The logical architecture of the smart city resource sharing and exchange model based on blockchain is mainly divided into network layer, blockchain infrastructure layer and business application layer. Based on the 3-layer model, five service support systems are formed, namely: P2P network service system, shared BNS service system, shared blockchain directory service system, shared intelligent exchange service system, and authentication and trust service system.

3.3. Smart city business collaborative process based on blockchain

In the traditional mode of government information sharing, a large amount of data between government functions is repeatedly collected,

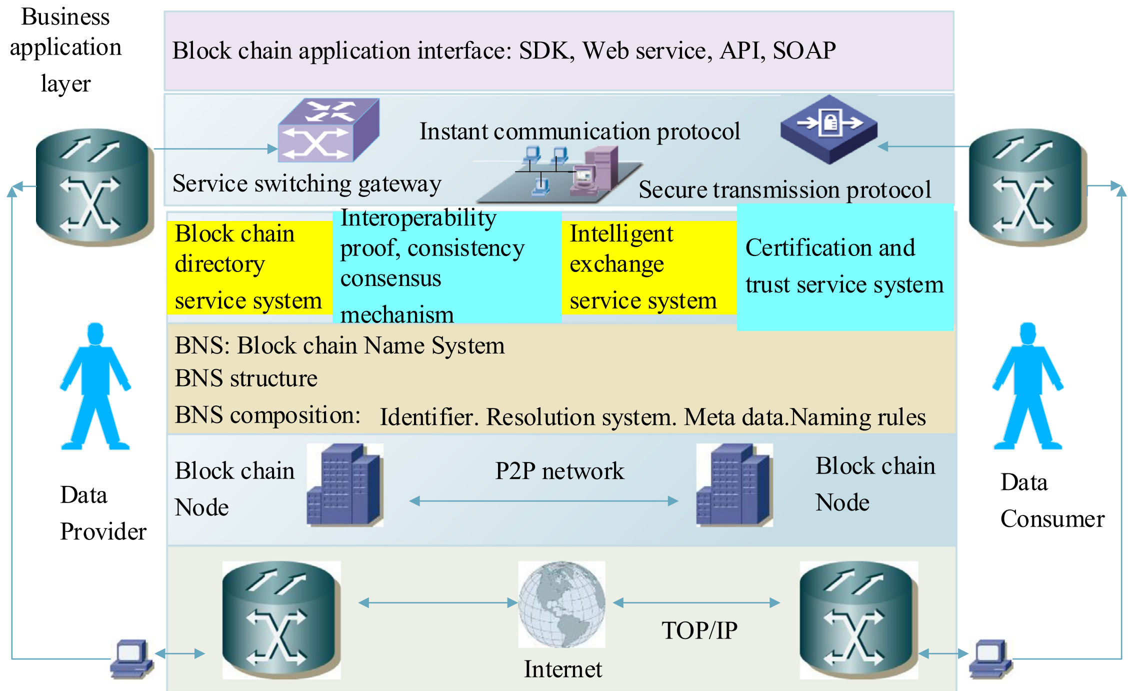

Fig. 6. Resource sharing and exchange model of blockchain in smart city.

re-processed and maintained; different functional departments have different definitions of the same data syntax and semantics, lacking the necessary communication and data exchange mechanism. There is an inconsistency between the same data. Therefore, in a system based on blockchain-based smart city resource sharing and exchange, institutions can establish a network of mutual communication. The consensus mechanism of blockchain and block data exchange can already carry transactions between institutions, but with the gradual enrichment of business scenarios, more requirements are put forward for "interoperability". In the business process, interoperability proves that the standard consistency incentive and constraint mechanism is achieved, thus achieving network consensus, which aims to effectively promote data interoperability and avoid unnecessary power consumption. Finally, the process of inspection, verification and preservation is automatically performed through the intelligent contract mechanism on the blockchain to ensure the real-time and unchangeable modification of the data exchange process.

The use of secure transport protocols to ensure the security of data transmission, thereby supporting cross-level, cross-department information sharing and business collaboration. According to the technical characteristics of the blockchain, the process of sharing and exchanging government resources as shown in Fig. 7 is designed.

As can be seen from the business process of Fig. 7, in a specific scenario, taking data exchange between the two departments A and B as an example, the department A applies to the department B for sharing and exchanging information, so the request (after signing the private key) Data is a smart contract, which is broadcasted to each node. Each core node queries and verifies according to the conditions of the smart contract. During this period, the department can use the instant communication protocol to send real-time notifications, or pass only two departments. Negotiate the data, and then the core node stores the block information on the chain through validity and interoperability certification. If the B department service switching gateway determines the authority of the authorized party A, the department B can encrypt the shared and exchanged data through the secure transmission protocol, and then transmit the asymmetric encrypted data URL point to point A, and the A department obtains the address through the link address. Requested decrypted source data. Throughout the process, the storage of data is still stored in the database system of department B, with ownership of the data. XML enables computers to process various kinds of information by tagging data and defining data types. It is not only a cross platform and content dependent technology in the Internet environment, but also an effective tool for dealing with distributed structural information. After years of application and development, it has good scalability and cross platform, making it widely used in network services, data exchange, e-commerce, content management and other fields. XML technology plays an important role in solving data exchange in heterogeneous environment, reducing the development difficulty of integration interface between different systems, and establishing semantic network environment. This is an important reason why structures use XML standard order instead of other methods.

4. Results and discussion

4.1. Model-based case verification

In the process of promoting the construction of smart cities, Hefei City concentrated on the development of smart networks, smart transportation, and smart government [17,18]. At present, the construction of smart transportation in Hefei has a long history and many achievements. The construction of smart networks and smart government affairs has invested heavily, and the scope of construction is expanding rapidly. Based on the data of Hefei City from 2012 to 2017, this paper compares the development level of smart cities in Hefei in recent years. The data sources of this paper are: "Annual Statistical Yearbook of Anhui Province" from 2013 to 2018, the government statistical bulletin of 2012~2017, the statistical bulletin of science and technology, the website of relevant government departments, the evaluation report of the level of smart city development, and the related research literature. We use the range method to standardize the forward and negative indicators in the raw data. The weights of each index are calculated according to the entropy weight method formula, and the results are listed in Table 2.

It can be seen from Table 1 that the overall weight of each indicator is small. Therefore, each index has a certain impact on the development

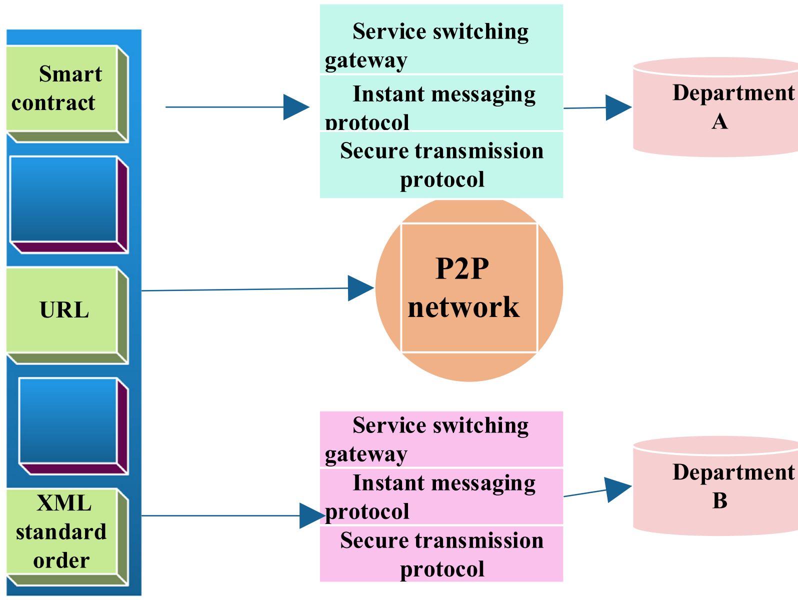

Fig. 7. Workflow of blockchain in smart city.

Table 2
Hefei City smart city development level index weighted normalization matrix.

Indicator (weight)	Year					
	2012	2013	2014	2015	2016	2017
X1(0.03460)	0.00000	0.01845	0.02763	0.02301	0.02754	0.03454
X2(0.03500)	0.00000	0.01384	0.02085	0.01776	0.02105	0.03485
X3(0.03530)	0.00000	0.00864	0.01807	0.02214	0.02650	0.03435
X4(0.03760)	0.00000	0.00193	0.01002	0.01576	0.02763	0.03752
X5(0.03786)	0.00000	0.00274	0.000709	0.01156	0.01902	0.03689
X6(0.03457)	0.00000	0.01396	0.02120	0.03503	0.02091	0.02087
X7(0.03649)	0.00530	0.00000	0.00776	0.02379	0.03174	0.03779
X8(0.03600)	0.00000	0.01031	0.01700	0.02523	0.03296	0.03516
X9(0.03575)	0.00000	0.01899	0.01820	0.02482	0.02849	0.03395
X10(0.03647)	0.00000	0.00468	0.00864	0.01742	0.02746	0.03701
X11(0.03529)	0.00000	0.01357	0.01840	0.02412	0.03201	0.03479
X12(0.03706)	0.00000	0.00368	0.00870	0.01362	0.02017	0.03716
X13(0.03669)	0.03826	0.02899	0.01403	0.00896	0.00643	0.00000
X14(0.03676)	0.00000	0.00370	0.01101	0.01847	0.02941	0.03694
X15(0.03786)	0.02217	0.04187	0.02531	0.05015	0.00000	0.04513
X16(0.03457)	0.00000	0.01491	0.02819	0.03574	0.03410	0.00719
X17(0.03649)	0.00000	0.01121	0.00846	0.02231	0.03588	0.03976
X18(0.03600)	0.00000	0.00894	0.01867	0.02715	0.03812	0.04912
X19(0.03575)	0.01513	0.00681	0.01762	0.03574	0.01942	0.00000
X20(0.03647)	0.00000	0.01215	0.01314	0.01723	0.01894	0.03521
X21(0.03529)	0.00000	0.04163	0.04175	0.04916	0.04175	0.00489
X22(0.03706)	0.00000	0.00992	0.00995	0.02796	0.03697	0.01156
X23(0.03669)	0.00861	0.00000	0.01354	0.02947	0.02945	0.03561
X24(0.03676)	0.03320	0.04925	0.02771	0.02408	0.00000	0.00319
X25(0.03786)	0.00000	0.01013	0.01951	0.02061	0.03546	0.01419
X26(0.03786)	0.00000	0.03557	0.03556	0.04119	0.04821	0.04894

level of smart cities in Hefei. For the six primary indicators, the indicators related to smart public services are more weighted [19]. This shows that the strengthening of public service construction is very beneficial to the improvement of the overall service level of smart cities. Combining the data in the table, we use the formulas to calculate the optimal indicator matrix and the worst indicator matrix. Then we can get the Euclidean distance and the gray correlation coefficient of the indicator matrix of each year to the optimal indicator matrix. In the same way, we can calculate the Euclidean distance and the gray correlation coefficient of each year's indicator matrix to the worst indicator matrix (R). The calculation results are shown in Table 3.

In economic management, dimensionless method is one of the steps of comprehensive evaluation. The covariance matrix of each index data processed by dimensionless method can reflect not only the variation degree difference of each index in the original data, but also the information of the influence degree difference of each index. Therefore, we further list the dimensionless formula applicable to this model. The formula are as follows.

Table 3
Computational results of the development level of smart cities in Hefei City.

Result	Year					
	2012	2013	2014	2015	2016	2017
S+	0.035214	0.027354	0.021794	0.01575	0.01735	0.01859
S−	0.011231	0.01794	0.019847	0.027654	0.02891	0.03192
R+	0.384825	0.459687	0.498591	0.65121	0.7014	0.90112
R−	0.895196	0.657645	0.5462	0.4512	0.46135	0.48258

$$S_i^+ = \frac{s_i^+}{\max_{isism} s_i^+} \tag{12}$$

$$S_i^- = \frac{s_i^-}{\max_{isism} s_i^-} \tag{13}$$

The matrixes after dimensionless quantization of the above formula are

$$S^+ = \left\{S_1^+,\ S_2^+, \dots,\ S_m^+\right\}, S^- = \left\{S_1^-,\ S_2^-, \dots,\ S_m^-\right\}$$

The larger the Si value is, the closer the index matrix is to the optimal index matrix. The larger the Si + value is, the farther away the index matrix is from the optimal index matrix.

Next, we deal with the Euclidean distance by dimensionless matrix. Then we get:

$$S^+ = \left\{1.00000,\quad 0.78622,\quad 0.6062,\quad 0.48791,\quad 0.44969,\quad 0.52395\right\}$$

$$S^- = \left\{0.47913,\quad 0.53665,\quad 0.64661,\quad 0.79883,\quad 0.89691,\quad 1.00000\right\}$$

According to the formula of relative closeness, we can get the relative closeness of the development level of Hefei smart city in 2012–2017 as follows:

$$C^+ = \left\{0.27117,\quad 0.43898,\quad 0.52476,\quad 0.61844,\quad 0.65912,\quad 0.66735\right\}$$

According to the first level indicators, the processed matrix is divided into six subsystems: smart city planning, smart infrastructure construction, smart industry development and innovative production, smart public service, smart government management and smart environment. The higher the value, the better the development of smart

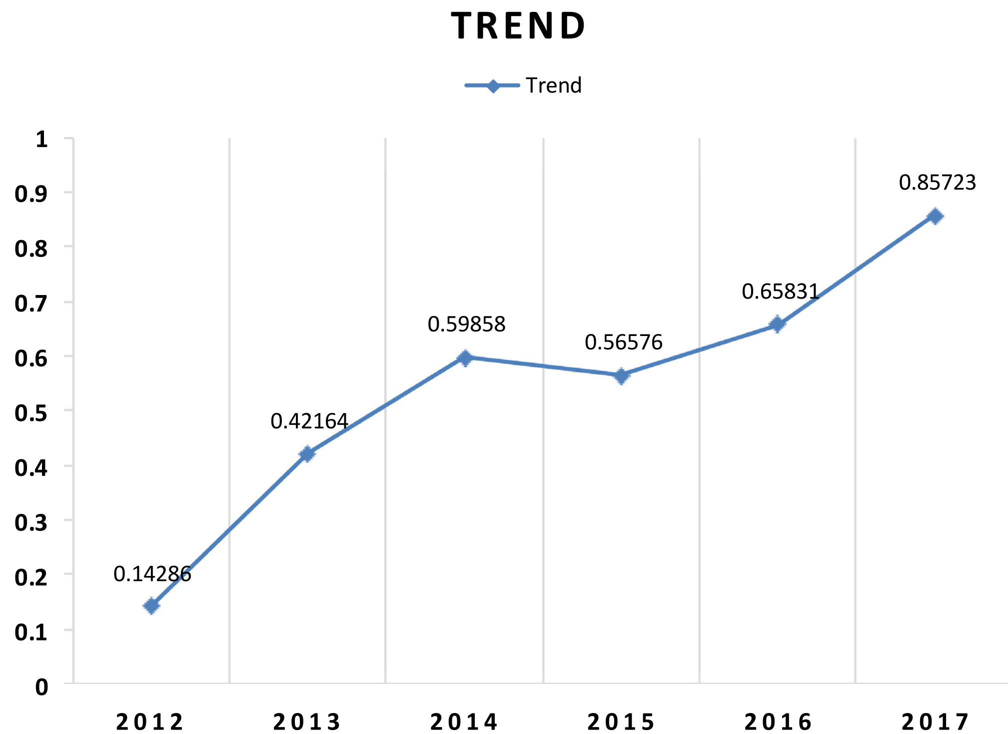

Fig. 8. Hefei smart city planning level change trends.

city is. It can be seen that the active participation of Hefei government, enterprises and other parties has further promoted the integration of resources, under the leadership of the correct and unified general direction. They have improved the mechanism of resource sharing, improved the efficiency and quality of R & D, and improved the level of urban public service and citizens' happiness.

We further divide the normalized matrix into six subsystems: smart city planning, smart infrastructure construction, smart industry development and innovative production, smart public service, smart government management, and smart environment [16]. Repeating the above steps, we get the weights and weighted normalization matrices of the six subsystems. They are listed in Table 4.

The above calculation is repeated according to the calculation results in Table 5. We get the relative closeness of the development of the six subsystems of Hefei Smart City from 2012 to 2017. The results are shown in Table 5.

By constructing the gray correlation-TOPSIS evaluation model, we calculate the closeness of the overall development level of the smart city in Hefei and the ideal values of the six subsystems. We further analyzed the changes in the development level of Hefei's smart city from 2012 to 2017. On the one hand, we can judge the development trend according to the trend change. On the other hand, we can clarify development advantages and shortcomings through further analysis of various factors. Therefore, we can make targeted recommendations for the sustainable development of Hefei City. According to the calculation results in Table 5, the relative closeness of the level of smart city planning and the trend of the smart city planning level of its response are shown in Fig. 8.

4.2. Results

It can be seen from the development trend in the figure that during the period of 2012~2017, the level of smart city planning in Hefei City is on the rise. It rose faster, from 0.14286 in 2012 to 0.85714. This shows that in just six years, government policy makers have deeply realized the importance of building a smart city and basically established the strategic position of smart city construction. We can see that 2014~2015 is not only an incubation period, but also a precipitation period for Hefei City in the construction of smart cities. In April 2013, the Hefei Municipal Government issued the "Key Points for Independent Innovation in 2013". It clearly sets out six key tasks such as accelerating the development of strategic emerging industries, enhancing the innovation capability of enterprises, strengthening the construction of innovation platforms, strengthening the construction of talent teams and optimizing the innovation environment. In 2014, the Hefei Municipal Government attached great importance to the reform of the science and technology system, emphasized the transformation of scientific and technological achievements, and proposed strategic support for the diversified path of smart city construction. In 2015 and 2016, as the closing year of the "Twelfth Five-Year Plan" and the beginning of the "Thirteenth Five-Year Plan", the Hefei Municipal Government has taken a higher level of emphasis on smart cities. In early 2015, Hefei City established the Hefei Smart Industry Industrial Technology Innovation Strategic Alliance headed by IFLYTEK CO.,LTD.. This further gathered innovative resources and accelerated the industrial innovation of Hefei City. Under the national policy call, the government has successively issued many documents. They are "Request for Issues Related to the Management System of the Smart City Construction of the Hefei Municipal Development and Reform Commission", "Comments on the Relevant Issues Concerning the Construction of the Smart Hefei Management Center", the "Support Plan for the New Urbanization Pilot Project of Hefei City" and other related supporting policies. This laid a good strategic foundation for the development of smart cities.

According to the calculation results above, the relative closeness of the development level of smart cities in 2012 to 2017 and the rational matrix in Hefei City is. Fig. 9 shows that the average annual growth rate of smart cities is more than 30%, urban resource allocation is 20%, and smart construction has become a new pillar industry. The greater the relative closeness, the higher the overall development level of the representation, and the trend is shown in Fig. 9.

4.3. Discussion

According to the calculation results, it is not difficult to find that Hefei City is continuously improving in the construction of smart cities

Table 4
Weighted normalization matrix for each subsystem.

Subsystem	Indicator (weight)	Year					
		2012	2013	2014	2015	2016	2017
Smart city planning	X1(0.32862)	0.00000	0.01875	0.02783	0.02201	0.02694	0.33474
	X2(0.3610)	0.00000	0.01384	0.02085	0.16776	0.02005	0.3385
	X3(0.3370)	0.00000	0.08641	0.01707	0.21214	0.25650	0.3475
Infrastructure for smart cities	X4(0.25632)	0.00000	0.01019	0.06902	0.10576	0.02763	0.25752
	X5(0.25681)	0.00000	0.01974	0.04909	0.08156	0.01902	024689
	X6(0.23457)	0.00000	0.09396	0.14120	0.23503	0.188091	0.14387
	X7(0.25649)	0.3612	0.00000	0.0576	0.17379	0.130174	0.24779
Smart industry development and innovative production	X8(0.16600)	0.00000	0.04731	0.07897	0.11745	0.14174	0.16437
	X9(0.15975)	0.00000	0.08704	0.08534	0.11488	0.12342	0.16002
	X10(0.17167)	0.00000	0.02893	0.04107	0.08172	0.12768	0.17089
	X11(0.16521)	0.00000	0.06357	0.08637	0.11197	0.14426	0.16199
	X12(0.17821)	0.00000	0.01668	0.03579	0.06181	0.09405	0.17191
	X13(0.17069)	0.17153	0.13208	0.06462	0.04102	0.02976	0.00000
Smart public service	X14(0.15176)	0.00000	0.01518	0.04541	0.07562	0.12143	0.15176
	X15(0.20786)	0.09213	0.17861	0.10351	0.20261	0.00000	0.18521
	X16(0.14856)	0.00000	0.06231	0.11676	0.14826	0.14153	0.03019
	X17(0.14792)	0.00000	0.04598	0.03297	0.09108	0.14881	0.12279
	X18(0.20283)	0.00000	0.03759	0.07708	0.11614	0.15772	0.21278
	X19(0.14763)	0.06217	0.02791	0.07162	0.14797	0.07856	0.00000
Smart government management	X20(0.3001)	0.00000	0.12704	0.1007	0.14392	0.15657	0.29031
	X21(0.40651)	0.00000	0.05431	0.34389	0.40512	0.34387	0.04071
	X22(0.30706)	0.00000	0.04072	0.08215	0.23021	0.34071	0.9389
Smart city planning	X23(021219)	0.05176	0.00000	0.07875	0.17415	0.17415	0.21028
	X24(030121)	0.19713	0.29138	0.16211	0.14235	0.00000	0.01636
	X25(0.20786)	0.00000	0.05879	0.12314	0.12175	0.20924	0.08132
	X26(0.29918)	0.00000	0.16725	0.21036	0.24918	0.28613	0.28919

Table 5
Relative development level of each subsystem.

Indicator (weight)	Year					
	2012	2013	2014	2015	2016	2017
Smart city planning	0.14278	0.41275	0.59578	0.65812	0.65793	0.85536
Infrastructure for smart cities	0.18822	0.25796	0.37731	0.57212	0.63798	0.77471
Smart industry development and innovative production	0.32418	0.41486	0.41968	0.51885	0.61470	0.67602
Smart public service	0.29078	0.41465	0.41970	0.51875	0.59768	0.62792
Smart government management	0.17916	0.35281	0.58049	0.73746	0.75516	0.51714
Smart environment	0.34599	0.51847	0.55589	0.63496	0.59049	0.56417

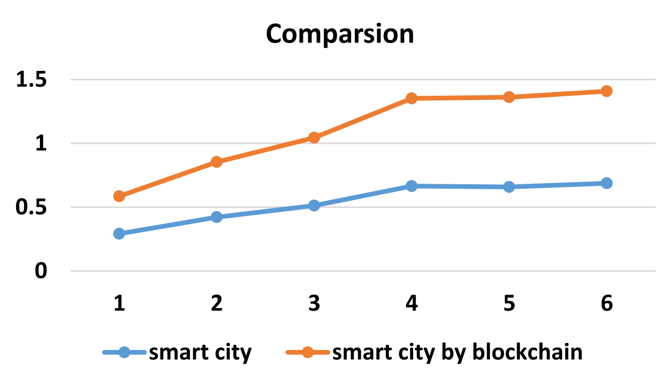

Fig. 9. Blockchain in the development level of smart cities in Hefei City.

from 2012 to 2017. The early stage of development was faster and gradually stabilized. Combined with the analysis of the six subsystems in the previous article, we can know: First, the construction achievements of Hefei City in recent years are affirmative. Especially in the officially approved smart city pilot demonstration in 2013, the growth rate is faster and the fit between the ideal value and the ideal value is increasing from the perspective of industrial development and innovative production. Second, in terms of public services, Hefei still needs to further integrate resources and increase research and development efforts to make public services more convenient. Third, in terms of environmental wisdom transformation, Hefei needs to strengthen supervision. It must control pollution emissions, promote the use of low-carbon and environmentally friendly new energy sources, and promote the sustainable development of the ecological environment. Fourth, the wisdom of Hefei construction has enormous challenges to government management, and it is a significant test for the government leadership team and all government affairs workers.

The supporting facilities around the smart products will also affect the use of the products. Difficulties in the construction of communication pipes in the old city have become the bottleneck for the construction of smart cities in Shenzhen. The government promotes the expansion of communication channels in the old city, expands and expands the access pipes of old and commercial buildings, reduces or merges the approval channels for communication pipeline construction, and accelerates the promotion of electronic approval. Actively explore and promote the construction of local laws and regulations, guarantee the construction of the right of passage, and urge all parties to build and share. Use big data to innovate government management service methods, vigorously improve e-government, promote cross-departmental and inter-regional horizontal docking and data sharing of e-government platforms, and improve the efficiency of government system operation. Coordinate the construction of a provincial-level government cloud platform to realize the intensive construction and sharing of the government's government system infrastructure and the intensive management of information resources. Promote the construction of new media for government affairs and improve the integrated online public service system.

5. Conclusion

With the continuous advancement of the national governance system and the modernization of governance capabilities, the development concept of "innovation, coordination, green, openness, and sharing" continues to deepen. The 13th Five-Year Plan has raised the development of smart cities to the height of national strategy. Big data is the technical foundation of smart cities, and block chain can effectively help data sharing in smart cities. Smart cities are deeply integrated with emerging technologies such as IoT infrastructure, cloud computing, big data, Internet of Things, mobile internet, artificial intelligence, and urban planning, construction, management, and operations. It implements the development concept of innovation, coordination, green, openness and sharing, and promotes the healthy development of the city. The blockchain government information resource sharing and exchange model designed in this study consists of three parts: network layer, blockchain infrastructure layer and business application layer. It is supported by five service systems to effectively solve the sharing of government information resources. It provides new ideas for issues such as trust islands in exchange, data ownership and peer management, standards consistency, and non-real-time exchange. For each department, organization, and enterprise in the cross-regional, cross-department, cross-platform and other multi-subjects to maintain control over data operations in the process of information interaction, and thus the government information resource sharing and exchange model has strong adaptability and high reliability in the context of multi-subject participation by the government and the public. This paper also constructs a comprehensive evaluation model based on TOPSIS method, and empirically evaluates the development level of smart Hefei from 2012 to 2017. According to the analysis results, the countermeasures and suggestions for the improvement of the construction level of smart cities in Hefei City are proposed.

The sharing of government information resources requires the use of new technologies, new ideas and new models, and the courage to innovate. Because of distributed ledger technology, intelligent contract infrastructure platform and distributed new computing paradigm, realizing the co-construction and sharing of e-government information resources and building Promote the scientific, democratic, intelligent and efficient government management and public services based on the security network system of the independence of government organizations, specific regions and the integrity of the organization system. Smart cities have changed from government-led and government-driven in the past to government regulation, socialization, and participation by the whole people. This not only reduces costs, reduces government workload, but also improves service efficiency and promotes organic integration of data and services. This will fundamentally promote the healthy and sustainable development of smart cities. Big data provides sufficient impetus for smart city construction and is the key foundation for urban intelligence. Big data in smart cities is a direct and important manifestation of intelligence, using cloud computing, big data, Internet of Things, mobile Internet, artificial intelligence and other new generation information technology to create a data decision center.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The work was supported by the Research on Quality Control of Equipped architecture Construction, China (No. R2018JG14).

References

[1] A. Brandão, H.S. Mamede, R. Gonçalves, A smart city's model secured by blockchain, in: J. Mejia, M. Muñoz, Á. Rocha, A. Peña, M. Pérez-Cisneros (Eds.), Trends and Applications in Software Engineering. CIMPS 2018, in: Advances in Intelligent Systems and Computing, vol. 865, Springer, Cham, 2019, http://dx.doi.org/10.1007/978-3-030-01171-0_23.

[2] J. Li, D. Greenwood, M. Kassem, Blockchain in the construction sector: A socio-technical systems framework for the construction industry, in: I. Mutis, T. Hartmann (Eds.), Advances in Informatics and Computing in Civil and Construction Engineering, Springer, Cham, 2019, http://dx.doi.org/10.1007/978-3-030-00220-6_7.

[3] S. Ølnes, A. Jansen, Blockchain technology as s support infrastructure in e-government, in: M. Janssen, K. Axelsson, O. Glassey, B. Klievink, R. Krimmer, I. Lindgren, P. Parycek, Hans J. Scholl, D. Trutnev (Eds.), EGOV 2017, in: LNCS, vol. 10428, Springer, Cham, 2017, pp. 215–227, http://dx.doi.org/10.1007/978-3-319-64677-0_18.

[4] M. Shen, X. Tang, L. Zhu, X. Du, M. Guizani, Privacy-preserving support vector machine training over blockchain-based encrypted iot data in smart cities, IEEE Internet Things J. (2019) http://dx.doi.org/10.1109/JIOT.2019.2901840.

[5] E. Mengelkamp, B. Notheisen, C. Beer, D. Dauer, C. Weinhardt, A blockchain-based smart grid: towards sustainable local energy markets, Comput. Sci. Res. Dev. 33 (2017) 207–214, http://dx.doi.org/10.1007/s00450-017-0360-9.

[6] M. Janssen, D. Praditya, Factors influencing the creation of information sharing arrangements between private and public organizations, in: M. Dečman, T. Jukić (Eds.), Proceedings of the European Conference on E-Government, Academic Conferences and Publishing International Limited Reading, 2016, pp. 154–161.

[7] H. Kubicek, R. Cimander, H.J. Scholl, Organizational Interoperability in E-Government: Lessons from Good Practice Cases All over Europe, Springer, Berlin, Heidelberg, New York, 2011, pp. 135–141.

[8] Shou-bin Kong, Miao-wei Wang, Bo-han Wang, et al., Research on the construction mode of local government information resource sharing platform based on cloud platform, E-Government (12) (2017) 46–53.

[9] Z. Zheng, S. Xie, H.N. Dai, X. Chen, H. Wang, Blockchain challenges and opportunities: a survey, Int. J. Web Grid Serv. 14 (4) (2018) 352–375.

[10] I. Konstantinidis, G. Siaminos, C. Timplalexis, P. Zervas, V. Peristeras, S. Decker, Blockchain for business applications: A systematic literature review, in: W. Abramowicz, A. Paschke (Eds.), Business Information Systems. BIS 2018, in: Lecture Notes in Business Information Processing, vol. 320, Springer, Cham, 2018, http://dx.doi.org/10.1007/978-3-319-93931-5_28.

[11] N. Suhaliana bt Abd Halim, M.A. Rahman, S. Azad, M.N. Kabir, Blockchain security hole: issues and solutions, in: F. Saeed, N. Gazem, S. Patnaik, A.S. Saed Balaid, F. Mohammed (Eds.), IRICT 2017, in: LNDECT, vol. 5, Springer, Cham, 2018, pp. 739–746, http://dx.doi.org/10.1007/978-3-319-59427-9_76.

[12] S. Bhardwaj, M. Kaushik, Blockchain—technology to drive the future, in: S.C. Satapathy, V. Bhateja, S. Das (Eds.), Smart Computing and Informatics, in: SIST, vol. 78, Springer, Singapore, 2018, pp. 263–271, http://dx.doi.org/10.1007/978-3-319-59427-9_76.

[13] L. García-Bañuelos, A. Ponomarev, M. Dumas, I. Weber, Optimized execution of business processes on blockchain, in: J. Carmona, G. Engels, A. Kumar (Eds.), BPM 2017, in: LNCS, vol. 10445, Springer, Cham, 2017, pp. 130–146, http://dx.doi.org/10.1007/978-3-319-65000-5_8.

[14] K. Toyoda, P. Mathiopoulos, I. Sasase, T. Ohtsuki, A novel blockchain-based Product Ownership Management System (POMS) for anti-counterfeits in the post supply chain, IEEE Access 5 (2017) 17465–17477, http://dx.doi.org/10.1109/ACCESS.2017.2720760.

[15] E. Munsing, J. Mather, S. Moura, Blockchains for decentralized optimization of energy resources in microgrid networks, in: 2017 IEEE Conference on Control Technology and Applications (CCTA), 2017, http://dx.doi.org/10.1109/CCTA.2017.8062773.

[16] D.A. Wijaya, J.K. Liu, D.A. Suwarsono, P. Zhang, A new blockchain-based value-added tax system, in: T. Okamoto, Y. Yu, M.H. Au, Y. Li (Eds.), ProvSec 2017, in: LNCS, vol. 10592, Springer, Cham, 2017, pp. 471–486, http://dx.doi.org/10.1007/978-3-319-68637-0_28.

[17] N. Kshetri, Blockchain's roles in strengthening cybersecurity and protecting privacy, Telecommun. Policy 41 (2017) 1027–1038, http://dx.doi.org/10.1016/j.telpol.2017.09.003.

[18] S. Alboaie, D. Cosovan, Private data system enabling self-sovereign storage managed by executable choreographies, in: L.Y. Chen, H.P. Reiser (Eds.), DAIS 2017, in: LNCS, vol. 10320, Springer, Cham, 2017, pp. 83–98, http://dx.doi.org/10.1007/978-3-319-59665-5_6.

[19] S. Grumbach, R. Riemann, Distributed random process for a large-scale peer-to-peer lottery, in: L.Y. Chen, H.P. Reiser (Eds.), DAIS 2017, in: LNCS, vol. 10320, Springer, Cham, 2017, pp. 34–48, http://dx.doi.org/10.1007/978-3-319-59665-5_3.

[20] Z. Zhao, T.-H.H. Chan, How to vote privately using bitcoin, in: S. Qing, E. Okamoto, K. Kim, D. Liu (Eds.), ICICS 2015, in: LNCS, vol. 9543, Springer, Cham, 2016, pp. 82–96, http://dx.doi.org/10.1007/978-3-319-29814-6_8.

[21] Y. Xu, Q. Li, X. Min, L. Cui, Z. Xiao, L. Kong, E-commerce blockchain consensus mechanism for supporting high-throughput and real-time transaction, in: S. Wang, A. Zhou (Eds.), CollaborateCom 2016, in: LNICST, vol. 201, Springer, Cham, 2017, pp. 490–496, http://dx.doi.org/10.1007/978-3-319-59288-6_46.

[22] K. Delmolino, M. Arnett, A. Kosba, A. Miller, E. Shi, Step by step towards creating a safe smart contract: lessons and insights from a cryptocurrency lab, in: J. Clark, S. Meiklejohn, P.Y.A. Ryan, D. Wallach, M. Brenner, K. Rohloff (Eds.), FC 2016, in: LNCS, vol. 9604, Springer, Heidelberg, 2016, pp. 79–94, http://dx.doi.org/10.1007/978-3-662-53357-4_6.