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# An innovative framework for sustainable and centralized material procurement management based on a full-domain set theory

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**ABSTRACT**

The purpose of this study is to propose a theoretical framework to solve the problem of insufficient data integrity, insufficient information circulation, and poor global data integration and linkage in the material procurement management subsystem. Based on the theory of full-domain set, this study proposes the conceptual framework, the full-domain linkage model, and the theoretical framework of centralized material procurement management. With the proposed innovative management framework, current problems such as insufficient data integrity, insufficient information circulation and data linkage in the procurement management system can be solved. This study provides reference significance for the construction of centralized material procurement management in the context of big data and offers theoretical guidance for large group enterprises to carry out centralized procurement management.

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## 1. Introduction

With the application of information technology in all walks of life, the traditional data order and management methods can no longer meet the development needs of enterprises, and the management innovation work based on big data is urgent [1]. The centralized procurement management of materials refers to the unified procurement department of the enterprise through access to marketing resources to meet the production process of equipment and materials and other production materials. The information technology process and digital transformation of enterprises have aggregated data from various production factors and nodes in the business management process into a huge material procurement dataset, making it possible to innovate centralized material procurement management with the help of big data technology. However, the diversity of the form of big data itself and the extensiveness of the sources have led to the

problem of dispersion and confusion among the subsystems of procurement management, mainly in the following ways: (1) Data are not complete. The heterogeneity of data between different subsystems in the procurement management system makes it difficult to integrate data. Most of the data collected and obtained by the procurement department are fragmented and incomplete. In order to make full use of them, it is necessary to spend a lot of human and material resources to analyze and process the data in the first place, which is costly. (2) Insufficient information flow. The lack of data integrity makes the integration of information between different systems poor, the procurement department and the demand department of material procurement information cannot be quickly synchronized. (3) Data cannot be linked. The limitations of the system and the heterogeneous structure of the data make the inter-departmental data across the system poorly linked, and it is impossible to track the materials from the perspective of their whole life cycle [2].

Current research on procurement, mainly focuses on the procurement research and supplier evaluation and selection under supply chain mode. They emphasized the dual relationship between suppliers and manufacturers [3-5], the ternary relationship between manufacturers and suppliers [6, 7]. It is mainly based on the procurement of manufacturing enterprises or commercial enterprises [8]. The purchased raw materials or components are used for processing and manufacturing (assembly) into new products, or retailers purchase products from suppliers for final sale. There are few literatures on the procurement of non-manufacturing large group enterprises, and there are few literatures on the analysis of procurement management combined with the procurement management practice system. From the overall research results, there are many existing researches have been constructed from the perspective of procurement process [9] and procurement behavior [10], which are mainly conducted through practical operation, organization and relationship management. Counting the number of relevant studies, we can obtain that almost one-third of the studies dealt with partnership issues, but fewer studies applied big data to material procurement management. In the era of big data, the connotation of material procurement management must be combined with big data thinking to enrich research content and expand procurement theory research. Combined with the current problem of the application of big data in the subsystems of procurement management that mentioned in paragraph one, we present the research question for this study: How to build an innovative centralized procurement management method based on big data?

The premise of centralized procurement management is to obtain the demand plans of different units for similar materials through effective communication. The motivation of this study is to innovatively integrate various business contents of procurement management, establish data linkage between the demand side and the procurement side, search for the inner linkage and synergistic mechanism of related material consumption, and realize intelligent centralized procurement management decision support based on big data. The contribution of this study can be summarized as follows: with the help of big data technology and the full-domain set theory, this study achieves management goals such as optimizing material procurement management by analyzing and modelling data that affects the production and operation rules of enterprises, studying the laws of material consumption and demand to forecast material demand, and studying supplier information that affects material acquisition and related factors that affect material procurement performance.

## 2. Conceptual framework of the innovation of centralized material procurement management

### 2.1 Current status of management of centralized material procurement

The centralized procurement mode is mostly applicable to large enterprise groups with large scale and many branches, aiming to improve the efficiency and effectiveness of procurement management. It usually targets procurement items with large volume, large procurement amount, important impact on enterprise production and operation and maintenance or strong commonality, unified technical specifications and easy to collect. Take the centralized procure-

ment of materials of a large enterprise group in the railway industry as an example (as shown in Fig. 1), its management activities involve a large number of cross-departmental and cross-organizational multi-level and multi-threaded complex issues horizontally. The vertical organizational process can be decomposed into a demand plan proposal, demand plan approval, demand plan submission, procurement plan preparation, procurement plan approval, procurement plan commissioning, procurement plan aggregation, procurement sourcing, contract signing, logistics, performance acceptance, etc. It has obvious characteristics of a dynamic and complex system.

With the process of information technology and digital transformation of enterprises, enterprises rely on information technology to record and save production factors and business processes such as people, machines, materials and the environment in the form of data, gradually forming big data for material procurement management. The procurement department uses the information system to manage the demand information of each unit in a unified manner and form a unified organization for procurement after consolidation and integration, which has greatly improved the efficiency of procurement. However, most of the existing participating units in the procurement chain only emphasize the magnitude and acquisition of data when building big data, without giving full consideration to the comprehensive analysis and utilization of data, which creates the problem of difficult coordination between different enterprises and business areas. For example, the information systems of different branches under the same group may be compartmentalized in terms of data storage and processing, making it difficult to directly integrate and summarize information on the procurement needs of different organizations when collecting them, instead requiring a certain amount of human resources to be invested in matching information, such as fields required by different systems, and the extra work defeats the original purpose of centralized procurement to reduce human and material costs and improve procurement efficiency.

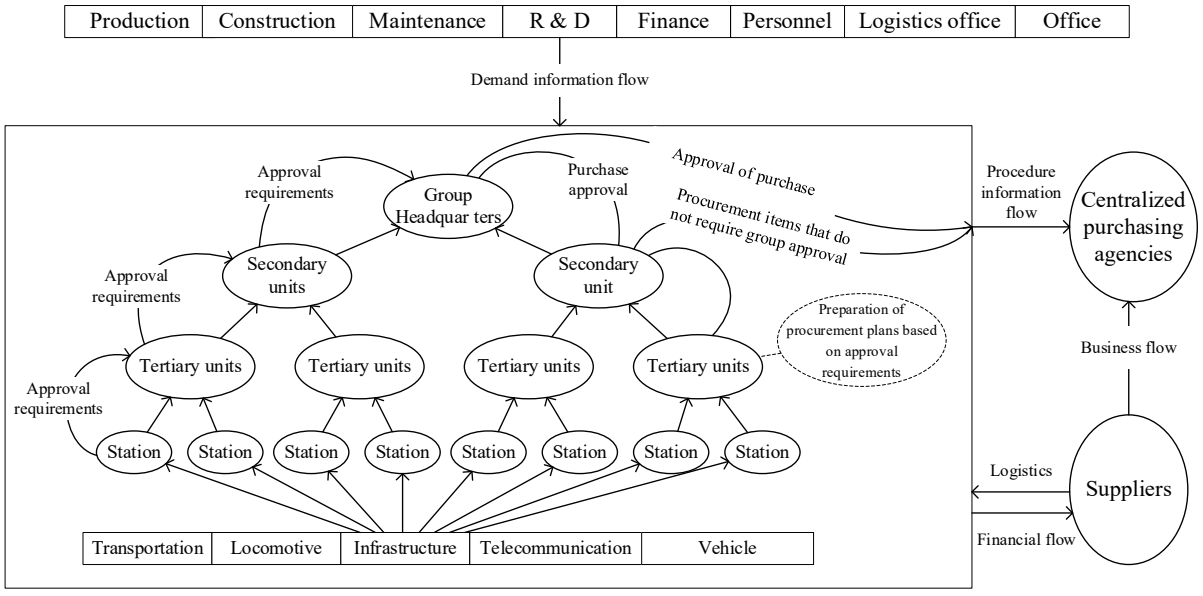


**Fig. 1** Schematic representation of the main centralized procurement process of a large enterprise group in the railway industry

### 2.2 The meaning of innovation in centralized material procurement management

Since Schumpeter introduced the concept of "innovation" in 1912, innovation theory has continued to mature. In this paper, the so-called innovation is all about the "new combination" of products, services, methods, technologies, and resources. In the context of the big data era, centralized material procurement management is not only the centralization of procurement forms, but also the integration of heterogeneous information systems to solve the problem of information silos, and at the same time to explore the intrinsic linkage and synergy mechanism of various business needs, and to realize the new management challenge of data-driven intelligent

procurement decisions. Therefore, centralized procurement management innovation in the context of big data should essentially be a process of systematically examining business processes from a data flow mindset, thinking deeply about decision-making behavior from an algorithmic mindset, and making full use of information technology, such as artificial intelligence, to transform the resulting innovative ideas into a new procurement model, which focuses on two points.

- The data flow thinking and data-driven role. The core is to use a data perspective to describe the business content of procurement management throughout its lifecycle, dig into the information contained therein, find the inherent synergy mechanism, and build a linkage mechanism, with the ultimate goal of achieving intelligent procurement decisions based on big data. The ultimate goal is to achieve intelligent procurement decision-making based on big data.
- The supporting role of algorithmic thinking and big data technology. The core of this is the use of big data algorithms to build a centralized material procurement model system from a holistic perspective. It mainly includes: constructing a model group of material consumption laws among various processes through quantitative analysis of enterprise production and operation laws; predicting demand information by combining market change trends to construct an optimal procurement model group; Studying supplier information affecting material acquisition and related factors affecting material procurement performance to construct a model group of internal and external dynamic optimization.

### 2.3 Characteristics of innovation in centralized material procurement management

Compared with the traditional centralized procurement management model, the centralized procurement model that integrates data flow thinking and big data technology is mainly based on big data related to the enterprise internal, market environment, macro policy environment and natural environment. It has the characteristics of full-domain (as shown in Fig. 2), which is manifested in three major features such as data integrity, information connectivity and management intelligence.

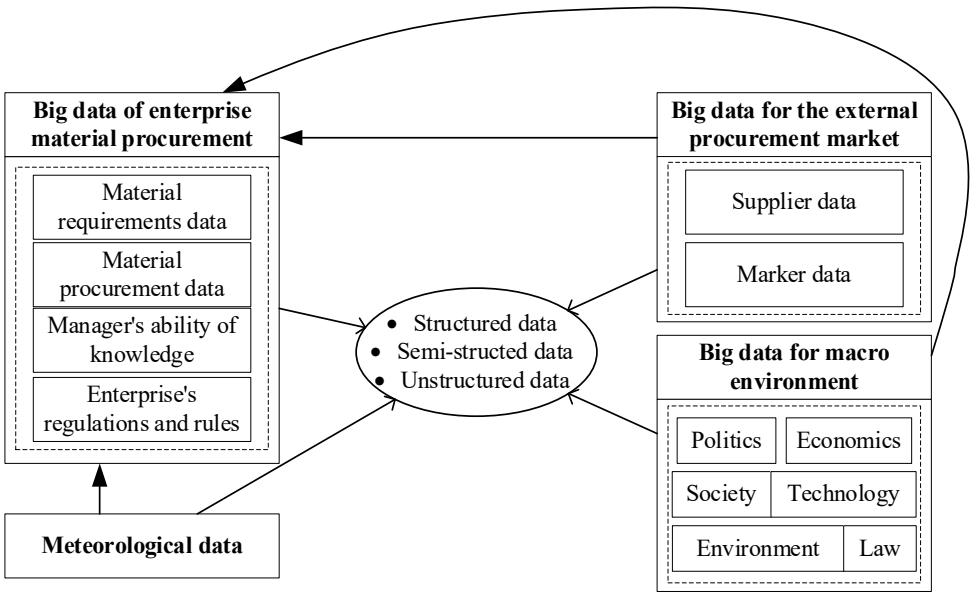


**Fig. 2** Materials procurement management full-domain data

*Data integrity*

From the perspective of the whole life cycle of the materials, its existence form changes from raw materials, finished products, commodities, enterprise production and operation materials to waste materials. Its properties and value of each stage and other information are stored in the form of data. Utilizing big data technology and related theories to organize and collect heterogeneous data from different system's collection, we can build a variety of materials life cycle of various information, which can serve as a basic data support for the enterprise low-cost, high

utilization rate of procurement of materials. Accurate prediction of demand and accurate use of materials require comprehensive and common data, and the integrity of data throughout the life cycle of materials is the basic support for intelligent procurement decisions.

*Information connectivity*

The purpose of centralized procurement is to achieve low-cost and high-efficiency communication and sharing, and the process involves the coordination of a large number of resources, so there are more uncertainties. There are many influencing factors in the material procurement process. Obtaining the global data affecting procurement through advanced information technology is the basis for carrying out intelligent procurement innovation In the context of the big data era, ensuring connectivity between the acquired information is the basis for achieving innovation in centralized material procurement management. One of the cores of centralized procurement management innovation is to solve the problem of data heterogeneity and information barriers between different systems. We can obtain external full-domain resources that affect procurement decisions through break down information islands and open up the data connection

*Management intelligence*

In the context of big data, centralized procurement management is no longer just about centralizing the demand information collected, but also about the dynamic management of material changes and the accurate estimation of demand, as well as the correlation and connection of different material demands. The innovation of centralized procurement management of materials can make full use of external market data, supplier data, macro environment data, etc. Through the cloud sharing mechanism, in accordance with the data sharing categories of private cloud, hybrid cloud, public cloud, we can personalized obtain the internal and external global resources that affect procurement decisions. With the help of big data and artificial intelligence and other data processing and modeling technology, we can dynamically and intelligently assist centralized procurement management decisions with instant adjustment and precise matching [11].

The three features of centralized material procurement management innovation complement each other and jointly support the intelligent identification of procurement decisions. Data integrity is a basic requirement for information connectivity, and only by fully grasping the data between various systems can we extract effective demand information. Information connectivity is an important guarantee of management intelligence, and intelligent management requires shared information as support, and unimpeded information exchange and sharing is an important prerequisite for intelligent centralized procurement management.

## 3. Model setting of the whole domain linked procurement system

The innovation of centralized procurement management based on big data emphasizes the integration of technology, internal and external integration, value integration and other comprehensive data integration. The development of information and data processing technology makes the relationship between technology and enterprise operation closer and closer. Incorporating the latest information technology into enterprise centralized procurement management is one of the innovative directions of management concepts in the new era. The effective integration of internal and external data of enterprises can provide powerful data resources support for purchasing decisions. The process of providing products and services by enterprises is closely integrated with that by using and accepting products and services by consumers, so as to create value together. The fusion of social values enhances the benefits of centralized procurement management innovation. To realize the all-round data integration of enterprises, this paper introduces the full-domain set theory to design the research framework of centralized procurement of materials, to realize the data-driven collaboration of multiple subjects and objects of centralized procurement, and to optimize the centralized procurement strategy to achieve intelligent procurement. The overall research logic framework of this paper is shown in Fig. 3.

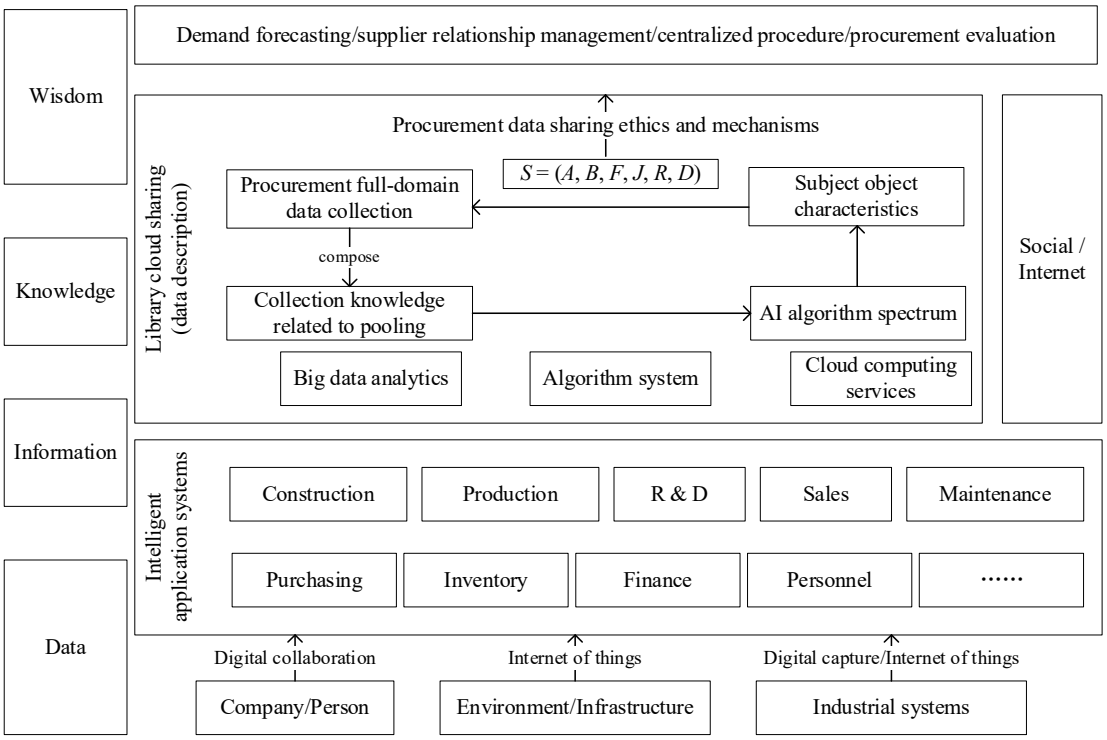


**Fig. 3** The logical framework of centralized procurement of materials based on the theory of the full-domain set with the full-domain linkage

Based on big data technology and the full-domain set theory, this study first collects and integrates the business requirements of various aspects of procurement management. This study describes the big data system of material procurement management in the full-domain set, and proposes a centralized procurement management target spectrum and determines the research boundary. This paper constructs a related global information collection for the data of the enterprise's internal material demand system information and the enterprise's external information involved in the target pedigree. Subsequently, based on the rules of centralized procurement management, we can determine the contextual function of the research boundary and the research objectives. Further, the global collection field data pair of the procurement management is trained by the dynamic function, and the spatiotemporal linkage rule set between the centralized procurement management and the global field is established. Finally, to solve the actual problems required by intelligent procurement and establish a decision set of centralized procurement targeting problems, this study the decision set of the centralized procurement targeting problem is established. This study adopts the deep learning technology to continuously mine the inherent laws and representation levels of the data, thereby forming an AI adaptive algorithm based on centralized procurement targeting problems and data pedigrees. In other words, the AI algorithm system can be adaptively adjusted based on the problem structure for different procurement management problems.

### 3.1 Definition of a centralized procurement of materials full-domain set

The concept of a full-domain set comes from the study of Borzooei *et al.* for full-domain control sets [12], as well as the study of several convex domains and their relations in multivariate complex spaces proposed by Cheng *et al.* [13]. Defining the full-domain set $S = (A, B, F, J, D)$, where $A$ and $B$ are non-empty classical sets, $A$ is used to describe the range from which the data arises, and $B$ is a description of all elements in $A$. $F$ denotes the mapping from set $A$ to set $B$, which defines the affiliation function of all elements in $A$, that is, defines a description for all elements in $A$. $J$ denotes the constraint scope of the membership function $F$, and $D$ represents the variable granularity of the data [14].

From the above definition, in terms of big data in a specific domain, and based on the studies of Lenin *et al.* [15] and Li *et al.* [16], this study gives the definition of each element in the centralized procurement of materials full-domain set $S_p = (A, B, F, J, R, D)$ in the business scenario as follows.

*Parameter A*. Parameter *A* represents the root field element of the material procurement management business system and associated systems, which contains all existing material procurement management systems, industrial systems, monitoring systems, management systems and external information of the enterprise, such as supplier information, market information, environmental factors information and other full-domain information root fields associated with material procurement management. The specific structure and fields of each system are represented by $A_i$, which is a power set of related fields for material procurement management. Therefore, there is a full-domain collection of root fields $A = A_i = \sum_{i=1}^{n} A_i$ $(i = 1,2,\cdots,n)$. The field structure of $A_i$ depends on the specific business system database.

*Parameter B*. Parameter *B* refers to the set of global root fields in different business scenarios drawn from the global root field set *A* by the material procurement management business module on the basis of goal management. To obtain this field set, we first need to carry out a scenario transformation based on the target decision conditions and logic change rules of the material procurement management business module, and describe the transformed field power set based on problem characteristics (labels). Then, the corresponding data sub-field meta-system is constructed for the contextual description of different business target scenarios. This is a process of automatic separation of the spectrum, with the aim of enhancing the relevance and accuracy of data analysis for each target business system and increasing the depth of knowledge mining. Through the contextual descriptions, different data genealogies can be formed for different material procurement management objectives, and the intelligent decision-making of each business module of data normalization management and procurement management can be realized.

*Parameter F*. Parameter *F* is an associative mapping relationship $A \xrightarrow{F} B$ between the root field set *A* and the field power set *B* in the material procurement management universe. *F* can be obtained by logical operations on a variety of traditional sets or by training with various AI algorithms, econometric models, etc.

*Parameters J* and *R*. Parameters *R* and *J* are the associated business scope and the data scope of the study, respectively, which transformed into *F* by the definition of the knowledge rules. The parameters *R* and *J* represent the business scope associated with the material procurement management full-domain data analysis requirements, and the data scope of the study according to the target spectrum extracted from the decision problem. They are used to define the scope of the thesis domain of the decision problem, which can be determined by the application scenario where the target problem is located.

*Parameter D*. Parameter *D* is the set of decision objectives, which represents the optimization objectives of the fields in the power set *B* after combining with the relevant scene data constituted by the realm-variant features, and it is the objective function for the operation of the AI algorithm system.

The full-domain set provides clustered and compressed various patterns by establishing the mapping between the target and the object features and constructing the image of the external information and the boundary shell. Moreover, it also transforms management coordination problems into data description problems through the effective management of related concepts, so as to realize the autonomous understanding of data on the objective world [17]. This idea can provide a standardized standard for the unified description of data, provide an effective protocol mechanism for simultaneously meeting the goals of confidentiality, business heterogeneity and barrier-free sharing of big data across specific business sectors. It is also an effective way to break through the information barriers of data resources in different sectors [18]. Zhang proposed collaborative analysis method for the management of data assets across the digital grid enterprise [19], Duan introduced a solution for a group-level full-domain data management and

sharing platform based on DCMM [20], and Elouneg *et al*. established an open-source framework based on full-domain data [21]. These researchers all demonstrate the effective role of full-domain set theory in describing big data fields and their target genealogies, exploring the standardized granular representations [22], breaking through data barriers between scenarios and systems, and establishing a standard data cloud repository.

### 3.2 Algorithm selection for material centralized procurement targeting problem scenarios

Along with the increasing digitalization of human society, algorithms have become the basic rules that affect the operation of the world. The rise of the third wave of AI development, represented by machine learning algorithms, has broken through the limitations of human expression as revealed by the "Polanyi paradox" and made algorithms self-producing. Modern AI-based algorithms can form rule sets by learning from large data sets and assist in perception and decision making in different scenarios [23]. In this paper, we believe that selecting suitable AI algorithms and apply them to different scenarios of centralized procurement of materials, mining and analyzing the intrinsic connections and laws of data in different business scenarios, and promoting the system to automatically select the matching algorithms according to the scenario transformation, can effectively assist centralized procurement management.

Artificial intelligence is the science of how to simulate the implementation of human intelligence. Among the many algorithms to achieve artificial intelligence, machine learning algorithms have developed faster and deeper. It is mainly studied how to simulate the implementation of human learning behavior with computers to acquire new knowledge or skills and reorganize the existing knowledge structure to continuously improve its performance. Deep learning is a branch of machine learning, and an algorithm that uses artificial neural networks as an architecture for learning representations of data. It obtains a deeper and more expressive model by superimposing simple models on top of each other. Machine learning can be divided into supervised learning according to whether the input data has labels or not: supervised learning, which models the correlation between several features of data and several labels (types), and unsupervised learning, which models the features of data without any labels, . Compared to supervised learning, unsupervised learning is more like an exploration of the data structure. Supervised learning algorithms can be further classified into subtypes and regression types according to whether the data are discrete or continuous values. Unsupervised learning algorithms can be further classified into aggregation types and dimensionality reduction types according to different operational purposes. In the innovation of centralized material procurement management based on the full-domain set theory, managers can select matching AI algorithms to provide decision support for scenario-specific targeting problems according to management objectives. For example, we can obtain the usage status of various materials in the chain by analyzing and mining the full-domain data of supply chain and production chain, and then combine the supply capacity of suppliers and the current procurement status of enterprises to select suitable algorithms to predict the next optimal procurement time and procurement quantity, thereby reduce the inventory pressure from the whole supply chain level. Currently, the available algorithms are logistic regression, ridge regression, K-means, support vector machine, Bayesian network, neural network, etc., which can be selected according to the actual situation.

### 3.3 Material centralized procurement full-domain linkage algorithm system construction

One of the key points of centralized procurement of materials based on global set theory is the construction of linkage relationship of full-domain data, the algorithm system of centralized procurement of materials involving the algorithm and linkage relationship is defined as follows.

*Unary operation*. The unary operation mainly includes the compound of selection operation, projection operation and relational operations.

*Binary operations*. Binary operation mainly includes Cartesian product operations, renaming operations, and linkage operations.

*Linkage relations*. On the basis of unary and binary operations, the linkage relations of data (Definition 1), the full-domain linkage relations of data (Definition 2), the equality relations of data (Definition 3), and the set size relations of data (Definition 4) are given as follows.

Definition 1: Linkage relations. Given the relations $r_1(R_1)$ and $r_2(R_2)$, $R_1, R_1 \in D$ let $X$ denote a relation instance, $X_1$ be a tuple of $r_1$, $A_1$ be the power set of fields in the relation $R_1$, $A_2$ be the power set of fields in the relation $R_2$, where $a_1 \in A_1$ and $a_2 \in A_2$, then a sample of the generalized Cartesian product between fields satisfying certain conditions from the relation $r_1$ and the relation $r_2$ can form a linkage operation

$$r_1 \rhd\lhd r_2 = \{X_1 \in R_1 \wedge X_2 \in R_2 \vee [X_1(a_1)] \leftrightarrow V[X_2(a_2)]\} \neq \emptyset \quad (1)$$

where $\leftrightarrow$ is the relationship comparator, $V(\cdot)$ is the field value. It can be seen that when $\leftrightarrow$ is the "equal sign",$r_1 \rhd\lhd r_2$ is the equal value link, and if $\{X_1 \in R_1 \wedge X_2 \in R_2 \wedge [X_1(a_1)] \leftrightarrow V[X_2(a_2)]\} \neq \emptyset$ exists, then the relationship $r_1$ is linked to the relationship $r_2$.

Definition 2: Full-domain linkage of data. Given a relation $R_i$ and its corresponding sample $X_i$, for a target system $D = \{R_1, R_2, \cdots, R_n\}$ containing multiple relations in the bounding shell, all relations $U_{j\in[1,n]}R_j$ satisfying the condition $\{X_i \in R_i \wedge X_j \in R_j \wedge V[X_i(a_i)] = V[X_j(a_j)]\} \neq \emptyset$ are full-domain linkage off the sample $X_i$ and $U_{j\in[1,n]}A_j$ is the full-domain field of the sample $X_i$.

Definition 3: Equivalence relationship. For two data samples $X_1$ and $X_2$ located in a common bounding shell $J_1 = J_2$ and business system $D_1 = D_2 = \{R_1, R_2, \cdots, R_n\}$, there is $S(X_1|J_1) = S(X_2|J_2)$ if $X_1$ and $X_2$ have the same full-domain linkage field $B_1^{'} = B_2^{'} = \cup_{i\in[1,n]} A_i$.

Definition 4: Set size relationship. The size of a full set represents the coverage of all data associated with sample $X$ within the bounding shell. Given a full set $S(X_1|J)$ and $S(X_2|J)$ under the condition of bounding shell $J$, the comparison of the set size relationship reflects the probability that the range of values of one full field $B(X_1)$ is greater than the range of values of another full field $B(X_2)$, let $B(X_1) = \{b_{11}, b_{12}, \cdots, b_{1i}, \cdots, b_{1m}\}$, $B(X_2) = \{b_{21}, b_{22}, \cdots, b_{2i}, \cdots, b_{2n}\}$, based on the full probability formula

$$P\{S(X_1|J) \geq S(X_2|J)\} = \sum_{i=1}^{s} P(N_i) P\left\{\frac{V[B(X_1)] \geq V[B(X_2)]}{N_i}\right\} \quad (2)$$

Where $N_i$ denotes the number of possible field range distributions for the $i$-th possible field. $V(\cdot)$ and, obviously, $\sum N_i = max\{m, n\}$. Let the full range of field values be denoted as: $V[B(X_1)] = [X^-, X^+]$, $V[B(X_2)] = [Y^-, Y^+]$, $x^- \in X^-$, $x^+ \in X^+$, $y^- \in Y^-$, $y^+ \in Y^+$.

In particular, when the range of values of the full field obeys the same distribution, the set size relationship can be expressed as

$$P\left\{\frac{V[B(X_1)] \geq V[B(X_2)]}{N_i}\right\} = \min\left\{\max\left\{\frac{x^+ - x^-}{x^+ - x^- + y^+ - y^-}, 0\right\}, 1\right\} \quad (3)$$

However, in many cases, the values of the full field do not necessarily obey the same distribution. For the case where the range of values of the fields do not overlap, the result of Eq. 3 can be followed. For the case where the range of values of the full field overlaps, let the interval between $[x^-, x^+]$ and $[y^-, y^+]$ be $[z^-, z^+]$, where the probability density of $[x^-, x^+]$ is denoted as $\psi_1(x)$ and the probability density of $[y^-, y^+]$ is denoted as $\psi_2(x)$. Dividing $[z^-, z^+]$ into $s$ equal parts and taking the limit, the set size relationship can be expressed as

$$P\left\{V[B(X_1)] \geq \frac{V[B(X_2)]}{N_i}\right\} = \begin{cases} 1, x^- \geq y^+ \\ \int_{y^-}^{z^+} \psi_2 dx - \lim\limits_{s\to\infty} \frac{1}{s^2} \sum_{p=1}^{s} \left\{\psi_2\left[z^- + \frac{p(z^+ - z^-)}{s}\right] \sum_{q=1}^{p} \psi_1\left[z^- + \frac{p(z^+ - z^-)}{s}\right]\right\} \\ 0, y^- \geq x^+ \end{cases} \quad (4)$$

# 4. Theoretical framework of the innovation of centralized material procurement management

## 4.1 Innovation of centralized material procurement target system

The material procurement management of large enterprise groups focuses on supplying materials required for production operations in a timely manner, with the main goal of not affecting the operational production of the enterprise, while ensuring safe production and implementing policy requirements such as low carbon emissions and green environment protection [24]. In this paper, the five comprehensive management objectives of Right quality, Right time, Right cost, Right quantity, and Right place, and the two emerging objectives of Safety and Sustainability are introduced. The "5R+2S" target model of material procurement management is constructed, and a multi-level target spectrum analysis is conducted around the target model, including four levels of target management indicators, business module description, information system, and data sources. The procurement management spectrum framework is shown in Fig. 4.

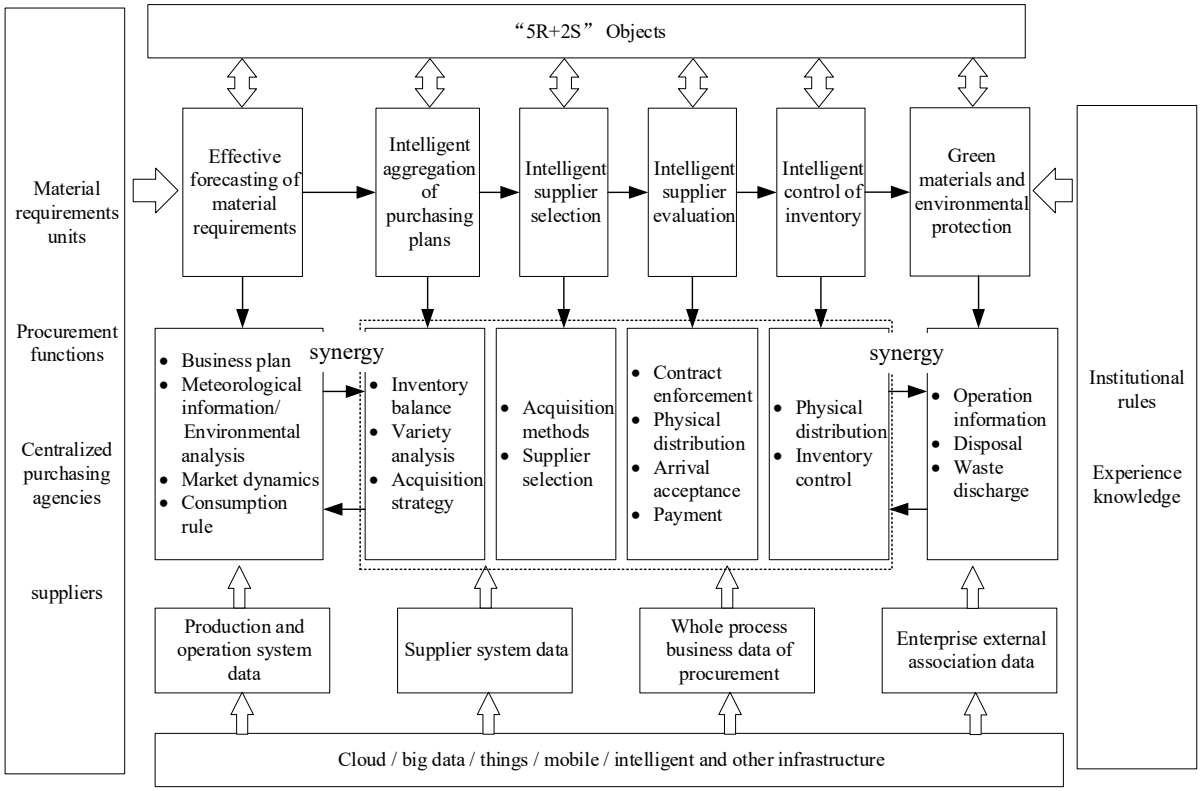


**Fig. 4** Material centralized procurement target system

- Quality (Right quality). Quality management is the life of the enterprise. The purchasing department should establish a strict quality management system, set standards for measuring quality, find out the possible quality problems of the products in the whole area through the analysis of data mining, identify poor quality products at the earliest, and give quality control and quality improvement and other aspects of quality management advice.
- Right time. Procurement managers not only need to achieve on-time and on-demand procurement goals and avoid unnecessary storage and warehousing costs, but also need to ensure supply and minimizing procurement costs in the face of market fluctuations, and maximize the organization's capital utilization and procurement management efficiency. Managers can apply new technologies such as mobile internet, big data, cloud computing, internet of things and artificial intelligence to achieve online, data-based and intelligent material management, and make reasonable forecasts of material consumption and supply time points to ensure supply and cost reduction.

- Right cost. The main indicator to measure the effectiveness of procurement management is the total cost of procurement. The centralized procurement management based on the full-domain set theory can break the information barrier of each link, make the procurement of materials more transparent, and grasp the usage status and inventory situation of the whole life cycle of materials to the greatest extent. Therefore the whole procurement demand chain can be managed prospectively and the procurement cost can be effectively reduced.
- Right quantity. Centralized procurement management based on the full-domain set theory can obtain clear production and demand information for each link in a timely manner. According to the accurate target information, we can use artificial intelligence-related algorithms to forecast the quantity of materials required for the production link and provide decision support for the procurement department.
- Right place. Enterprises are often prone to take the initiative in cooperation with suppliers that are close to them, and it is best for enterprises to choose close suppliers to implement when choosing pilot suppliers. Proximity not only makes it easier for buyers and sellers to communicate and deal with matters more quickly, but also reduces procurement logistics costs.
- Safety. The centralized procurement management of materials based on the full-domain set theory can accurately provide detailed labels for each material, each link in the production process, and even all kinds of data on the environmental conditions required for accidents to occur in the warehouse. Based on the system's analysis and prediction of potential dangers in advance warning, we can maximize the elimination of products and warehouse security risks.
- Sustainability. The centralized procurement of materials based on the full-domain set theory has a strong scale and accuracy, symbolizing not only the comprehensive development of procurement management from paper to electronic, but also the change of management from decentralization to centralization. The accumulation of data gradually improves the accuracy of the algorithm, resulting in more accurate forecasting of demand budgets and a virtuous and sustainable cycle.

### 4.2 Innovation in the management concept of centralized material procurement

In accordance with the concept of supply chain management, we innovate the procurement model and establish a supplier integrity system to reduce procurement costs. Exploring the multi-life cycle management of materials and equipment based on the whole life cycle management of materials and equipment. Specific measures are shown as follows:

- By continuously optimizing and improving the information system, the scientific level of management of the entire supply chain is improved, and upstream and downstream visibility of the supply chain is achieved. The supplier collaboration function deployed in the system realizes horizontal collaboration with suppliers in terms of inventory resources, delivery and receipt, logistics progress and invoice settlement; the big data analysis system provides reliable data and analysis tools for the entire supply chain to carry out decision-making analysis; Through the electronic material issuance intelligence system and the joint management of inventory by suppliers and other aspects of information technology, the collaboration level of the overall supply chain is improved to achieve management low-cost and efficient operation.
- The intensive procurement model was further applied. Carried out framework agreement procurement business for collectively procured materials. We establish a strategic cooperation model with suppliers, set up an integrated information sharing platform for procurement and supply, and establish procurement and supply-wide data. On the other hand, through framework agreements for the procurement of bulk goods, the supply chain cooperation model is continuously innovated.

- Promote localization substitution and new product trials. Study the main content of localization work, the way to carry out it, and how to support and encourage localization work from the material procurement management system and bidding and procurement strategy. For example, set up an assessment index of "completion rate of high-end parts development" to ensure the process and quality of high-end parts development.
- Establish a supplier integrity management system. Use big data technology to establish a secure information channel. We can establish a set of honest supplier management system by continuously optimize business processes, create a clean procurement environment, cultivate a group of honest and excellent suppliers, and provide a guarantee for intensive procurement, sunshine procurement and green procurement.

### 4.3 Innovation of centralized material procurement management mechanism and system

The centralized procurement management of materials based on the full-domain set theory can link information from various departments, so that operations such as demand information reporting no longer have to be done centrally in a limited time, but can be managed as part of daily work and reported in real time. With the help of a global platform, the procurement management department can change the procurement model from the original multi-layer structure to a flatter system, improving the flexibility of the organization and the efficiency of procurement management [25].

Large groups of companies often set up supply chain management committees or similar bodies to lead the group-wide procurement management, with systems and regulations to clarify and ensure that data owners can share the required data with purchasers. In addition, the group needs to work with suppliers to build an appropriate big data sharing system based on the actual situation of each department [26]. At the group level, develop group company procurement strategies, models, basic management systems for procurement management and consider major procurement matters. A full-time procurement management department is set up to independently categorize procurement as responsible for procurement management system construction, centralized procurement plan management, tender and procurement management, information system construction, supplier management, material reserve management and procurement supervision and management, laying the institutional foundation for the realization of a region-wide data platform.

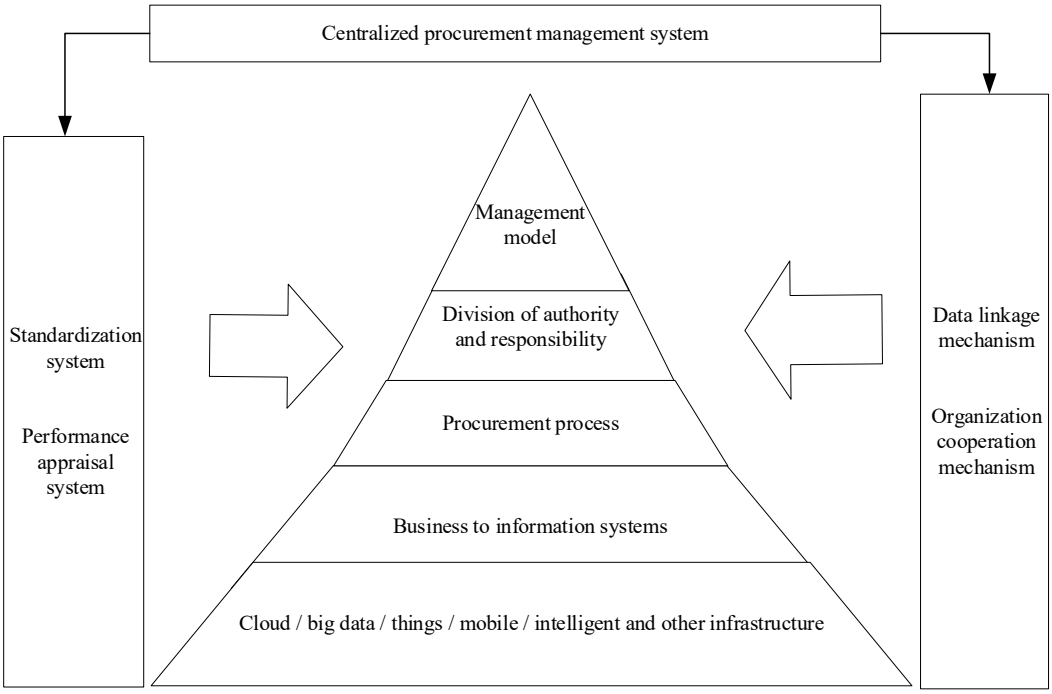


**Fig. 5** Centralized procurement management system

Horizontally, it coordinates various functional departments at the group level to carry out procurement-related business audits, and vertically coordinates enterprises at all levels to ensure smooth information communication. At the same time, a specialized procurement execution unit is set up to execute group-wide procurement operations, forming a management model with "separation of management and administration" and "clear authority and responsibility" with the group's procurement management department to ensure sunshine procurement. Secondary enterprises have a clear department responsible for the implementation of procurement management. The centralized procurement management system is shown in Fig. 5.

## 5. Concluding remarks

In this paper, in view of the problems existing in material procurement management based on big data, the full-domain set theory is introduced, the theoretical basis of material centralized management innovation is discussed, and the corresponding theoretical framework of material centralized management innovation is constructed. The analysis in this paper shows that: Firstly, there are problems of incomplete data, insufficient information circulation and inability to link data in material centralized management in the context of big data. Secondly, the connotation of innovation in material centralized management in the context of big data and its three distinctive features of data integrity, information connectivity and management intelligence are proposed to provide strong support for the in-depth exploration of material centralized management innovation in the perspective of the full-domain. Furthermore, the theory of full-domain set is introduced into centralized material procurement management, proposing a logical framework for centralized procurement of full-domain linkage, and illustrating that existing artificial intelligence algorithms provide a technical basis for the solution of material centralized targeting problem scenarios. Finally, through the innovative definition of the target system, management system, management concept and management mechanism of centralized material procurement, a theoretical framework for centralized material procurement management innovation based on the theory of full-domain set is built. This paper provides innovative ideas for large group enterprises to carry out centralized procurement management in the era of big data.

### Data availability statement

All data could be accessed upon request to the corresponding author.

### Conflicts of interest

The authors declare no conflict of interest.

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