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A Framework of Blockchain-Supported Remanufacturing Trading Platform through Gap Analysis

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Abstract: Considering that consumers are more willing to buy products online, companies are increasingly selling remanufactured products online through e-commerce platforms. Notwithstanding the high attention it elicits from researchers and companies, the study about the remanufacturing trading platform is in its infancy. Thus, we investigate 20 remanufacturing trading platforms related nowadays and make a gap analysis among them in terms of: (i) business model, (ii) product display, (iii) delivery products, (iv) quality assurance and after-sales service, (v) product review and star rate and (vi) transaction and payment. On this basis, we analyze features and trends for the development of remanufacturing trading platforms and propose six key applications aimed at filling the identified gaps. The consortium blockchain has the characteristics of security and transparency, high credibility, traceability and unfalsifiability, low cost, and strong scalability, which can provide effective support for the six key applications. Then, we construct the technical framework and the model of a consortium blockchain-supported remanufacturing trading platform. Further, we analyze the coupling mechanism between consortium blockchain and remanufacturing trading platform to explain how the remanufacturing trading platform supported by consortium blockchain achieves development characteristics. This study provides important guidance for the development, construction, and operation management of remanufacturing trading platforms.

Keywords: remanufacturing trading platform; gap analysis; consortium blockchain; coupling mechanism

1. Introduction

Considering economic development and the increasing pressures of environmental protection, the forces of urban sustainable development are sweeping across the world. In order to promote urban sustainable development, it is necessary to maintain the balance between green and economy in urban development. Due to the dual needs of sustainable development and economic development, remanufacturing has been paid increasing attention. Remanufacturing can save energy 60%, save material 70%, and reduce air pollutant emissions by more than 80%, compared with manufacturing a new one [1]. Since remanufactured products trading is one of the important links in the remanufacturing process, establishing an efficient trading platform plays a vital role in the development of remanufacturing.

Notwithstanding the interest it elicits from researchers and companies, academic research in remanufacturing trading platforms is still in its infancy. Research addressing the trading platform of remanufactured products has focused exclusively on marketing strategy and product service. Fabrizio et al. [2] investigated information and reputation mechanisms in auctions of remanufactured goods and found that the reputation mechanisms operating for goods of different values are different.

João et al. [3] investigated the factors that influence the price difference between used, remanufactured and new iPods, and confirmed that remanufactured products are sold at a discount relative to new products. Xun et al. [4] investigated the influence of e-service offerings in four stages of online transaction on customers' purchase intention of remanufactured products in auctions and fixed-price transactions and indicated that e-service offerings in the information stage have the greatest impact on customers' willingness to pay in the two types of transactions. Kaiying et al. [5] considered the enterprises that sell new products and remanufactured products online under the background of carbon tax policy and studied the optimal online return strategy for remanufactured products. Yu et al. [6] examined the environmental and economic impacts of product-service systems in a highly competitive remanufacturing market and developed a two-phase programming model to capture the key elements that drive the original equipment manufacturer's strategy choice. Zhu et al. [7] studied the two-sided pricing structure of remanufacturing trading platforms and indicated that increased service differentiation would increase the platform's pricing for single-user vendors without affecting multiple users, and profits would increase accordingly. In summary, the development of remanufacturing trading platforms is currently facing three major problems.

Firstly, the traditional remanufacturing trading model has insufficient market influence and asymmetric information between buyers and sellers, making it difficult to match a suitable trading partner in the transaction process. Specifically, the buyer's demand for remanufactured goods and the seller's supply capacity cannot be better matched. Secondly, due to the special nature of remanufactured products, the logistics mode of the existing remanufacturing trading platform cannot meet the customer's demand for transparency and traceability of the logistics and transportation process. The logistics system of the remanufacturing trading platform needs to achieve information transparency and full traceability. Finally, the traditional remanufacturing trading platform lacks a sound system and regulator, its information is easily tampered with, security is poor, and both sides of the transaction often face the challenge of integrity risk and opportunistic behavior.

In recent years, blockchain has emerged as a key disruptive technology in logistics and production systems and has attracted research interest from a wide range of fields [8]. Based on our analysis and research findings, we believe that blockchain technology is an appropriate option to improve the current state of remanufacturing transactions and facilitate the development of remanufacturing trading platforms. Blockchain technology is a distributed data management system with many participating subjects working together to complete the construction and maintenance work, which features distributed storage, multi-party security, cryptographic features, smart contracts, etc [9]. Blockchain technology uses a chain structure to save key data and encrypts the saved data through various cryptographic methods in cryptography to ensure its transmission security. Blockchain's chain structure improves the authenticity and transparency of transaction data [10]. The data is also generated, saved and updated through the corresponding consensus mechanism, and can be saved on all nodes at the same time, eliminating single point of failure and making the information saved on the blockchain system cannot be deleted or modified [11].

Blockchain relies on each node to form a powerful computation that can defend against external attacks without human intervention. Participants can complete transactions in an environment of trust with complete anonymity. It protects the privacy of all parties involved and increases the security and trustworthiness of transactions. In addition, each node on the blockchain stores complete data, and as long as no more than 51% of the nodes in the network are occupied by attackers, the system remains secure and stable [12]. Blockchain technology is an integrated intelligent mechanism that forms a decentralized and scalable ecosystem consisting of a data layer, a network layer, a consensus layer, an incentive layer, a contract layer, and an application layer through the interoperability of each technology or protocol [13].

Rana et al. has developed a blockchain-based healthcare system that helps improve the healthcare environment by eliminating highly complex processes and manual interventions [14]. Choi T M et al. used the mean-variance (MV) approach to investigate the implementation of blockchain technology to facilitate mean-risk analysis of global supply chain operations [15]. Saberi S et al. examine the potential applications of blockchain technology and smart contracts in supply

chain management and provide insights to overcome barriers and adopt blockchain technology for supply chain management [16]. Lin Q et al. propose a food safety traceability system through blockchain and EPC information services technology that can effectively detect and prevent food safety problems and trace responsibility [17]. Babich V et al. fills a gap in this area of research by examining the strengths and weaknesses of blockchain technology as applied to operations management from multiple business and policy perspectives [18]. Orji I J et al. examine a theoretical framework of key factors influencing the successful adoption of blockchain technology in the freight logistics industry and prioritize them in favor of improving overall organizational competitiveness [19]. Kouhizadeh M et al. analyze the use cases of blockchain in different scenarios and examine how blockchain technology can advance the realization of a circular economy [20]. Yang C S et al. studied the application of blockchain in the maritime supply chain and found through empirical analysis that dimensions such as customs clearance and management, standardization and platform development facilitate blockchain-based digitization of maritime transport [21]. Tian Z et al. proposed a blockchain-based method for evaluating customer satisfaction in the context of urban logistics and designed a smart contract to compensate or refund customers when they are less satisfied with the delivery service [22]. Shen B et al. studied the value of blockchain applications for used product resale platforms and showed that horizontal integration was more effective in increasing the total profitability of the supply chain [23]. Manupati V K et al. developed a distributed ledger-based blockchain approach to minimize total supply chain costs and carbon emissions and validated the feasibility of the proposed approach by comparing the results with those of a non-dominated ranking genetic algorithm [24]. Tozanlı Ö et al. incorporate blockchain technology into the formation of manufacturing and logistics architectures to determine optimal trade-in policies that not only maintain the profitability of original equipment manufacturers, but also ensure the sustainability of closed-loop supply chain activities [25]. van Engelenburg S et al. designed and evaluated a blockchain framework for the supply chain to explore its feasibility in reducing information asymmetry while protecting sensitive data [26]. Cai Y J et al. apply blockchain technology to a clothing rental platform to overcome moral hazards and reduce the unethical gains that retailers can make through opportunism [27]. Ismanto L et al. has built a blockchain-based e-commerce platform that improves the security and transparency of the transaction process [28].

These studies show that blockchain technology can better solve supply chain related problems and enable secure and efficient transactions. However, little research has focused on the integration of blockchain technology with remanufacturing trading platforms. Therefore, this research constructs a remanufacturing trading platform based on the consortium blockchain and explores their coupling mechanism. In this research, we study today's trading platforms related to the reverse manufacturing process as far as the model and the service. We carry out our research as a gap analysis of these platforms about their business models and the services they can provide to customers. For the purpose of assessing the limitations of the current remanufacturing trading platforms and finding out the gaps that need to be filled, we compare and analyze typical remanufactured products trading platforms along six different dimensions, including business model, product display, delivery products, quality assurance and after-sales service, product review and star rate, as well as transaction and payment. According to the result of this assessment, we put forward some features for the development of remanufacturing trading platform aimed at filling in the identified gaps.

To the best of our knowledge, our study is the first to analyze the gaps in remanufacturing trading platforms. Our insights serve companies to build a comprehensive remanufacturing trading platform and provide high-quality service for customers and also contribute to the research area of remanufactured product trading.

The rest of this paper is organized as follows. In section 2, we review today's trading platforms related to the reverse manufacturing process. And in section 3, we make a gap analysis of typical trading platforms and list the characteristics of the newly remanufacturing trading platform. This is followed by a consortium blockchain-based remanufacturing trading platform built in section 4. In addition, the results of the remanufacturing trading platform research are discussed in detail in Section 5. Finally, we summarize the conclusions of this research in section 6.

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2. Review of today's trading platforms related to the reverse manufacturing process

In this section, we survey existing trading platforms related to the reverse manufacturing process, including multi-product trading platforms, specialized remanufactured products trading platforms, auto recycling platforms, automobile parts recycling platforms and vehicle recycling data management platforms. The list of the twenty typical trading platforms related is selected, ordered alphabetically and numbered (for example, [Platform 1], where 1 also refers to the "ref" column in Table 1).

Table 1 lists some fundamental states of surveyed platforms, which are designed for distinguishing these platforms. Column (a) describes the types of the platform. Column (b) enumerates the established time of the platform. The regions served by the platform are shown in Column (c).

Table 1. Existing trading platforms related to reverse manufacturing process.

Ref	Platforms	a) Type	b) Established Time	c) Service region
1	Amazon	Multi-product	In 1995	The global
2	ASM Auto Recycling	Auto recycling	In 1986	The UK
3	Beijing Scrap Car Disintegration	Auto recycling	in 1998	China
4	Bejing Xianglong Borui	Auto recycling	In 2010	China
5	CAGDS	Vehicle recycling data management	In 2013	China
6	Callparts	Auto recycling	In 1997	Germany
7	Cambridge Car Solutions	Auto recycling	In 2014	The UK
8	CAMDS	Vehicle recycling data management	In 2009	China
9	CEX	Specialized remanufactured products	In 1992	The global
10	Chaichejian	Automobile parts recycling	In 2006	China
11	eBay	Multi-product	In 1995	The global
12	ELVS	Auto recycling	In 2000	The USA
13	Gigarefurb	Specialized remanufactured products	In 2013	The UK
14	IDIS	Vehicle recycling data management	In the mid-1990s	The global
15	IMDS	Vehicle recycling data management	In 2000	The global
16	JD	Multi-product	In1998	China
17	Lianxin	Auto recycling	In 2019	China
18	Remanshop	Specialized remanufactured products	In 2017	China
19	Shouchezhan	Auto recycling	In 2016	China
20	Taobao	Multi-product	In 2003	China

3. Gap analysis

In the previous section, we introduced the basic information of twenty trading platforms related to the reverse manufacturing process that were surveyed. But in fact, multiple gaps can be discovered among these platforms. According to the type and size of the 20 platforms mentioned in Table 1, we select seven typical platforms: Amazon, eBay, Remanshop, Gigarefurb, CEX, Taobao and JD. And a

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gap analysis is elaborated in this section with the purpose of providing targeted suggestions for building a remanufacturing trading platform. The dimensions covered by the analysis include (i) business model, (ii) product display, (iii) delivery products, (iv) quality assurance and after-sales service, (v) product review and star rate and (vi) transaction and payment.

3.1. Business model

Different business models of platforms appeal to different customer groups to make a profit. Among the seven selected platforms, Amazon, eBay, Taobao and JD are multi-product trading platforms, which sell not only remanufactured products but also general products. The remaining three platforms sell diverse products, but all are related to remanufacturing. Remanshop sells remanufactured automotive parts, while Gigarefurb sells refurbished IT equipment, and CEX mainly aims to second-hand goods chain in technology, computing, video Games, DVDS and technology repair, as summarized in Table 2.

Table 2. Gap analysis of platforms in business model

Platforms	Business model	Gaps
Amazon	•General purchase •B2C e-marketplace	G1.1 The market lacks a professional remanufacturing trading platform G1.2 The customer group determines the business mod
eBay	•General purchase •B2C and C2C E-marketplace	
Remanshop	•Remanufactured automotive parts •B2B e-marketplace	
Gigarefurb	•Refurbished IT Equipment •E-commerce	
CEX	•Second-hand goods chain in technology, computing, video games, DVDs and technology repair •E-commerce •Both physical stores(600+ stores)/online	
Taobao	•General purchase •B2C and C2C e-marketplace	
JD	•General purchase •B2C e-marketplace	

According to the different sellers and customer groups of e-commerce platforms, e-commerce models mainly include B2B(Business-to-Business), B2C(Business-to-Customer) and C2C(Customer-to-Customer). Therefore, Amazon and JD are B2C e-marketplaces. Taobao and eBay are B2C and C2C e-marketplaces since their sellers include not only enterprises but also individual users. And Remanshop is a B2B e-marketplace because it's sellers and customer are both enterprises. Nevertheless, Gigarefurb and CEX are e-commerce platforms, not e-marketplaces. In addition, CEX has more than 600 physical stores offline.

3.2. Product display

What the platform presents to customers seem to be approximate as far as product display is concerned, as summarized in Table 3, they mainly include title, brand, price, condition, reviews, delivery, payment, warranty, etc. However, they still have subtle differences. For instance, buyers

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communicate with sellers only by email on Amazon, and they are more likely to use reviews and Q&A to get product information. On other platforms, buyers usually communicate with the platform's customer service online nevertheless.

Table 3. Gap analysis of platforms in product display

Platforms	Product display	Gaps
Amazon	•Title, brand, product information, product guides and documents, videos, product description, the manufacturer, review etc. •Communicate via email •Suggests a Buy Box	
eBay	•Title, condition, item specifics, seller information, compatibility, payment, shipping etc. •Online communication	
Remanshop	•Product name, id, price, model, matching car model, emission (for engines), year of made, quantity, detailed introduction of seller, review of product, questions about the product etc. •Online communication	G2.1 Product presentation in line with customers' habits
Gigarefurb	•Name, code, description, specification, price, payment, reviews, warranty etc. •Online communication	G2.2 Effective communication
CEX	•Name, price, condition, introduction, reviews, warranty etc. •Online communication	
Taobao	•Name, price, color classification, introduction, reviews, service commitment, payment, distribution etc. •Online communication	
JD	•Name, price, color classification, introduction, specifications and packing, after-sale protection, reviews, distribution etc. •Online communication	

In terms of product search results, the platforms present results to customers owing to their own set of algorithms. For example, Amazon's catalog makes it easy for customers to compare prices and suggests a Buy Box in product search results. While eBay presents customers with many results for screening and research, hence, customers need to compare them through product details so as to select their favorite product. However, other platforms display all search results ranking them by relevance.

3.3. Delivery products

There are two ways for today's trading platforms to deliver products to customers: self-run logistics and third-party logistics. For instance, Amazon has its own distribution mode: FBA (Fulfilment by Amazon), as shown in Table 4. Similarly, in China, JD has FBP (Fulfillment By POP) distribution mode and SOP (Sale On POP) distribution mode while Taobao's Tmall also has its own logistics distribution mode, and they commonly can deliver products to consumers as soon as the

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same day or the next day. Furthermore, many trading platforms have no independent logistics systems so they need to rely on third-party logistics companies to achieve product delivery. As a consequence, they spend more time delivering products than platforms that have their own independent delivery systems.

Table 4. Gap analysis of platforms in Delivery products

Platforms	Delivery products	Gaps
Amazon	•Do-it-yourself •Amazon deliver- Fulfilment by Amazon (FBA).	G3.1 Self-run logistics and third-party logistics
eBay	•Delivery by sellers	
Remanshop	•Delivered by remanufacturing enterprises	
Gigarefurb	•Delivery arranged by Gigarefurb •Next Day Delivery	
CEX	•Delivered via Royal Mail, delivery should take no more than 3 to 5 working days	
Taobao	•Delivery by sellers	
JD	•FBP distribution mode and SOP distribution mode	

3.4. Quality assurance and after-sales service

Table 5 shows that platforms have different regulations on the warranty and after-sales service. For remanufactured products, trading platforms other than CEX typically offer a one-year warranty. As mentioned in Table 5, after-sales service for products includes return service and exchange service. We discovered that both Taobao and JD offer a '7 days refundable, 15 days exchangeable' service to customers. In addition, Remanshop provides return and exchange service for customers within 7 days if the conditions are met. Amazon offers to buy or return service within 30 days for AmazonBasics brand, while a money-back guarantee policy is offered by eBay.

Table 5. Gap analysis of platforms in Quality assurance and after-sales service

Platforms	Quality assurance and after-sales service	Gaps
Amazon	•Buy or return an AmazonBasics brand within 30 days, with a one-year limited warranty	G4.1 Provide a long warranty G4.2 Return and exchange time
eBay	•Offer a money-back guarantee policy •12 months warranty	
Remanshop	•Provide return and exchange service within 7 days if the conditions are met •12 months warranty	
Gigarefurb	•12 months warranty	
CEX	•24-Months Warranty. •Removable consumable parts - will be covered for 30 days from purchase. •Non removable consumable parts - sealed batteries will be covered for the full duration of the warranty	
Taobao	•7 days refundable, 15 days exchangeable •12 months warranty	

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JD	•self-run commodities: return goods within 7 days without any reason the goods of the three parties: 7 days refundable, 15 days exchangeable •12 months warranty

3.5. Product review and star rate

In our opinion, customers are more likely to judge the quality of goods and logistics services by browsing the reviews and stars of goods in the selection process. After the order is finished, customers will review and rate the products. As shown in Table 6, each platform nearly has diverse systems for product review and star rate. Remanshop and CEX invite customers to finish comprehensive evaluation (1-5 stars) while Gigarefurb invites customers to finish two evaluations covering reviews for individual products and reviews for platforms. Besides, Amazon, eBay and Taobao invite customers to accomplish comprehensive evaluations (good, medium and poor), and the corresponding indicators are evaluated one by one. It's also worth mentioning that the evaluation system of JD is divided into product satisfaction (1-5 points) and after-sales service satisfaction (platform monitoring index).

Table 6. Gap analysis of platforms in Product review and Star rate

Platforms	Product review and Star rate	Gaps
Amazon	•Comprehensive evaluation (good, medium and poor) •The consumer's single score (+1, 0, -1) is directly accumulated as the merchant's final credit score	
eBay	•Comprehensive evaluation (good, medium and poor) •Whether the product is consistent with the description, the satisfaction of communication with the seller, the satisfaction of delivery speed, and the reasonable degree of transportation cost	
Remanshop	•Comprehensive evaluation (1-5 stars)	G5.1 Different evaluation indicators G5.2 The impact of the Evaluation results
Gigarefurb	•Reviews for individual products, reviews for platforms (1-5 stars)	
CEX	•Comprehensive evaluation (1-5 stars)	
Taobao	•Comprehensive evaluation (good, medium and poor) •The degree of conformity with the description, the service attitude of the seller, and the quality of the logistics service	
JD	•Divided into product satisfaction (1-5 points), after-sales service satisfaction (platform monitoring index) •Product description matching, seller's service attitude, logistics delivery speed, delivery personnel's attitude, transaction dispute rate, return and exchange rate, repair rate, after-sale processing time	

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3.6. Transaction and payment

The general process of commodity transactions is as follows:
(1) The buyer submits the order.
(2) The buyer makes the payment, and the payment is kept by the platform.
(3) The seller delivers the goods.
(4) The buyer receives the goods.
(5) The platform pays the payment to the seller.
(6) The evaluation of the buyer.

Different from the above, other transaction processes have been introduced by Amazon, Taobao and JD in order to provide more convenient services for customers. To be specific, Amazon, Taobao and JD all provide 'Payment after Arrival of Goods' for customers who meet their requirements. In addition, Taobao and JD have launched 'Use First, Pay Later' and 'Try First, Pay Later' services respectively. In order to respond to the clients' various payment needs demands, the trading platform provides customers with different payment methods, as shown in Table 7.

Table 7. Gap analysis of platforms in Transaction and Payment

Platforms	Transaction and Payment	Gaps
Amazon	•General Transaction Procedures •Payment after Arrival of Goods •Online payment includes: credit/debit card payment; Alipay and WeChat payment; Gift Card Payment •Payment after Arrival of Goods: cash, POS machine	
eBay	•General Transaction Procedures •PayPal, credit card, check or money order	
Remanshop	•General Transaction Procedures •Alipay, bank remittance	
Gigarefurb	•General Transaction Procedures •PayPal, credit/debit card	
CEX	•General Transaction Procedures •Cash payment, Visa and Mastercard credit cards, Visa Debit, Maestro and Solo debit cards, CeX voucher, Apple/Android Pay	G6.1 Special transaction process
Taobao	•General Transaction Procedures •Use first, pay later, Payment after Arrival of Goods •Online payment includes： Alipay pay, bank card pay, Alipay friends help pay, cash. •Payment after Arrival of Goods: cash, POS card and other mobile payments.	G6.2 A variety of payment methods
JD	•General Transaction Procedures •Try first, pay later, Payment after Arrival of Goods •Online payment includes: Jingdong payment (Jingdong IOU, pocket money, wallet balance, coins, etc.), online bank payment, WeChat payment, WeChat friend payment; •Payment after Arrival of Goods: cash, POS card, check; •Company Transfer.	

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3.7. Features of the new remanufacturing trading platform

In the previous section, we evaluated today's trading platforms related to the reverse manufacturing process with a thorough gap analysis. In this section, features and trends for the development of remanufacturing trading platforms will be made in view of the identified gaps.

Feature 1: Multiple customer groups. From the viewpoint of the business model, the market lacks a professional remanufacturing trading platform at present. In our opinion, the platform builder first needs to determine the customer group of the platform to determine the business model of the platform. Based on the survey results, we suggest that platform builders build a B2C and C2C combined e-commerce platform in order to attract both enterprise users and individual users.

Feature 2: Transparent and efficient transaction. When designing the product display page, the platform builder should show the features of the product to consumers to help consumers quickly understand the product. As for designing the search algorithm, the optimal search results should be sorted according to the relevance of the keywords entered and the shopping habits of consumers. In the design of communication between sellers and buyers, the platform builder should aim to provide convenient and effective communication.

Feature 3: Reliable logistics and distribution. When it comes to delivery products, remanufacturing platform builders need to decide whether to build their own logistics system in consideration of their economic and technological level. Generally speaking, when the scale of remanufacturing platform is small, it is more reasonable to use the third-party logistics platform to realize product distribution. In contrast, remanufacturing platforms can maximize benefits by means of building their own logistics systems while the platform arrives on a larger scale.

Feature 4: High level of after-sales service. The remanufacturing platform can quickly attract the customers and expand customer base by extending the warranty period of remanufactured products and improving the quality of after-sales service. Furthermore, consumers have a prejudice against remanufactured products [29]. As a consequence, the after-sale service of remanufactured products should be attached importance by platform builders.

Feature 5: Effective product evaluation. It has been demonstrated that customers can get up-to-date information about products and services from other customers through product reviews and star ratings, thus influencing customers' purchase intention [30]. Therefore, while auditing product quality and improving service quality, platform builders should also build reasonable evaluation system to help buyers objectively evaluate the whole process of product purchase.

Feature 6: Diversified payment modes. In terms of the transaction of remanufactured products, some distinctive modes can be provided by platform builders for attracting customers such as 'Payment after Arrival of Goods'. Beyond that, they should provide various payment methods to meet the needs of different customers.

In order to satisfy the features and trends for the development of remanufacturing trading platforms, six key applications were proposed which contain transaction matching, payment and settlement, logistics management, trading information, commodity information and credit rating. Furthermore, blockchain technologies can provide effective support for the six key applications, especially in solving the problems of poor traceability and low transaction efficiency as shown in Figure 1.

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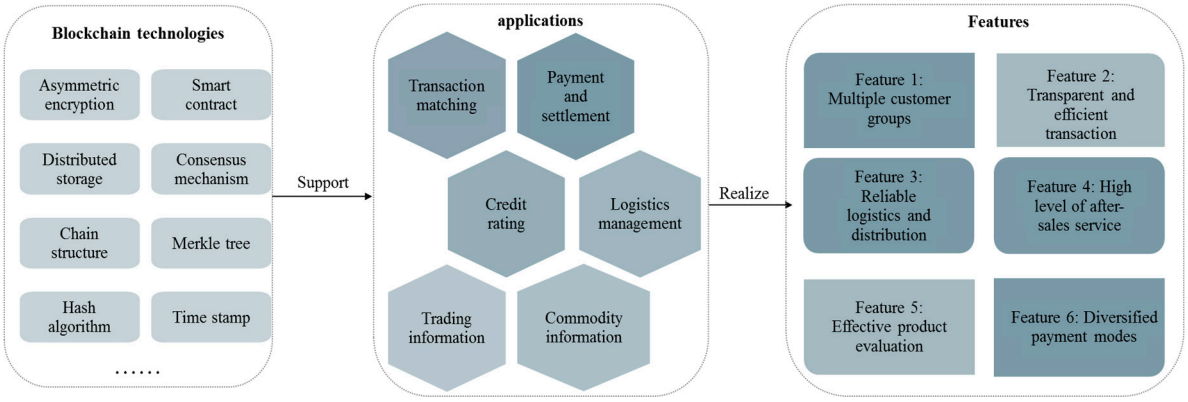

Figure 1. Key applications supported by blockchain

4. Consortium blockchain-based remanufacturing trading platform

4.1. Categories of Blockchain

At present, blockchain technology is divided into the public chain, private chain and alliance chain according to different access criteria and thresholds, and the three categories differ in terms of the form of participation and the subject-oriented. The public chain is an open blockchain, where people in the network can join or exit at will through the blockchain nodes, and carry out processes such as recording and reading of public chain data. The private chain is controlled by an organization or an individual, and the read access can be optionally developed for the public. Its small number of nodes, more centralized data and lack of decentralization are suitable for specific organizations or small enterprises. The consortium chain is a form of technology between public and private chains, capable of setting permissions for personnel access under certain rules, ensuring distributed and decentralized features while retaining part of the centralized control, with the characteristics of high trustworthiness, low cost and scalability. Through consensus protocols, multiple organizations can join together to create a consortium system for a common purpose [31].

4.2. Consortium blockchain-based technology framework for remanufacturing trading platform

With its low cost, high trustworthiness, stability and data transmission security, consortium blockchain provides effective technical support for the construction of the framework of remanufacturing trading platform. The consortium blockchain decentralized remanufacturing transaction system can ensure the safety of other nodes when a single node is attacked, and the distributed ledger can effectively prevent over-centralization of remanufacturing transaction information storage. For the signature and verification method of encryption technology, a certificate-free signature scheme can be used, thus ensuring the traceability of data information and reducing the cost of traceability. In addition, smart contracts can improve the efficiency and credibility of remanufacturing transactions, complete the supervision and audit of information related to personnel in the whole chain, and greatly improve the effectiveness of supervision.

In the previous sections, we assessed today's trading platforms related to the reverse manufacturing process and proposed trends in the remanufacturing trading platforms by analyzing the gaps in business models, product display, delivery of products, quality assurance and after-sales service, product reviews and star ratings, and transactions and payments for the seven platforms. In order to overcome the shortcomings of traditional e-commerce platforms, comply with the development of remanufacturing trading platforms and achieve sustainable urban development, we propose a technological framework for remanufacturing trading platforms based on a consortium blockchain. The platform contains four types of nodes: enterprise, customer, third-party logistics (3PL), and regulator. These four nodes share data through the consortium blockchain-based remanufacturing trading platform, as shown in Figure 2.

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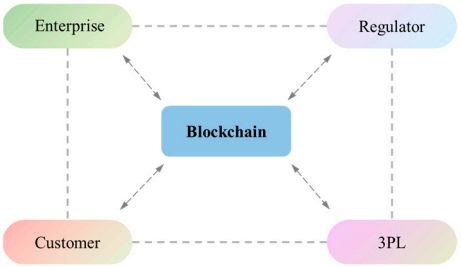

Figure 2. Node types

In consortium blockchain, all nodes participating in transactions are nodes that have been authenticated by the organization, and the purpose of enterprises and customers joining the remanufacturing transaction platform supported by consortium blockchain is to match transactions, share information, track transactions and evaluate feedback, rather than to obtain certain rewards. Therefore, there is no incentive layer in the technical framework of the consortium blockchain-based remanufacturing trading platform, and there are five layers of structure, as shown in Figure 3.

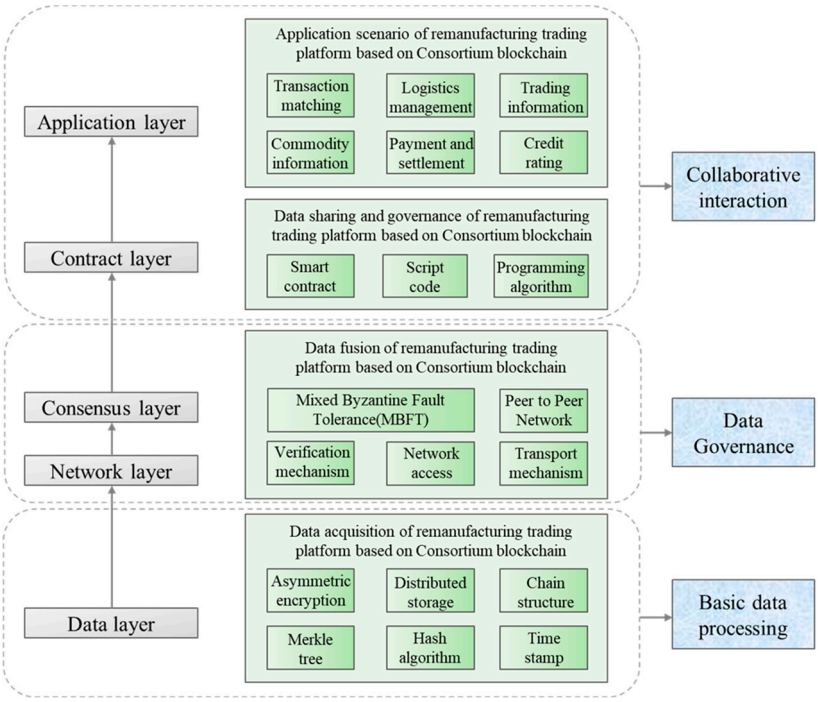

Figure 3. Technology framework

Among them, the data layer is the underlying data structure of the consortium blockchain and is the basic module of the platform technology framework, which contains asymmetric encryption, distributed storage, chain structure, Merkel tree, hash algorithm and time tamp, mainly completing the basic data processing of the remanufacturing trading platform and improving the accuracy and security of data information. The network layer consists of Peer to Peer (P2P) network, verification mechanism, network access, and transport mechanism, which ensures that all nodes on the blockchain can participate in the transmission and interaction of data on the remanufacturing trading platform on an equal footing. The consensus layer includes consensus mechanism and consensus algorithm. Due to a large number of enterprises and customers of the remanufacturing trading platform and frequent transactions, we choose Mixed Byzantine Fault Tolerance (MBFT) as the consensus mechanism. It uses slicing and layering techniques to functionally partition the nodes involved in the consensus process, and MBFT also introduces a random node selection mechanism and credit mechanism with good scalability, security, and high throughput [32]. The contract layer encapsulates various types of script codes and algorithms, and through the combination of different

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rule variations, it derives smart contracts with complex structures and diverse functions. Smart contracts are self-managed electronic contracts, and nodes will automatically execute transactions when the corresponding terms are touched, ensuring intelligent execution of contracts and improving the data processing efficiency and transaction speed of the remanufacturing trading platform. The application layer not only provides services to the members of each node on the blockchain but also provides many business services for the supply chain. The application layer contains various application scenarios in the operation of the remanufacturing trading platform, including transaction matching, logistics management, transaction information, commodity information, payment and settlement, and credit rating. Through the application layer of blockchain, the whole process of the remanufacturing trading platform is made open and transparent, and all information can be queried and monitored in real-time by each node in the transaction process. At the same time, due to the high reliability of blockchain information, complete transaction information and financial information are provided to the regulator of the platform, which ensures the supervision and credit evaluation of the transaction process, reduces labor costs and also greatly improves the efficiency of supervision.

4.3. Consortium blockchain-based remanufacturing trading platform model

The data of remanufacturing trading platforms has the characteristics of sensitivity, privacy and antagonism, so it is very important for data authority management. In the previous section, we proposed four nodes on the blockchain and designed a technical framework for a remanufacturing trading platform supported by the consortium blockchain. Based on the four-node type and technical framework, we constructed a remanufacturing trading platform model, which consists of data chain, transaction chain, P2P network, application framework and technical framework, as shown in Figure 4.

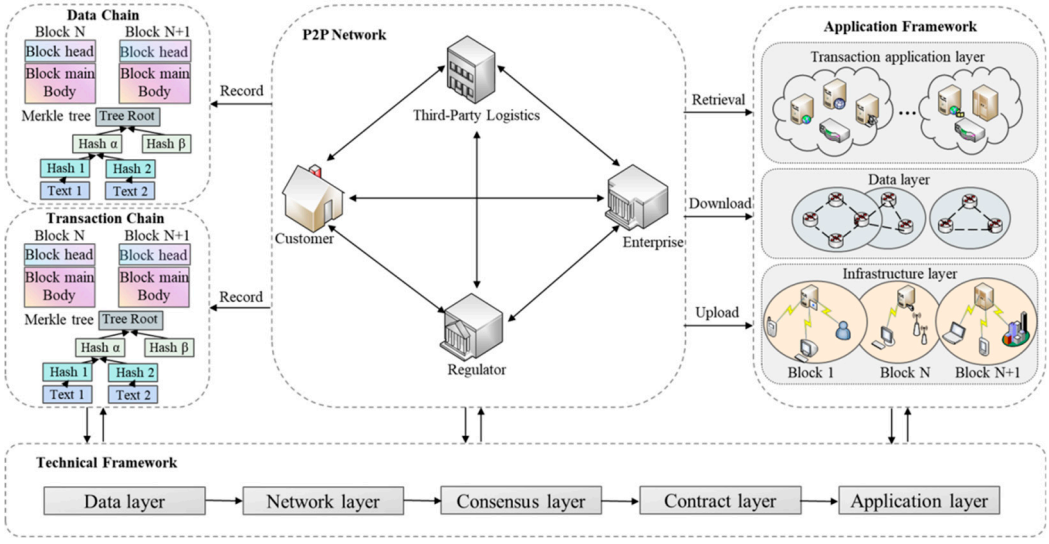

Figure 4. Remanufacturing trading platform model based on Consortium blockchain

The application framework contains an infrastructure layer, a data layer, and a transaction application layer to provide data sources and interaction interfaces for the remanufacturing trading platform. Among them, the infrastructure layer is necessary for the whole platform, providing software and hardware equipment for platform construction. The data layer mainly completes the distributed storage of remanufacturing trading platform data. In addition, all nodes on the blockchain maintain a distributed ledger, and enterprises and customers can rely on the data on the distributed ledger to perform different operations. The transaction application layer is the core of the application framework, providing service interfaces for data transmission, retrieval and transaction of the remanufacturing trading platform. Nodes in the consortium blockchain can complete platform services such as transaction matching, logistics management, transaction information, commodity

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information, payment settlement and credit rating through these interfaces. The data chain is used to store the ciphertext and key obtained using asymmetric encryption technique and hash algorithm, and encapsulates all data into a block with time stamp. The transaction chain mainly stores transaction information, order information, logistics information, etc., ensuring the traceability and immutability of remanufacturing trading platform data.

4.4. The coupling mechanism of consortium blockchain and remanufacturing trading platform construction

The consortium blockchain's asymmetric cryptography, smart contracts, consensus mechanism, timestamps, distributed storage, chain structure and other features make the consortium blockchain decentralized, transparent information, automatic execution, safe and reliable, traceable and unforgeable. The consortium blockchain will support the construction of the remanufacturing trading platform from six main aspects: accurate matching of transactions, data security supervision, accurate traceability of transaction items, intelligent logistics management, payment and settlement management, and credit evaluation of each node to improve the function and efficiency of the modern remanufacturing trading platform and further promote the intelligent development of the remanufacturing industry.

The remanufacturing trading platform based on consortium blockchain is centered on blockchain technology, and its technical framework and platform model meet the requirements of data governance in the remanufacturing transaction process, reducing costs and improving transaction efficiency. In the remanufacturing trading platform, information needs to be exchanged and stored equally among the nodes, and the technology of consortium blockchain can just guarantee the integrity of information access among multiple nodes. Secondly, consortium blockchain technology enables every transaction to be saved on the chain, and enables efficient and tamper-proof exchange across the chain with digital signatures and asymmetric encryption, enabling remanufactured transactions between nodes under low-cost trust. In order to better reveal the inner logic of blockchain technology supporting the construction of the remanufacturing trading platform, we depicted the coupling mechanism between consortium blockchain and remanufacturing trading platform construction, as shown in Figure 5.

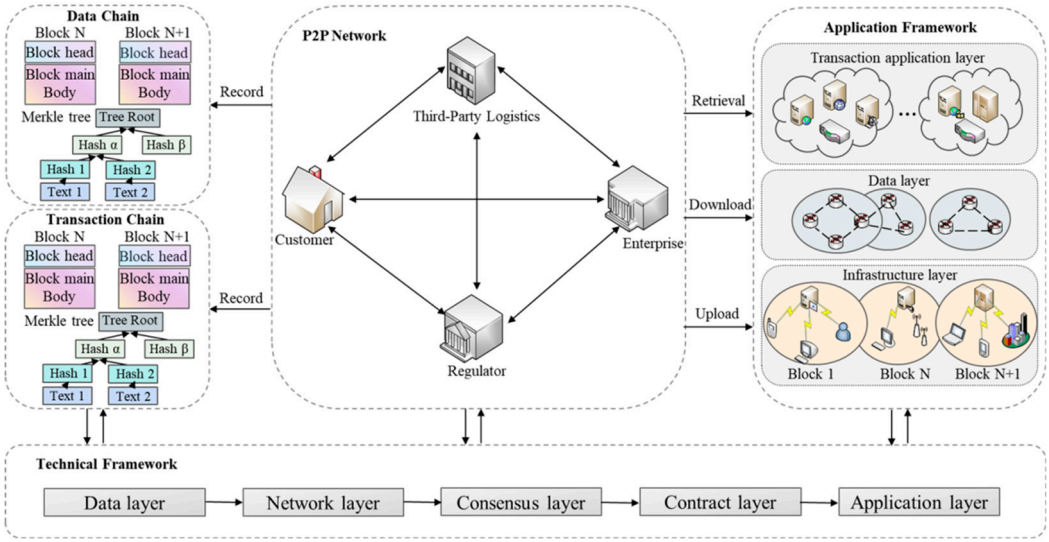

Figure 5. Blockchain and remanufacturing trading platform coupling mechanism

5. Discussion

Due to the imperfect structure and information asymmetry of the remanufacturing trading platform, enterprises and customers have difficulties in transaction matching, transaction traceability, logistics management, payment and settlement, and credit rating, etc. Consortium blockchain protects the privacy of all participants with asymmetric cryptography, smart contract, consensus mechanism, timestamps, distributed storage, and chain structure, which increases transaction

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security and credibility, making the remanufacturing trading platform with the advantages of decentralisation, information transparency, automatic execution, safety and reliability, traceability and non-falsification.

In our research, we first investigated and analyzed 20 remanufacturing trading platforms, and analyzed their gaps from six aspects: business model, product display, delivery products, quality assurance and after-sales service, product review and star rate, and transaction and payment. On this basis, we put forward the development characteristics and trends of remanufacturing trading platforms: Multiple customer groups, Transparent and efficient transaction, Reliable logistics and distribution, High level of after-sales service, Effective product evaluation, and Diversified payment modes. In order to solve the problems of poor traceability and low transaction efficiency of the remanufacturing trading platform and realize the six development characteristics obtained through the gap analysis, we propose a technical framework for the remanufacturing trading platform based on the consortium blockchain. The platform contains four types of nodes: enterprises, customers, third-party logistics (3PL) and regulators, which share data through a blockchain-based consortium remanufacturing transaction platform. The technical framework of remanufacturing trading platform based on consortium blockchain is composed of data layer, network layer, consensus layer, contract layer and application layer. Among them, the data layer is the underlying data structure of the consortium blockchain, which is mainly responsible for the basic data processing of the remanufacturing trading platform; The network layer ensures that all grade points participate in data transmission and interaction in an equal position. The consensus layer includes the consensus mechanism and consensus algorithm. We choose hybrid Byzantine fault-tolerant (MBFT) as a consensus mechanism, so that all nodes can reach consensus in the decentralized network. The contract layer encapsulates various types of script codes and algorithms to ensure the intelligent execution of contracts and improve the data processing efficiency and transaction speed of the remanufacturing trading platform. The application layer includes various application scenarios in the operation process of the remanufacturing trading platform, including transaction matching, logistics management, transaction information, commodity information, payment settlement and credit rating.

Based on this technical framework, we build a remanufacturing trading platform model, which is composed of data chain, transaction chain, P2P network, application framework and established technical framework. The core of the application framework is the transaction application layer, which provides service interfaces such as data transmission, retrieval and transaction of the remanufacturing trading platform. Nodes in the consortium blockchain can complete platform services such as transaction matching, logistics management, transaction information, commodity information, payment settlement and credit rating through these interfaces. The data chain is used to store ciphertext and keys, encapsulating all data into a time-stamped block. The transaction chain stores transaction information, order information, logistics information, etc., to ensure the traceability and security of the data of the remanufacturing trading platform.

Finally, we analyzed the coupling mechanism of consortium blockchain and remanufacturing trading platform construction, and explained how the platform can help enterprises and customers solve remanufacturing transaction problems from six aspects: accurate matching of transactions, data security supervision, accurate traceability of transaction items, intelligent logistics management, payment and settlement management, and credit evaluation of each node. First of all, according to the commodity information and demand information uploaded by the two sides of the transaction, the platform obtains the optimal transaction scheme through the transaction matching algorithm, and provides the results to the two sides of the transaction as a reference basis for decision-making, so as to improve the transaction efficiency and economic benefits. Secondly, due to the sensitivity and antagonism of remanufacturing transaction data, it is difficult to ensure data security in the transaction process. The platform uses technologies such as asymmetric encryption and distributed storage to improve the accuracy and security of data information and ensure that the whole process of data supervision is controllable. In addition, the platform permanently records transaction information and logistics information on a distributed ledger, which facilitates accurate traceability

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and intelligent logistics management. Fourth, due to the decentralized structure, the platform also supports Payment methods such as 'Payment after Arrival of Goods' to meet the payment needs of different customers. Finally, the behavior of enterprises and customers will be permanently recorded on the platform, and both sides of the transaction can view the credit rating of both sides during the selection exchange, thus improving the quality of remanufacturing transactions.

6. Conclusions

This article focuses on practical issues in the remanufacturing trade, and based on the results of literature analysis and structured research, we have surveyed a number of available remanufactured products trading platforms as far as the model and the service. The trading platforms related to the reverse manufacturing process were evaluated via a gap analysis that outlined their gaps in (i) business model, (ii) product display, (iii) delivery products, (iv) quality assurance and after-sales service, (v) product review and star rate and (vi) transaction and payment. Collectively, these gaps reflect the difference of the emphases in the platform construction of each trading platform.

Based on the results of the survey and the gap analysis, we propounded the characteristics of a new remanufacturing trading platform. Considering the characteristics of a new remanufacturing trading platform, we choose the consortium blockchain to build a remanufacturing trading platform and design its technical framework and platform model. We depict the coupling mechanism between consortium blockchain and remanufacturing trading platform construction from five aspects, and structurally reveal the intrinsic correlation features between them. The consortium blockchain-based remanufacturing trading platform presented in this paper could potentially benefit both the policymakers and practitioners in remanufacturing trading platforms.

In future research, the mechanism of blockchain supporting the construction of remanufacturing trading platform can be further explored to provide design principles and analysis basis for the optimization and upgrading of remanufacturing trading platform. In addition, we need to realize that diversified cutting-edge technologies are required to complete the profound changes in the remanufacturing trading industry, and we should integrate and develop the remanufacturing trading platform ecosystem with technologies such as big data, 5G, and IoT, so as to achieve the transformative optimization of the remanufacturing trading platform.

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Appendix A. Reviewed the remanufacturing trading platforms

Platform 1: Amazon (https://www.amazon.com/)

Amazon is the shopping platform of the world's largest e-commerce company. Amazon provides consumers with 32 categories and tens of millions of products, including books, music, movies, cell phones, digital, home appliances, toys, health, beauty and makeup, watches and jewelry, clothing and bags, shoes and boots, sports, food, mother and child, sports, outdoor and leisure, IT software, etc. Through "home delivery" service and Through "home delivery" service and "cash on delivery", Amazon provides consumers with a convenient and fast online shopping experience.

Platform 2: ASM Auto Recycling (https://www.asm-autos.co.uk/)

ASM Auto Recycling is widely regarded as one of the most modern and professional vehicles salvage agents and parts recyclers in the UK. It also has an extensive used car parts center, with over 2,500 cars stored for dismantling at their facility, ASM can supply used car parts for a huge range of

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cars in the UK and around the world. Customers can also purchase a large selection of used car parts using the ASM Autos eBay store, which stocks a wide range of tested engines, alloy wheels, stereos, navigators and more. Car dealers, car dealers and the public can also use ASM's fast professional scrap collection service.

Platform 3: Beijing Scrap Car Disintegration (http://jtc.cn/index.html#bloc-5)

Beijing Scrap Car Disintegration is always committed to serving customers and society, actively promoting the use and development of renewable resources, constantly exploring the experience of recycling, dismantling and reuse of spare parts of end-of-life vehicles, and establishing a set of operating procedures for recycling and dismantling of end-of-life vehicles as well as rules and regulations for the flow chain. In recent years, they have changed the previous crude dismantling, added new devices such as assembly dismantling platform, briquetting machine, shearing machine and sewage treatment equipment and facilities that are conducive to the recycling of renewable resources, and carried out comprehensive ground hardening for the plant against seepage, and invested a total of more than 20 million yuan to strengthen environmental protection construction.

Platform 4: Bejing Xianglong Borui (https://xlbrauto.bxam.com.cn//article/1005.html)

With auto sales and maintenance business as the core, Bejing Xianglong Borui has gradually developed into an auto service trade enterprise integrating parts marketing, used car brokerage, special maintenance, auto decoration, auto testing, scrap car dismantling, insurance claims, technical consultation and information service, and operating in the whole industry chain. The business scope of the enterprise is: recycling and dismantling of end-of-life vehicles; sales of dismantled scrap metal; sales of dismantled auto parts; technical promotion services, etc.

Platform 5: CAGDS (http://www.cagds.org.cn/)

CAGDS is an information platform built for automobile manufacturers to meet the requirements of domestic and international regulations, implement producer responsibility, and provide technical support and guidance for end-of-life vehicle recycling and dismantling enterprises. With the help of this system, vehicle enterprises can easily and conveniently complete the filling and release of model dismantling information and realize efficient management of model dismantling data and information, while dismantling enterprises can make real-time inquiries online to quickly and accurately guide actual dismantling operations. CAGDS is mainly for vehicle enterprises and scrap car recycling and dismantling enterprises, and the vehicle enterprises release scrap car dismantling information online through CAGDS, and the scrap car recycling and dismantling enterprises inquire dismantling information online, so as to guide the dismantling enterprises to dismantle scrap cars in an environmentally friendly, safe and efficient way. It is used to guide dismantling enterprises to dismantle and recycle end-of-life vehicles in an environmentally friendly, safe and efficient manner.

Platform 6: Callparts (http://www.callparts-recycling.de/)

Callparts has its own recycling and dismantling factory, with a large number of remanufactured parts and inventory workshops, parts products involving German Volkswagen, Audi, BMW and many other brands of car companies, and with these car companies to reach a targeted recycling feedback processing reporting mechanism, Callparts specifically developed for the whole life cycle of auto parts traceability management system, and secondly. Callparts with the help of the Internet platform to achieve convenient and fast parts search rather than the traditional on-site one-to-one customer (individual or repair business) demand to achieve a great expansion of the parts business customer base, exponentially improve the degree of customer cheap, subverting the traditional auto disassembly parts business model.

Platform 7: Cambridge Car Solutions (https://www.cambridgecarsolutions.co.uk/)

Cambridge Car Solutions is a specialist company based in Fordham, Cambridgeshire. They offer a 24 hour breakdown and recovery service nationwide, as well as secure vehicle storage and vehicle diagnostic services in Cambridgeshire, Suffolk and Norfolk. Cambridge Car Solutions also offer vehicle parts available for sale, and if you want to sell your old or scrapped vehicle, they offer a free collection service .

Platform 8: CAMDS (http://www.camds.org.cn/)

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CAMDS helps the automotive industry to carry out information management of all links and levels of products in the automotive parts supply chain. With the help of this system, parts suppliers can complete the filling and submission of parts products to vehicle manufacturers, clarify the use of basic substances and materials of parts, and carry out unified classification management of the products filled in. On the basis of this data, vehicle manufacturers can complete the tracking and analysis of the use of banned/restricted substances in vehicle products at various stages of product design, manufacturing, production, sales and end-of-life recycling, providing the automotive industry with a solution that can track the chemical composition of parts and components throughout the supply chain and comprehensively improve the level of end-of-life recycling of automotive parts and components materials.

Platform 9: CEX (https://uk.webuy.com/)

CEX is a British second-hand retailer, mainly in the field of technology and entertainment products, second-hand category of products from cell phones, computers, headphones and other electronic products, to games, albums, movies and DVDs, such as entertainment products, everything, CEX not only online website recycling and sales of second-hand products, but also offline physical stores for customers to trade.

Platform 10: Chaichejian (http://www.chaichejian.com/)

Chaichejian website has established integrity in the industry through wrecking parts alliance, auto aftermarket science and technology innovation center; relying on maintenance technology network, wrecking parts network, reuse parts network, collection station, violation query network, auto parts network, auto supplies network, auto repair equipment network and other hit selection, B2C platform, has attracted more than 5000 auto parts stores, more than 80,000 auto repair shops to join.China Wrecking Parts Network is the world's first professional e-commerce trading platform for wrecking parts, sponsored by Guangzhou Wrecking Parts Information Technology Co., Ltd, which is the website of China Auto Aftermarket Network; dedicated to providing comprehensive and authoritative information services for auto parts stores, auto repair shops, auto users and parts factories on scrap cars, wrecking parts, accident cars, car salvage, auto repair, remanufacturing, etc.

Platform 11: eBay (https://www.ebay.cn/)

eBay is an online auction and shopping site that allows people around the world to buy and sell items online. Every day, millions of pieces of furniture, collectibles, computers, and vehicles are listed, sold, and sold on eBay. Items can be listed on eBay as long as they do not violate any laws or are on eBay's prohibited listings. Services and virtual items are also available for sale. eBay launched a new service called "Instant Sales" on October 23, 2018, to help users sell their old smartphones on its online marketplace. Consumers use eBay's "Instant Sale" feature to sell their old phones.

Platform 12: ELVS (http://elvsolutions.org/)

ELVS has contracted with Environmental Quality (EQ), an environmental services company with national capabilities and 50 years of experience, to facilitate dismantlers/recyclers to remove mercury switches from vehicles prior to end-of-life vehicles.ELVS provides end-of-life vehicle solutions to collect, transport, distill, recycle or dispose of elemental mercury from vehicle switches. They also provide educational outreach and promote vehicle recycling and proper management of substances of concern.

Platform 13: Gigarefurb (https://www.gigarefurb.co.uk/refurbished-laptops)

Gigarefurb offers a range of high-quality refurbished Bluetooth and WiFi products, including wireless keyboards and mice, WiFi dongles and other refurbished wireless peripherals. gigarefurb also offers a range of refurbished laptops from many top manufacturers, all graded according to their condition to help you find exactly what you're looking for.

Platform 14: IDIS (https://www.idis2.com/)

IDIS is a central repository of end-of-life vehicle disposal information compiled by manufacturers from Europe, Japan, Korea, Malaysia, India, China and the United States. The software system was developed with the support of the IDIS2 consortium of major European, Japanese, and U.S. automakers, with the primary goal of providing information to automotive dismantlers that is useful for the environmentally sound disposal of end-of-life vehicles and for maximizing the use of

recycled resources. Safety-related issues such as HV battery disposal, potentially recyclable parts and other safety-related elements mentioned in the EU End-of-Life Vehicle Directive.

Platform 15: IMDS (https://public.mdsystem.com/zh/web/imds-public-pages/home)

IMDS is a database system for parts and materials in the automotive industry. It was jointly developed by car manufacturers Audi, BMW, DaimlerChrysler, Ford, Opel, Porsche, Volkswagen and Sweden's Volvo Car Group. IMDS stores and maintains information about all materials used in the manufacturing process of the vehicle. At the same time, each supplier has an ID that identifies the supplier of the submitted material. The supplier only needs to use IMDS system to provide parts data to multiple manufacturers, which can greatly reduce the cost.

Platform 16: JD (https://global.jd.com/)

JD is an integrated e-tailer in China and one of the most popular and influential e-commerce sites in China's e-commerce sector, selling millions of high-quality products from tens of thousands of brands in 12 categories, including home appliances, digital communications, computers, home department stores, apparel and clothing, mother and child, books, food, and online travel, online. With a 49% share of China's self-operated B2C market in 2012, JD continues to expand its dominance in China's e-commerce market with its full supply chain. JD has established six logistics centers in North China, East China, South China, Southwest China, Central China and Northeast China, as well as core city distribution stations in over 360 cities nationwide.

Platform 17: Lianxin (https://7chehuishou.com/home/index.html)

Lianxin is an online automotive service platform that can provide you with a one-stop solution for all kinds of car scrapping, and has an experienced team of business and technical professionals with a relatively advanced and complete range of professional machinery and equipment. The main business and service items of Lianxin include: recycling, dismantling, processing and sales of end-of-life motor vehicles, end-of-life mechanical and electrical equipment, decommissioned equipment of troops, scrap steel and scrap non-ferrous metals.

Platform 18: Remanshop (http://www.remanshop.com/)

Remanshop is a professional e-commerce platform for remanufactured products in China, creating a new B2C sales model for the remanufacturing industry, applying advanced Internet and Internet of Things technology, committed to become the authoritative information and trading platform for remanufactured products in China. At present, Remanshop is in close contact with the national professional remanufacturing enterprises to provide customers with high quality, guaranteed and traceable auto parts remanufacturing full series products.

Platform 19: Shouchezhan (http://www.shouchezhan.com/)

Shouchezhan is the world's largest portal for scrap car accident car replacement, and an open service platform for the automotive aftermarket. It is a national accident car, used car, replacement car, soaked car, scrap car, yellow standard car, scrap car valuation and consultation, with car scrapping, vehicle scrapping, scrap car, scrap motor vehicle, car subsidy, scrap car recycling, dismantling car information and consultation website. It provides accident cars, used cars, fire cars, soaked cars, etc. One-click scrap car, vehicle scrapping, scrap car valuation and consulting services.

Platform 20: Taobao (https://www.taobao.com/)

Taobao is the larger online retail, business community in the Asia Pacific region, founded by Alibaba Group in May 2003. Taobao is a popular online retail platform in China with nearly 500 million registered users and over 60 million regular visitors per day, while the number of products online has exceeded 800 million per day, with an average of 48,000 products sold every minute. With the expansion of Taobao and the increase in the number of users, Taobao has also transformed from a single C2C online marketplace into a comprehensive retail circle that covers C2C, group buying, distribution, auctions and other e-commerce models. It has become one of the world-wide e-commerce trading platforms.

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