The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/0263-5577.htm

Industrial Management & Data Systems

Unlocking blockchain's potential in collaborative remanufacturing and data sharing: a case study on electric vehicle batteries

Keru Duan, Gu Pang, Yong Lin and Christopher Lonsdale
University of Birmingham, Birmingham, UK

Received 24 November 2024
Revised 4 March 2025
Accepted 31 March 2025

Abstract

Purpose – In this paper, we present a case study to explore both how end-of-life electric vehicle batteries (EVBs) might be remanufactured efficiently and the data sharing required to support such remanufacturing. Specifically, the paper explores how blockchain technology can enhance transparency, traceability and efficiency in the lifecycle of EVBs.

Design/methodology/approach – The research employs a case study methodology to study the remanufacturing processes of EVBs at Tesla, China. This approach is chosen for its effectiveness in examining complex phenomena within their real contexts and is particularly suitable for exploring the interplay between technology and industry practices.

Findings – Our findings suggest that implementing blockchain technology allows stakeholders to manage data regarding battery quality and battery history. Although the adoption of blockchain in remanufacturing faces challenges, the research suggests that integrating blockchain could revolutionize the EVBs remanufacturing process by ensuring more effective and secure data management across the supply chain.

Research limitations/implications – The study's focus on Tesla in China as a unique case limits its generalizability, as Tesla's advanced technology and China's specific regulatory environment may not reflect the conditions faced by other EV manufacturers or in different regions, necessitating adaptations for broader applicability.

Practical implications – Based on the insights from participants at a leading EV manufacturer, this study proposes a blockchain-based closed-loop supply chain (CLSC) to monitor battery production, usage, remanufacturing and reuse, ensuring real-time data sharing among key stakeholders.

Originality/value – The research highlights blockchain technology's pivotal role in enhancing the traceability, security and efficiency of remanufacturing EVBs within CLSCs. It enriches the existing theoretical frameworks by integrating regulatory influences and advanced data-sharing mechanisms, addressing consumer trust issues and proposing sustainable practices that could be adopted across the industry.

Keywords Electric vehicle, Electric vehicle battery remanufacturing, Blockchain, Closed-loop supply chain, Data sharing, Collaborative remanufacturing

Paper type Case study

1. Introduction

The rapid expansion of electric vehicles (EVs) over the past decade has significantly contributed to combating global warming and promoting sustainable mobility due to their energy and environmental advantages over conventional fossil-fuel-powered vehicles (Li *et al.*, 2018). Currently, one in every seven cars sold worldwide is EV, and it is estimated that the global EV population will surge from 40 million in 2022 to over 900 million by 2040 (Ellerbeck, 2023).

However, this growth will, of course, also generate a substantial increase in the production of electric vehicle batteries (EVBs), and there is a growing consensus among researchers that EVs can only be considered a sustainable option if efforts are made to reduce the environmental impact of EVB production, use and disposal within its supply and value chains. In particular, it is

© Keru Duan, Gu Pang, Yong Lin and Christopher Lonsdale. Published by Emerald Publishing Limited. This article is published under the Creative Commons Attribution (CC BY 4.0) licence. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this licence may be seen at http://creativecommons.org/licences/by/4.0/legalcode

Industrial Management & Data Systems
Vol. 125 No. 7, 2025
pp. 2321-2347
Emerald Publishing Limited
e-ISSN: 1758-5783
p-ISSN: 0263-5577
DOI 10.1108/IMDS-11-2024-1137

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

said there is a need for an increased focus on repurposing practices, such as recycling, remanufacturing for second-life applications and the proper disposal of used EVBs (Silva *et al.*, 2023). EVBs are deemed to reach their "end-of-life" when their capacity falls below 80% of the original maximum so it is not surprising that there is increasing economic and environmental interest in harnessing the residual value of these used EVBs as their numbers increase (Kampker *et al.*, 2021; Dai *et al.*, 2019).

In response to the challenge, the European Union, for example, has set a goal to recycle 70% of Lithium-ion batteries by 2030. However, according to a Transport Environment report (2024), the efforts within the European Union (and the United Kingdom) have thus far only been partially successful. On the positive side, more than 30 remanufacturing or material recovery projects have either been announced or are currently under construction, with major companies involved including BASF (Germany), Fortum (Finland), Aurubis (Belgium) and Northvolt (Sweden) (Transport Environment, 2024). For instance, BASF has invested in a battery recycling plant in Germany, which is supported by a robust collection network for end-of-life EVBs and is intended to help accelerate the transition toward a sustainable, circular electromobility ecosystem (Brian, 2024).

Yet, despite these efforts, nearly half of these circular economy initiatives face significant challenges. Issues such as increased complexity of the projects, high operational costs, and the absence of mature operational models have put several projects, including those by Eramet and the Suez (France) joint venture, as well as BASF, either on hold or at risk of not proceeding (Transport Environment, 2024). At least within the European Union and the United Kingdom, there is still a long way to go in creating a circular economy for EVBs.

These current efforts at developing a circular economy for EVBs focus on establishing a closed-loop supply chain (CLSC). This approach aims to facilitate the recovery of components and materials from used EVBs, reintroducing them into the supply chain through practices such as reuse, remanufacturing and recycling. Several studies have explored the optimal structures of a CLSC (Gu *et al.*, 2018, 2021), effective pricing strategies (Zhao *et al.*, 2021) and the impact of government subsidies (Liu and Wang, 2024). These studies significantly contribute to our understanding of the environmental and economic dynamics of CLSC.

However, a recurring limitation in this early research is an oversight regarding the importance of both vertical and horizontal cooperation among stakeholders in the supply chain, a lack of which we argue here has hindered the identification of collaborative solutions for remanufacturing businesses. An exception to this oversight has been Silva *et al.* (2023), who highlighted that the transformation toward a closed-loop EVB supply chain is constrained by inadequate data sharing among key stakeholders, which is crucial for supporting the transition. As such, Silva *et al.* (2023) advanced a decentralized network where battery suppliers, EV manufacturers and even customers can share essential information such as the type, usage history and quality status to better inform remanufacturing decisions and point to a potential way forward.

A further challenge is consumer acceptance of remanufactured batteries. Any remanufacturing model must be designed to meet customer needs to ensure economic viability. While numerous studies have examined customer perceptions of remanufactured batteries, the results have been mixed. On one hand, evidence suggests that although customers possess limited knowledge about remanufactured components, they are aware of the benefits and do not exhibit significant risk aversion in their purchasing decisions (e.g. Milios and Matsumoto, 2019; Chinen *et al.*, 2022). On the other hand, other research indicates a noticeable consumer reluctance to buy remanufactured components due to perceptions of lower quality, reduced lifespan and inferior performance (e.g. Hazen *et al.*, 2017; Huster *et al.*, 2024). These conflicting findings underscore the need to close the knowledge gap among consumers and enhance their trust through certification schemes and a transparent supply chain that provides reliable technical documentation (Belbağ and Belbağ, 2023; Chun *et al.*, 2023).

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

With its inherent features of decentralization, transparency and immutability, blockchain technology has been identified as a viable solution to address both of these challenges (Duan *et al.*, 2023). Blockchain ensures transparent and secure transaction recordings and unlike traditional information systems, it allows all stakeholders access to tamper-proof data. Seamless and secure data exchange among manufacturers, retailers, recyclers, remanufacturers and other stakeholders has the potential to foster collaboration, improve decision-making, enhance accountability and minimize the potential for data manipulation along the supply chain (Chen *et al.*, 2024; Duan *et al.*, 2023).

However, while the theoretical benefits of blockchain are well-noted, the practical application of this technology in enhancing the efficiency of CLSCs for EVBs requires further exploration. Both Silva *et al.* (2023) and Chen *et al.* (2024) have emphasized the need for more empirical studies to validate how blockchain can specifically support the development of a CLSC for EVBs, indicating that this area of research is still evolving. In this context, and building on current knowledge of the EVB supply chain and leveraging insights from key industry players, this study seeks to understand how to develop a blockchain-based CLSC for used EVBs and does so by exploring two main research questions:

RQ1. How does blockchain technology influence the network design of facilities for remanufactured EVBs?

RQ2. What role does data sharing, which blockchain technology can facilitate, play in enhancing the efficiency of the EVB CLSC?

This study initiates the first research question by thoroughly analyzing the existing network configurations for remanufactured EVBs. It scrutinizes how these systems manage the collection, sorting, remanufacturing and redistribution of used EVBs. By introducing blockchain technology, the study speculates on transformative adjustments that could be made to enhance data transparency, security and cooperation across various stakeholders. This includes exploring the potential of blockchain to automate certain processes through smart contracts, securely log the lifecycle of batteries and ensure the integrity of data across the network.

The second research question focuses on data management within the EVB CLSC. It examines key data types, such as battery health data, usage history and remanufacturing information, that are pivotal in optimizing the remanufacturing processes and the lifecycle management of EVBs. The study assesses how sharing these critical data types among relevant stakeholders, including manufacturers, remanufacturers and end-users, can lead to significant improvements in operational efficiencies. This could involve analyzing the impact of real-time data access on reducing downtimes, enhancing inventory management and facilitating more accurate forecasting and planning.

To address these research questions, the study employs an in-depth case study research method. This methodology involves detailed empirical investigations into selected real-world examples of networks integrating or experimenting with blockchain technologies and advanced data-sharing frameworks. This approach not only provides a detailed examination of the practical implications of blockchain but also assesses the operational changes and benefits that enhanced data sharing brings to the remanufactured EVB network. Our case study is analyzed to understand the specific impacts of technology integration on operational efficiency and network redesign.

Our study aims to draw actionable insights into how blockchain technology can fundamentally alter the architecture and efficiency of remanufactured EVB networks, thus offering scalable and innovative solutions to the challenges faced by the EV industry today. This expanded focus ensures a holistic view of the technological and operational dynamics shaping the future of EVB remanufacturing.

The contribution of this study to the field of EVBs remanufacturing and CLSC is extensive, addressing the complexities and the critical interactions among diverse stakeholders within the

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

supply chain. This research provides an in-depth examination of the importance of coordination and collaboration for EVB remanufacturing. More specifically, by exploring the integration of blockchain technology, the study initiates discussions on enhancing transparency, traceability and efficiency in remanufacturing supply chains. The research proposes centralized and decentralized models for a blockchain-based EVB CLSC, contributing practical solutions with potential benefits and challenges for EVB industry adaptation. Furthermore, it highlights the significant role of data management, advocating for standardized protocols to facilitate effective data sharing and collaboration across the supply chain.

In addition, the study serves as a reference for policymakers and industry leaders by aligning findings with existing literature and proposing a developmental framework for EVB CLSCs, suggesting that structured remanufacturing processes supported by blockchain can meet regulatory demands and market needs. Lastly, the research accentuates blockchain's potential to enhance traceability and security, increasing customer trust and market acceptance of remanufactured products, which is vital for the industry's growth. This comprehensive analysis offers actionable insights and frameworks that can guide academic research and practical implementations in the evolving landscape of sustainable automotive technologies.

The remainder of the paper is structured into five sections. Section 2 provides a review of the existing literature. Section 3 introduces the case study methodology. Section 4 presents the findings from the case study. Section 5 analyzes the significance of these findings. Sections 6 and 7 conclude the research contributions, limitations and directions for future research.

2. Theoretical background

2.1 Current network configuration for remanufactured EVB

2.1.1 Closed-loop supply chains for EVBs. The lithium-ion battery (LiB) is a crucial component of EVs. The production of these batteries requires rare materials such as lithium and cobalt, which are in limited supply on Earth and are associated with significant environmental challenges (Kumar *et al.*, 2023). It is not surprising, therefore, that LiB and EVB, in general, have been the subject of attempts to create more sustainable production. The concept of sustainability and the circular economy focuses on both the forward and reverse flows of materials, which are fundamental to establishing a CLSC (Zhao *et al.*, 2021). A CLSC is a system that manages the entire lifecycle of material flow, from production through to usage and eventual repurposing, to minimize waste and reduce environmental impact (Zhang *et al.*, 2024). Within this system, reuse, remanufacturing and recycling are pivotal, as they enhance resource efficiency and contribute to a more sustainable and effective supply chain (Li *et al.*, 2024; Gu *et al.*, 2018, 2021).

Research on EVB closed-loop supply chains is expanding, typically with the assumption that responsive consumption and waste management can significantly reduce environmental and economic burdens. For example, Zhao *et al.* (2021) studied the optimal CLSC pricing strategy for EV batteries across three recycling channels within a CLSC and found that a centralized decision-making model yielded higher profits than a decentralized one. This finding suggests that enhanced communication between the upstream and downstream sectors of the supply chain is crucial for boosting profitability. Liu *et al.* (2023) proposed a model for optimally recovering used batteries within a CLSC, considering the uncertain residual capacity required for remanufacturing. The model includes an EVB supplier and an EV manufacturer, focusing on strategies for collection and remanufacturing. This study concluded that a CLSC dominated by the EV manufacturer is more effective in stimulating demand for remanufactured batteries.

In addition, Chai *et al.* (2024) modeled a two-period CLSC for used EVBs, involving one manufacturer and one remanufacturer. In Period 1, batteries are produced from raw materials by the original equipment manufacturer (OEM). In Period 2, end-of-life EVBs are collected, sorted and remanufactured based on their quality. Similarly, Gu *et al.* (2018) described a three-

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

period CLSC which involves an EVB manufacturer, a remanufacturer and upstream suppliers. The process begins with battery production from raw materials, followed by the collection and sorting of used batteries, and finally, their remanufacture into new materials or refurbished batteries, depending on the quality of the returned products. Recycled materials are then reintegrated as raw materials for initial production. Collectively, these studies affirm that remanufacturing end-of-life EVBs is technically feasible and environmentally and economically beneficial.

While the aforementioned studies provide insights into CLSCs for EVBs, they overlook the unique challenges posed by the raw materials of batteries. End-of-life LiBs are classified as hazardous materials and are hence subject to stringent regulations which complicate their handling compared to conventional products (Kumar *et al.*, 2023). Each end-of-life EVB must be individually assessed before repurposing, as their condition varies widely depending on usage, highlighting the need for greater transparency and reliable information sharing within the supply chain.

However, tracing the origin and lifecycle of these EVBs is challenging because of the intricate and interconnected relationships among participants in the supply chain (Wang *et al.*, 2023) This complexity arises from the numerous stakeholders involved, such as manufacturers, suppliers, recyclers and remanufacturers, each contributing different pieces of information. Without proper coordination and visibility, monitoring the complete journey of a battery from production to end-of-life becomes challenging. In addition, remanufactured EVBs cannot be directly reused in new vehicles, which disrupts the typical flow of a CLSC. Compounding these challenges are issues such as inadequate regulations, poor enforcement (Xiong *et al.*, 2020), complex supply chain structures (Muhammet *et al.*, 2021), unverifiable end-user identities and the absence of uniform industrial standards and management practices (Li *et al.*, 2018).

2.1.2 Collaboration and data-sharing issues in the EVB supply chain. For the EV industry, a closed-loop supply chain that minimizes raw material extraction, extends product and material lifespans and reduces waste is highly desirable (Grati *et al.*, 2024). Yet, although it is now technically possible to recycle end-of-life EVBs or extract valuable materials for new battery production, several significant challenges complicate these processes. These include difficulties in tracking and valuing end-of-life batteries, regulatory uncertainties, liability risks, the need to minimize logistics costs and issues arising from the non-uniform design, packaging and condition of end-of-life batteries. These factors all affect the efficiency of value recovery from remanufacturing processes (Xiong *et al.*, 2020; Grati *et al.*, 2024). Moreover, the efficient remanufacturing of end-of-life EVBs faces obstacles from information silos created by disparate data forms generated at different stages of the battery lifecycle by various companies (Silva *et al.*, 2023). This fragmentation hampers effective collaboration and information sharing, crucial for implementing a successful CLSC for EVBs (Silva *et al.*, 2023).

In response, research emphasizes the importance of multi-party collaboration to enhance supply chain efficiencies and achieve true sustainability (Li *et al.*, 2024; Zanoletti *et al.*, 2024). This includes improving logistics, transportation, battery disposal and the utilization of remanufactured batteries (Nurdiawati and Agrawal, 2022; Yadav *et al.*, 2020). Utilizing information technology is vital for enabling seamless and secure cooperation among supply chain partners. However, the traditional collaboration model, often dominated by OEMs and their suppliers, may not be suitable for the EVB aftermarket (Silva *et al.*, 2023). This sector includes a variety of actors such as recyclers, cell manufacturers and component suppliers, each potentially claiming leadership in the recycling process due to their specific capabilities or access to resources (Niese *et al.*, 2020).

Furthermore, trusted information sharing is essential to develop mutually beneficial stakeholder relationships (Parviziomran and Elliot, 2024). For example, remanufacturers can more effectively assess the residual value of EVBs if they have access to detailed usage and maintenance records. This transparency also aids customers of remanufactured batteries in making informed decisions. Despite the importance of sharing data related to manufacturing,

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

usage, transportation, storage and remanufacturing options (Neumann *et al.*, 2022), structural barriers and traditional linear business cultures create significant challenges. These challenges hinder the commitment to sustainability goals and complicate the remanufacturing process (Kirchherr *et al.*, 2018).

Given the dynamic nature of the EVB value chain and OEMs' potential inadequacy to maintain a central role, alternative collaborative and information-sharing models that do not rely on a dominant actor are needed. Blockchain technology, as a distributed ledger system, therefore emerges as a promising solution to interconnect stakeholders within the CLSC for EVBs, fostering collaboration and enhancing information sharing across the network.

2.2 Blockchain adoption in supply chain management

Blockchain technology is a distributed ledger system that securely records transactional data and other relevant information across multiple nodes. It is governed by a consensus mechanism and safeguarded by cryptography techniques (Kshetri, 2018), ensuring that data are not controlled by any single entity and remains decentralized (Duan *et al.*, 2023). This setup enhances the integrity and security of the data, making it a permanent and immutable record that, in the supply chain context, fosters enhanced collaboration and information sharing across various participants in the supply chain (Hastig and ManMohan, 2020). In the further context of supply chain sustainability, Liu and Wang (2024) contend that blockchain implementation significantly enhances transparency and trust, ultimately improving firm value and increasing market acceptance of “green” products.

Empirical studies have extensively discussed the benefits of blockchain in supply chain management (SCM). Shoaib *et al.* (2020) prioritized blockchain success factors for SCM using an integrated framework and highlighted that trackability and traceability are prime factors for blockchain's successful adoption. Nath *et al.* (2022) found that supplier firms' intention to adopt blockchain in supply chains is driven by factors such as relative advantage, compatibility, perceived trust, top management support, absorptive capacity, information sharing, collaborative culture and trading partner influence, while regulatory support currently plays a limited role. Xu *et al.* (2023) illustrated that blockchain technology helps mitigate manufacturer cannibalization and introduces a cascading advantage where profit trends shift when (and only when) pricing power and blockchain inputs are combined. Schmidt and Wagner (2019) analyzed the impact of blockchain using transaction cost theory, finding that it notably reduces costs associated with opportunistic behavior. Moreover, the technology's capability for smart contracts facilitates automated decision-making, addresses complex transactions and mitigates issues related to human limitations in decision-making.

2.3 Research gap

The theoretical background section on remanufactured EVBs focuses on establishing a sustainable, efficient CLSC. The discussion highlights the critical role of EVBs and the concept of a CLSC is emphasized as a way to manage the lifecycle of materials to minimize waste and environmental impact through practices like reuse, remanufacturing and recycling.

Significant research has focused on optimizing CLSC for EVBs to mitigate environmental and economic burdens, with studies by Zhao *et al.* (2021) and Liu *et al.* (2023) suggesting that centralized decision-making within the supply chain could enhance both profitability and operational efficiency. However, challenges related to the handling of these EVBs as hazardous materials, the need for transparent and reliable data sharing and the complexity of stakeholder relationships complicate the effective management of a CLSC and require further research.

Moreover, the research gap outlines collaboration and data-sharing issues within the EVB supply chain, stressing the importance of multi-party collaboration and the use of technologies like blockchain to improve information sharing and transparency. This could lead to a better assessment of the residual value of EVBs and support informed decision-making. Advocacy

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

for an open standard electronic exchange system further underscores the need for comprehensive data accessibility across the battery's lifecycle to support sustainable practices. Thus, advancing the remanufacturing of EVBs requires addressing industrial and corporate requirements through innovative methodologies that integrate environmental, economic and technical aspects. This paper addresses these gaps by exploring the integration of blockchain technology within the EVB supply chain, enhancing collaboration and data sharing among stakeholders, thereby fostering a more transparent and efficient management of the CLSC for remanufactured EVBs.

3. Methodology

3.1 Research design

Given the specific nature of our research concerning the remanufacturing processes of EVBs at Tesla, China, a case study methodology was selected as the most appropriate approach. The case study approach allows us to explore a phenomenon or research topic within real-life contexts (Yin, 2018). This method is particularly effective in addressing the "how?" and "why?" questions central to our study. Specifically, it helps us investigate how end-of-life EVBs can be remanufactured efficiently and why data sharing is necessary to support this remanufacturing process. This method allows for an in-depth exploration of complex phenomena within their real-life context, which is particularly suited to studying the nuanced interactions of technology, policy and industry practices (Yin, 2018). Our research involved multiple interviews with five experts working at the case company and a review of a wide range of secondary sources, including industrial research reports and news from leading EV and LiB manufacturers. This comprehensive approach enabled us to gain deep insights into market trends, the industry landscape, stakeholder concerns and key opportunities and challenges in the sector.

However, the case study approach has its limitations. According to Peter *et al.* (2000), the conclusions drawn may be specific to the organizations studied and not necessarily generalizable to other contexts. Yin (2018) suggests mitigating this issue by clearly defining the context and boundaries of the research. It is also important to explain how the research questions are linked to data collection, research protocols and the interpretation of results. This transparency allows readers to determine the applicability of the findings to other contexts.

In addition, acknowledging common critiques of qualitative research regarding the rigor of its design and the reliability of findings (Berg and Lune, 2012; Harley and Cornelissen, 2022), we meticulously adhered to the criteria established by Yin (2018, p. 78) for ensuring research quality: construct validity, internal validity, external validity and reliability. By rigorously following these criteria, we enhanced the trustworthiness and depth of our findings, thus leveraging the strength of case study research to generate novel concepts and ideas. This methodological rigor not only strengthens our research outcomes but also substantiates the use of a single-case study design, providing detailed, contextually rich and empirically grounded insights that are crucial for understanding and advancing blockchain's application in EVB remanufacturing.

3.2 Case selection

Selecting a case is essential for enhancing the generalizability of a case study's findings, particularly in complex and technology-driven sectors (Yin, 2018; Flyvbjerg, 2006). Our study specifically aims to gather in-depth information on the integration of blockchain technology within the network design of facilities dedicated to the remanufacturing of EVBs. The choice of Tesla as our focus was driven by its prominent role in battery remanufacturing, as evidenced in its 2023 Impact Report (Tesla, 2023). Tesla is not only incorporating battery recycling facilities at its Shanghai Gigafactory in line with Chinese environmental regulations but is also at the forefront of employing blockchain technology to trace raw materials and strengthen connections with key stakeholders like battery manufacturers and recyclers.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Our selection of Tesla as the primary company for our case analysis is also justified by its establishment of a closed-loop system for battery manufacturing. As an early adopter of such systems, Tesla provides a valuable setting with unique mechanisms, materials and operational experiences relevant to our study's focus on blockchain applications in EVB remanufacturing. Additionally, we obtained unique access to Tesla's processes, further enhancing the depth and relevance of our analysis.

Addressing potential criticisms of relying on a single case study, it is worth noting the established precedent of single-case studies for generating rich, in-depth insights (Peter *et al.* (2000). Tesla's advanced practices and integration of blockchain technology within its remanufacturing processes provide a unique opportunity to explore specific mechanisms and derive meaningful lessons. Rather than offering the final word, this study seeks to establish a foundation for future research and contribute to ongoing discussions in the field.

3.3 Data collection

This study employs a data collection methodology spanning two years (Nov 2022–Nov 2024), during which we closely observed the construction and development of the EVB remanufacturing facilities at Gigafactory in Shanghai, China. To capture changes over time, we interviewed each participant four times at six-month intervals, enabling us to document key developments, challenges and interventions. While this approach provides a rich temporal context, the research is primarily cross-sectional. This means that data collection focuses on specific points in time rather than tracking changes over an extended period. Although the periodic interviews add a degree of temporal depth, the cross-sectional nature of the study reflects its aim to analyze snapshots of participant experiences and facility developments during distinct intervals, rather than adopting the long-term tracking characteristic of a fully longitudinal study.

We conducted semi-structured interviews with five industrial experts from Tesla, including one senior manager and four engineers, based at the company's remanufacturing center. These experts provided detailed insights into the architecture of their remanufacturing supply chain and contributed crucial preliminary data for our analysis. Discussions focused on their strategic plans for remanufacturing used batteries, primary challenges in production planning and control for remanufacturing processes, as well as their desire for further-reaching solutions. The authors mapped a physical network, guided and informed by the interview data, and then presented these findings on the EVB CLSC's physical network to five experts to gather their feedback. Given the complexity of supply chains and the absence of standardized solutions, their specialized knowledge proved crucial in guiding our informed decisions.

To further enhance the construct validity of our study, we incorporated secondary data for triangulation (Yin, 2018). This integration included (1) the legal framework governing LiB remanufacturing in China, (2) an analysis of secondary resources such as industrial research reports and media articles and (3) corporate announcements from leading EV manufacturers (e.g. Nio, XPeng, BYD and LiAuto) and LiB manufacturers (e.g. CATL). This comprehensive market analysis provides essential insights into the current dynamics of the EV LiB market, detailing the industrial landscape, stakeholder concerns and expectations, key opportunities, challenges and pressing issues.

Table 1 provides a summary of the primary and secondary data sources used in this study, together with the details for five participants and interview schedules. Our study primarily involved five participants from Tesla's operations in China (Table 1). Readers can find interview questions in the supplementary material.

3.4 Data analysis

The qualitative data were analyzed using the thematic analysis method, as illustrated in the thematic analysis flowchart (Figure 1). This iterative process consists of three critical steps: coding, categorizing and theme-building (Lochmiller, 2021).

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Table 1. Summary of data collection

	Interviewee	Professional background	Areas of expertise	Collection time and duration
Primary data	A	Head/Senior Manager of the Remanufacturing Center	15+ years' experiences in remanufacturing center operations, cost management and business development	Nov/3/2022 (3h) Apr/14/2023 (3h) Oct/13/2023 (3.5 h) June/28/2024 (3h)
	B	Senior Engineer	Specializes in research and development of remanufacturing technology and battery testing	Nov/11/2022 (3.5 h) Apr/7/2023 (3h) Oct/28/2023 (3h) Jul/19/2024 (3.5 h)
	C	Project Manager	Specializes in battery remanufacturing-related projects	Dec/2/2022 (3h) May/12/2023 (3h) Sep/08/2023 (4h) Apr/26/2024 (3h)
	D	Senior Operations Management Manager	18+ years' experiences in after-sales operations management and environmentally friendly strategies development	Dec/16/2022 (3h) June/2/2023 (3.5 h) Nov/21/2023 (2.5 h) Jul/26/2024 (4h)
	E	Senior Engineer in the remanufacturing center	Specializes in research and development of battery remanufacturing technology and production line management	Jan/13/2023 (4h) June/9/2023 (3h) Dec/1/2023 (3h) Jul/5/2024 (4h)

	Source	Key information	Available at	Access date
Secondary data	Local news	Volume of end-of-life LiB	Dialogue Earth https://dialogue.earth/en/pollution/how-can-china-address-its-ev-battery-recycling-challenge/	Jul 21, 2024
		Difficulties and challenges for LiB remanufacturing		
	Official company website and social media accounts	LiB remanufacturing policy	MIIT https://jx.ah.gov.cn/group6/M00/0B/98/wKg8Bma9tkSAN2BLAAYaDMXJXnw215.pdf	Aug 26, 2024
		Inter-organizational cooperation on LiB remanufacturing Business strategies	CNBC https://www.cnbc.com/2024/04/05/chinas-nio-to-expand-battery-swap-services-to-gain-ev-infra-edge-.html	Aug 28, 2024
			NIKKEI https://asia.nikkei.com/Spotlight/Electric-cars-in-China/China-s-CATL-to-recycle-EV-batteries-with-Volvo-Car	

(*continued*)

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Table 1. Continued

Source	Key information	Available at	Access date
Industry reports on end-of-life EVB remanufacturing	Market prospects and challenges of LiB remanufacturing	1 WEP https://wepub.org/index.php/TEBMR/article/view/2730 2 IEA https://www.iea.org/reports/global-ev-outlook-2024/trends-in-electric-vehicle-batteries	Jul 23, 2024
	Business strategies on LiB remanufacturing	China Briefing https://www.china-briefing.com/doing-business-guide/china/sector-insights/china-s-electric-vehicle-supply-chain-and-its-future-prospects	Jul 24, 2024
	Industry analysis of the LiB industry	1 IMARC https://www.imarcgroup.com/china-electric-vehicle-battery-market 2 IBISWorld https://www.ibisworld.com/china/market-research-reports/battery-manufacturing-industry/ 3 Markets and Markets https://www.marketsandmarkets.com	Jul 17, 2024
Local laws and regulations on EVB remanufacturing	National policies, legislation and standards on the treatment of toxic and harmful materials and substances	1 National platform for battery traceability https://evmam-tbrat.com/ 2 Law of the People's Republic of China on Promoting Circular Economy, 3 Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste 4 Standard Conditions for the Comprehensive Utilization of Used power Batteries for New Energy Vehicles (2024)	June 17, 2024–Sep 18, 2024
	Local policies and regulations on LiB remanufacturing	1 Hangzhou Renewable Resources Recycling Industry Pollution Improvement Implementation Plan, http://sthjt.zj.gov.cn/col/col1694103/index.html 2 Shanghai Renewable Resources Recycling Management Measures https://www.shanghai.gov.cn	Jul 30, 2024

Note(s): All five participants are based at Tesla's Gigafactory in Shanghai, China. The interview questions utilized in this study are detailed in the supplementary materials. Readers may refer to these questions for a comprehensive understanding of the data collection methodologies employed

Source(s): Case company participants' insights

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

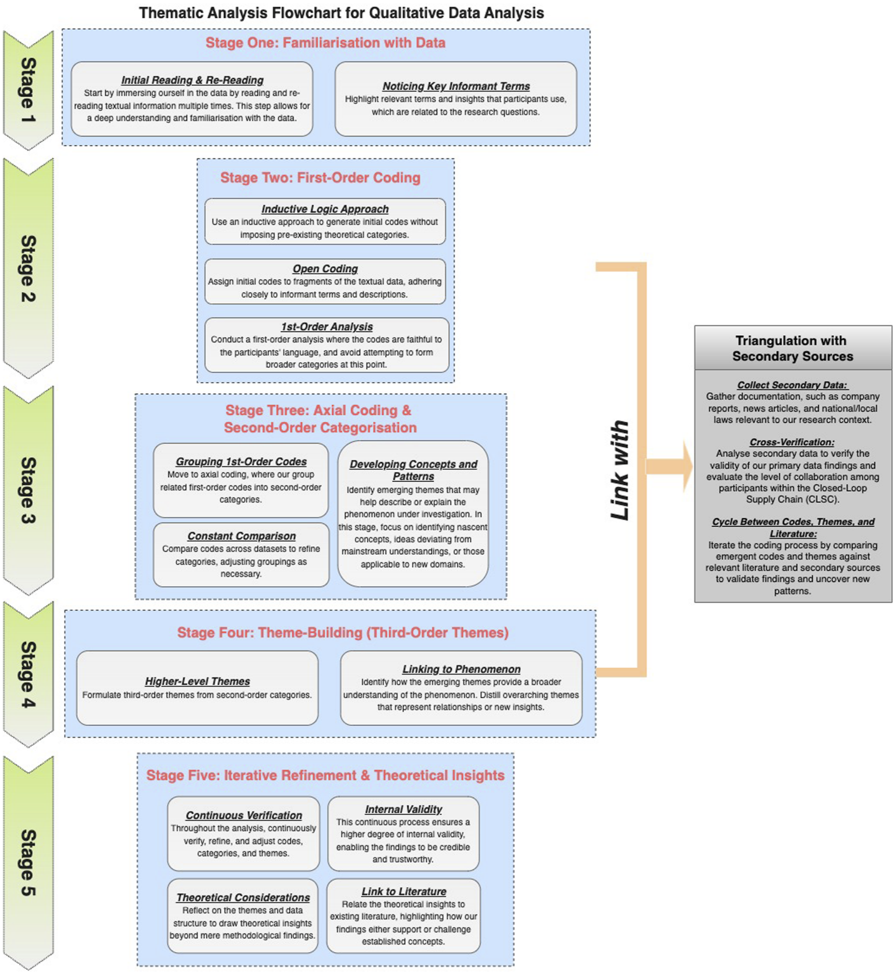

Figure 1. Thematic analysis flowchart for qualitative data analysis. (Source: Authors' own work)

The data analysis process began with an inductive coding approach. This involved multiple rounds of reading and re-reading the textual data to familiarize ourselves with the dataset (stage one, in Figure 1). During this stage, we identified informant terms and codes that were relevant to the research questions. In this first-order analysis, we adhered closely to informant language, making minimal attempts to distill broader categories.

As the research progressed, the first-order codes (stages two and three in Figure 1) were grouped into second-order categories through axial coding. This allowed us to explore whether the emerging themes suggested concepts and patterns that could describe and explain the phenomenon under investigation (Strauss and Corbin, 1998). At this stage, we prioritized nascent concepts and ideas that were either new to existing literature or deviated from mainstream understandings. We also focused on concepts relevant to novel domains.

With a complete set of first-order codes and third-order themes (stage four in Figure 1), we constructed a data structure. This not only helped us configure the data into a coherent visual pattern but also provided a graphical representation of how the analysis progressed from raw

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

data to codes and themes. Constructing this data structure was instrumental in demonstrating the reliability of the qualitative research (Tracy, 2010; Yin, 2018). Moreover, it compelled us to think theoretically about the data, going beyond methodological considerations to extract theoretical insights. In addition, we triangulated the interview data with documentation from secondary sources such as company reports, news articles and national and local laws and regulations related to EVBs. These sources were analyzed to verify the legitimacy of operations within the entire CLSC and to assess the level of cooperation among participants across different stages of the chain.

Throughout the analysis, we iterated (stage five in Figure 1) between emergent data, codes, themes and insights from relevant literature and secondary sources. This iterative process ensured that our findings were not only grounded in the data but also contextualized within existing research. The continuous cycle of verification and refinement enhanced the internal validity of our study (Yin, 2018).

4. Findings

Remanufacturing end-of-life EVBs is subject to a complex set of technological, legal, environmental and economic constraints and involves intricate interactions among stakeholders across the supply chain. Our research focuses on examining these complexities and identifying the multiple challenges and problems that influence the development of a CLSC for EVB remanufacturing. From our interviews, it became evident that addressing these challenges, along with leveraging blockchain technologies, is crucial to making remanufacturing a truly sustainable solution in the long term. Additionally, we explore the data-sharing and collaboration practices among various supply chain actors. By analysing interview transcripts and secondary data, we examine the current network configuration for remanufactured EVBs and assess how integrating blockchain technology could enhance the network design.

4.1 EVB closed-loop supply chain network

4.1.1 Remanufacturing process. According to the latest regulations on used EVBs (including *Law of the People's Republic of China on Promoting Circular Economy*, the *Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste* and the *Standard Conditions for the Comprehensive Utilization of Used Power Batteries for New Energy Vehicles (2024)*), multi-level and multi-purpose utilization of end-of-life EVBs should be realized through two suggested methods which include cascade utilization and regeneration utilization (MIIT, 2024). Cascade utilization refers to the process of reusing discarded batteries in other areas after being tested, dissembled and reassembled, while regeneration utilization refers to the process of recycling metal elements in the batteries (MIIT, 2024; Global Times, 2024).

A close look into Tesla's remanufacturing center disclosed how EV batteries were remanufactured under this industry standard. As shown in Figure 2, the participants described the remanufacturing process as involving seven critical steps: (1) collection and initial assessment, (2) disassembly, (3) cell and module testing, (4) battery packs remanufacturing through either refurbishment or reassembly, (5) testing and quality control of remanufactured battery packs, (6) appropriate use of remanufactured battery packs through either reintegration or secondary use and (7) valuable material recovery from unrecoverable components.

The case study research found, however, that the current remanufacturing business was inefficient due to "*a lack of a systematic and standard remanufacturing framework*" (Participant A) and structural and technical challenges like "*low volume of batteries currently eligible for remanufacturing*" (Participant A), "*difficulties to handle the diversity of battery chemistries and to ensure component compatibility*" (Participant B), difficulties to "*maintain safety and performance standards*" (Participant B) and the requirement for "*an*

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

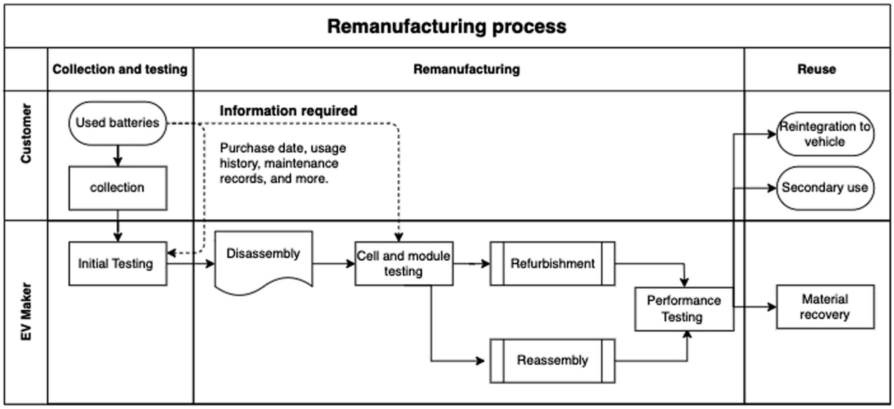

Figure 2. EVBs remanufacturing process. (Source: Authors' own work)

efficient reverse logistics network to minimize cost and delay" (Participant C). The experts agreed that a significant level of data sharing was required and necessary to support the initial testing and performance testing work to enable remanufacturers "*leverage data analytics for decision-making*" and make "*the best-fit secondary-life application of each battery*" (Participant D).

4.1.2 Possible usage of remanufactured EVBs. The analysis, from an economic perspective, posits that remanufacturing becomes pertinent only if there is adequate demand for remanufactured batteries as spare parts, particularly for scenarios where their use in new EVs is not feasible (Huster *et al.*, 2024). Therefore, it is essential to explore viable applications for remanufactured batteries and develop strategies that ensure quality performance and customer satisfaction. Interview participants from Tesla's remanufacturing center in China identified two primary applications for remanufactured batteries: warranty and after-sale services and the production of the company's internal fleet.

First, remanufactured batteries significantly offset the high costs associated with maintenance and warranty services. EV manufacturers face substantial expenses during the warranty period to ensure vehicles perform to standards. Utilizing remanufactured batteries as spare parts for warranty services emerges as a cost-effective strategy, as highlighted by both Participants D and E, who noted that "*remanufactured batteries help manage asset costs efficiently within the company.*" In addition, for out-of-warranty repairs, "*customers are presented with an option to choose between expensive new battery packs and more affordable, certified remanufactured ones, further mitigating after-sale service costs*" (Participant E). The success of this approach relies on a robust system for handling warranty claims, where "*customer feedback drives process improvements and enhances satisfaction*" (Participant C).

Second, remanufactured batteries are deployed in the production of internal fleet vehicles, including display vehicles, test-driving vehicles, after-sales rescue vehicles and engineering test vehicles. According to Participant D, "*the internal fleet in China numbers between 1,500 and 2,000 vehicles, a figure anticipated to grow alongside increases in sales and the number of retail outlets.*" This expansion, in turn boosts the demand for remanufactured batteries, yielding significant cost savings in production by reusing batteries internally. This study depicts these distinct lifecycle pathways for EV batteries, capturing the crucial role that remanufactured batteries play in meeting diverse demands within the industry.

4.1.3 Design of a closed-loop supply chain for EVBs. After exploring remanufacturing strategies and the potential for using remanufactured batteries, we propose a mode for end-of-life EVB remanufacturing within a CLSC network, adhering to China's current regulatory

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

frameworks. Notably, the proposed CLSC specifically targets EV manufacturers, as current regulations (i.e. Chinese Government, 2024) place the onus on EV manufacturers to manage battery recovery. Manufacturers are mandated to establish recycling channels and service outlets to collect, store and transfer used batteries to remanufacturing sites. Ideally, EV manufacturers, in collaboration with battery manufacturers, should form their closed-loop systems.

Data collection revealed that "*prominent Chinese EV manufacturers are setting up remanufacturing centers*" (Participant D) and partnering with recyclers to secure end-of-life batteries, thereby creating self-sufficient closed-loop supply chains (Christian *et al.*, 2023). The five participants shared their insights on two EVB remanufacturing CLSCs, one that integrates blockchain technology, one that does not. As shown in Figures 3 and 4, each model comprises five types of facilities: assembly lines, service centers, after-sales service centers, collection centers and remanufacturing centers.

The centralized CLSC (see Figure 3) features centralized facilities where all after-sales service centers share a single collection and remanufacturing center. Under this mode, remanufacturing is centralized due to the high impacts of "*economies of scale on this processing step*" (Participant A). When EV manufacturers fully integrate production, disassembly, remanufacturing and repurposing, the CLSC allows "*flexible and maximized capacity utilization*" (Participant A). These advantages make the centralized CLSC a preferable option.

Further complications arise from the fact that some end-of-life batteries may not be suitable for reuse in vehicles and require material recovery through processes such as smelting or chemical treatment, which have additional environmental impacts. Moreover, remanufacturers are challenged to prove that their outputs are economically viable compared to using newly mined materials. The efficiency of logistics is also critical to reduce transportation costs and minimize the environmental impacts of the operations.

The decentralized CLSC (see Figure 4) presents another viable option for remanufacturers with decentralized facilities. In this network configuration, each after-sales service center is paired with a designated regional collection and remanufacturing center, eliminating the need for long-term transportation. This decentralized approach may simplify the logistics of

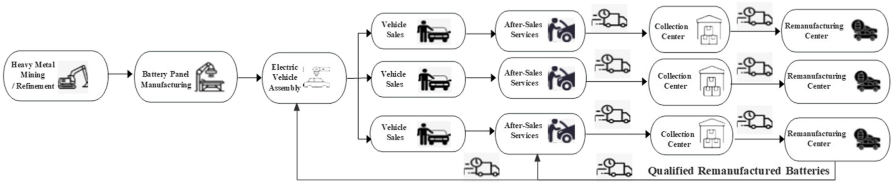

Figure 3. A centralized CLSC for EVB remanufacturing. (Source: Authors' own work)

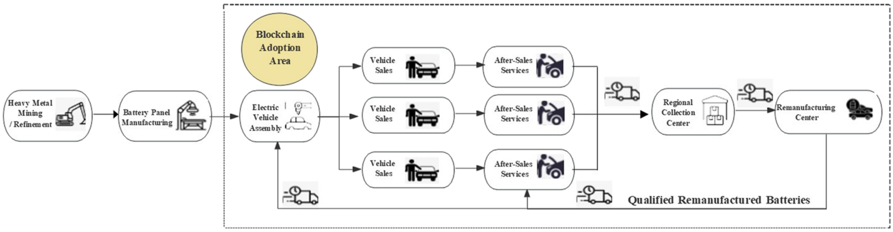

Figure 4. A decentralized CLSC for EVB remanufacturing. (Source: Authors' own work)

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

allocating and shipping collected EVB packs (Participant A). However, it potentially reduces efficiency in central coordination and information exchange about EVBs.

Industry experts observed that China's battery recycling industry was still developing, with ongoing refinements in relevant legislation and oversight mechanisms (Niu, 2023). In this decentralized model, the remanufacturing market lacks the structured oversight prevalent in other segments of the battery supply chain, complicating supervision and quality control efforts. The decentralization of manufacturing and remanufacturing leads to information asymmetries in all critical steps and may encourage opportunistic behavior as independent actors are likely to optimize their local contribution margin. Consequently, the overall costs associated with this supply chain model are anticipated to be high.

4.2 Data sharing within the EVB CLSC

Data sharing is critical for the remanufacturing of EVBs as it significantly influences operational efficiency and the quality of the remanufactured products. In this study, we addressed two critical aspects of data sharing, including the types of data that are most critical for the remanufacturing of EVBs and the potential mechanisms that standardize data ownership, sharing and usage of data across the entire value chain.

Initially, when a used battery is collected for remanufacturing, detailed data is imperative to assist engineers in assessing the battery's quality and determining appropriate remanufacturing strategies. According to Participant C, batteries deemed suitable for remanufacturing are identified at service centers and then transported to the Giga 3 Shanghai remanufacturing center for reassembly. Quality and performance-related data, such as chemical composition (Participant B), charge cycles and maintenance records, enable service centers' personnel to evaluate the batteries, their residual capacities and make informed decisions on whether the batteries should be remanufactured, recycled or repurposed. Participant D noted, "*increased visibility into battery history and status aids in selecting appropriate transport, dismantling, and remanufacturing methods, while ensuring compliance with regulatory and environmental standards*."

The EV battery market in China is currently fragmented, however, featuring a multitude of stakeholders, including EV manufacturers, battery manufacturers (i.e. OEMs) and recyclers, all aiming to secure their foothold in this burgeoning sector. Data related to product design and innovation serves as a crucial asset for these entities to obtain a competitive edge, thus, there are obstacles, in the form of conflicts of interest, to data sharing.

Participant D remarked that "*companies prefer to keep their data*" or "*develop their business ecosystems with limited participants*." Participant B noted the "*low incentives for participants to share data*." Such reticence is particularly disadvantageous for remanufacturers in the EVB supply chain, as "*they often lack access to critical data*," stated Participant A. Moreover, the presence of "*unregulated and gray remanufacturing and recycling channels*" further exacerbates industry challenges by impeding the efficient management of end-of-life batteries (Participant A).

Although some efforts to standardize data exchange and develop a digital passport for each battery have been initiated by industry players and the government, progress has been slow. The Chinese Government (2024) has launched a platform (see https://evmam-tbrat.com/) to trace EV batteries, which aims to lay the groundwork for a standardized battery recycling system. Every vehicle battery produced in or imported to China is assigned a unique serial number. EV manufacturers, battery producers, EV retailers and independent recycling or repurposing companies are expected to update information on the platform regularly to ensure the proper handling of disused batteries.

Nevertheless, participation in this information-sharing initiative remains voluntary, resulting in a low uptake given the above-mentioned incentives for stakeholders to focus on their commercial development. These findings indicate the necessity for a novel mechanism that motivates data sharing without compromising competitive advantage, an essential development for the advancement of EVB remanufacturing.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

4.3 Blockchain value

The participants in this study agreed about the potential significance of blockchain technology in advancing traceability, security and efficiency within remanufacturing operations. Blockchain significantly improves the transparency available to stakeholders concerning a battery's condition, location, ownership and usage history. This increased visibility fosters a trusted environment conducive to data sharing between CLSC stakeholders and remanufacturing processes. As mentioned earlier, trust is also an essential element influencing customers' decisions to use remanufactured batteries. Within this technological framework, smart contracts can be used to automate the enforcement of contractual terms, ensuring reliability and allowing for instantaneous verification by all parties involved. The technology also facilitates continuous updates on each action taken, which enhances both accountability and trust.

Although blockchain is still evolving, the participants concurred that its attributes are suited to overcoming the challenges facing EVB CLSC. Blockchain technology "*guarantees the security and authenticity of data records*" (Participant B). It also establishes "*a new trust mechanism that renders the EVB supply chain visible, informative, and intelligent*," according to Participant C. Furthermore, blockchain's transparent and immutable ledger contributes to mitigating human fraud and speculative activities, thus safeguarding product quality and boosting customer confidence in remanufactured batteries, a significant advantage given that "*many retired power batteries are recycled through informal channels*," as observed by Participant B.

Participant A also pointed out that "*blockchain technology enhances decision-making related to logistics, remanufacturing strategies, and the distribution of remanufactured batteries*." Similarly, Participant C highlighted "*the necessity of integrating blockchain to augment the efficiency of managing returns and logistics.*" In addition, Participant D emphasized "*the crucial role of blockchain in ensuring regulatory compliance and in facilitating strategic decisions aimed at process improvements*." From an operational perspective, "*blockchain significantly enhances supply chain security by enabling real-time and immutable tracking of battery conditions and histories*," as noted by Participant D. This capability lays the groundwork for a transformative business model in which all materials are traceable from extraction through to remanufacture and eventual reuse.

Despite the advantages, the integration of blockchain into the EVB remanufacturing process presents several challenges. The participants identified multiple barriers: Participant A cited "*technology immaturity, data privacy, and security concerns*" alongside "*the high initial investment required for infrastructure development*." Furthermore, Participant A mentioned "*the substantial operational, maintenance and support costs, such as energy consumption.*" Participant E echoed these concerns. In addition, Participant D pointed out a "*scarcity of qualified talent within the country and significant costs associated with employee training*." Despite these impediments, blockchain is considered an ideal solution for "*tracing and managing second-life batteries.*" According to Participant C, "*blockchain significantly enhances the authenticity of information and reduces risks associated with the gray market*."

5. Discussions

In the previous section, we outlined the findings from our case study research, enriched by insights from case study participants. These insights have deepened our understanding of the current remanufacturing strategies, potential applications for remanufactured EVBs, necessary data-sharing protocols and the significant role that blockchain technology plays in enhancing traceability, security and operational efficiency in remanufacturing processes. We introduced two CLSCs specific to EVBs, emphasizing the data-sharing requirements inherent in these networks. To underscore the relevance of our findings, we now juxtapose these insights with the existing literature and propose a developmental framework for an EVB CLSC. This framework is specifically designed to facilitate secure information sharing, utilizing blockchain technologies to ensure the integrity and confidentiality of data.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

5.1 Significance of the findings

The rapid expansion of EVs in the automotive industry has notably increased interest among industries, public bodies and academia in the environmentally sound treatment of end-of-life batteries. A substantial number of studies have developed theoretical models of CLSCs for EVBs. While prior research has suggested standardizing battery designs and developing data-sharing platforms and communication protocols as viable solutions (Gao *et al.*, 2022; Rufino *et al.*, 2022; Niu, 2023), there are ongoing concerns about potentially stifling innovation in such critical vehicle components (Silva *et al.*, 2023).

As such, access to cell-level data is considered to be an essential alternative route to an efficient remanufacturing process. Aligning with case study participants' opinions cited in Silva *et al.* (2023), our interviewees recognized the significant role of blockchain technology in tracing battery components and facilitating valuable, environmentally sustainable data sharing throughout the battery life cycle. Our interviewees further advocated for a blockchain-based platform to enhance transparency and enable lifelong tracking of EVBs across the supply chain.

A primary concern highlighted in remanufacturing studies, such as those by Zhang *et al.* (2023a, b) and Li *et al.* (2023), is the end-consumers lack of trust in the quality of remanufactured products, which impedes the growth of the remanufacturing industry. Our research shows that blockchain technology offers significant potential to alleviate these concerns by enhancing traceability and transparency, thereby mitigating quality uncertainties, bolstering customer trust and increasing market demand for remanufactured batteries. As underscored by Cole *et al.* (2019), Li *et al.* (2023) and Zanoletti *et al.* (2024) and corroborated by case study participants in our study, blockchain serves as an optimal tool to foster enhanced cooperation among diverse enterprises and streamline collaborative processes.

The implementation of key blockchain features, timestamps, a distributed ledger, consensus mechanisms and smart contracts enables a platform that supports a peer-to-peer network. This network ensures secure, real-time verification and communication, effectively addressing major challenges such as inadequate stakeholder cooperation and competition from unregulated or gray recycling channels, as identified in our interviews and supported by the literature (e.g. Zhang *et al.*, 2023a, b). Furthermore, the decentralized nature of blockchain ensures a balanced distribution of power among all major stakeholders, including battery manufacturers, EV manufacturers, retailers, service centers, collection and remanufacturing centers and logistics providers, thus preventing any single entity from exerting undue dominance.

Blockchain technology also plays an indispensable role in ensuring legal compliance and mitigating costs within the remanufacturing business. Prior research, including works by Kampker *et al.* (2021) and Dai *et al.* (2019), has raised concerns about the legal and economic challenges accompanying remanufacturing in addition to environmental impacts. Participants in our study highlighted that blockchain's enhanced tracking capabilities could effectively resolve liability issues and conflicts of interest within the battery supply chain. This supports Schmidt and Wagner's (2019) argument that blockchain technology can deter opportunistic behavior in the battery market.

In response to these advantages, we have proposed an integrated system for EVB remanufacturing. This system merges an updated CLSC with blockchain technology and emphasizes data sharing at each critical juncture of the supply chain.

5.2 Integrated system for EVB remanufacturing based on blockchain

The blockchain-based system we are advancing integrates key actors across the entire supply chain. The adoption of blockchain technology enhances this system by enabling equal participation among multiple stakeholders, which is expected to enhance various aspects of the supply chain, including planning, incentivization, governance, mutual learning and continuous improvement. The central framework of this system builds on the centralized CLSC discussed earlier in this study. We identify two main practical paths within the current regulatory and business contexts of China: maintenance and warranty services and the

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

production of internal fleet vehicles. We will further elucidate this system from both social and technological perspectives.

The ecosystem of the EVB CLSC involves various key stakeholders, each playing a specific role with distinct data-sharing requirements to enhance the lifecycle management of batteries. Table 2 summarizes the roles and data responsibilities in the EVB supply chain. Each stakeholder's contribution to data sharing supports a comprehensive view of the battery lifecycle, facilitating effective management and remanufacturing of EVBs while ensuring environmental and safety standards are met.

As depicted in Figure 5, the proposed blockchain architecture is tailored specifically for the EVB CLSC, focusing on ensuring quality and safety management throughout the chain. This architecture incorporates several key components: a distributed ledger that maintains secure, immutable records; a decentralized data storage system to prevent centralized vulnerabilities; smart contracts that automate and synchronize processes; and consensus mechanisms that minimize fraudulent activities and obviate the need for a central overseeing authority. Changes to the information within the blockchain can only be made with the unanimous consent of all network members.

In the blockchain architecture for the EVB closed-loop supply chain, distributed ledger technologies function as a digital database. These ledgers record battery transactions across multiple nodes, with each transaction being immutably logged along with its time and date. Since these distributed ledgers lack centralized administration or data storage, they minimize reliance on intermediaries and enhance transparency for all participants in the network. Here, "nodes" refer to the networked devices that integrate supply chain participants into the blockchain system, enabling them to access and retrieve data.

Recognizing the high implementation costs, which may be prohibitive for smaller participants, we have adopted Chen *et al*'s (2024) recommendation to incorporate various types of nodes to accommodate different levels of participation. For instance, smaller after-sales service centers might operate a light node that records transactions and service information without significantly impacting the broader supply chain.

More specifically, Figure 5 delineates a comprehensive framework for managing data across various stakeholders in the closed-loop supply chain of EVBs utilizing blockchain technology. Figure 5 illustrates a comprehensive framework within a CLSC for EVBs, engaging various stakeholders and employing advanced technologies to manage and secure data effectively.

At the onset of the battery life cycle, the battery manufacturer plays a critical role by initiating production and documenting extensive data, including raw material sources, battery identification and adherence to quality and safety standards. This initial data foundation is crucial as the batteries move through their lifecycle, managed by EVB remanufacturers and recyclers who ensure that remanufacturing and recycling processes uphold these standards, providing detailed information on the refurbished batteries. EVB collection centers gather used batteries, logging their condition for further processing, while after-sales service centers track battery performance after maintenance or repair services. In addition, customers contribute valuable usage data, such as mileage and charging histories, enhancing the dataset. EV manufacturers and sales units further document production and sales specifics, enriching the data pool with vehicle identification and performance statistics.

To handle this diverse and voluminous data, the system integrates data acquisition devices that capture real-time information, RFID and IoT for inventory tracking and Web APIs alongside the IBM blockchain platform to facilitate secure, decentralized data storage and sharing. The blockchain architecture supports this structure with a distributed ledger that ensures data transparency and immutability, smart contracts that automate and secure transactions and a decentralized database that offers robust and scalable data storage solutions. Managed data types span from ownership and identification specifics to detailed product, technology, operations, safety and environmental information, ensuring comprehensive oversight and facilitating a high degree of traceability and compliance throughout the battery's lifecycle. This holistic approach not only boosts operational efficiencies but also promotes sustainable practices within the automotive industry by fostering a reliable, transparent and collaborative ecosystem.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Table 2. Roles and data responsibilities in the EVB supply chain

Stakeholder	Role description	Information provided
Rare material suppliers	Are tasked with providing the essential raw materials needed by battery manufacturers	They share detailed information about the origin, components, quantity, quality and safety of these materials, which is essential for guiding manufacturing and remanufacturing decisions and for evaluating the environmental impacts associated with the supply chain
Battery manufacturers or original equipment manufacturers (OEMs)	Are responsible for the initial creation of the batteries	They provide critical data on battery design, material composition and production processes, as well as key performance indicators like life expectancy, weight and quality control measures. This information aids engineers at manufacturing and remanufacturing centers in assessing the quality and safety performance of the batteries
EV manufacturers	Integrate these batteries into vehicles on the assembly line	They furnish detailed data on vehicle design, power needs and specifics regarding the integration of the battery, including the installation time and place, along with implemented safety measures to prevent issues like short circuits or thermal runaway. Vehicles are also equipped with terminal detection systems to gather continuous safety-related data, which is crucial for assessing performance and determining maintenance needs
Sellers or distributors	Manage the sale and distribution of EVs and provide after-sales services	They track and share data regarding inventory, transportation conditions and detailed records of vehicle maintenance, modifications and retrofits. This shared information helps engineers evaluate the ongoing performance of batteries and plan the best routes for batteries reaching the end of their life
Regional end-of-life battery collectors	Play a pivotal role by collecting used batteries from consumers, adhering to strict safety and regulatory guidelines during collection and transportation	They document detailed information about the collection logistics, including the time and place of collection, conditions during transport and initial testing and handling practices
Remanufacturers	Focus on repurposing batteries at the end of their life	They are tasked with ensuring that these remanufactured batteries meet quality and safety standards comparable to new batteries. They provide comprehensive data on the condition and performance of these batteries, which is crucial for informing potential users and guiding their usage decisions

Source(s): Authors' own work

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

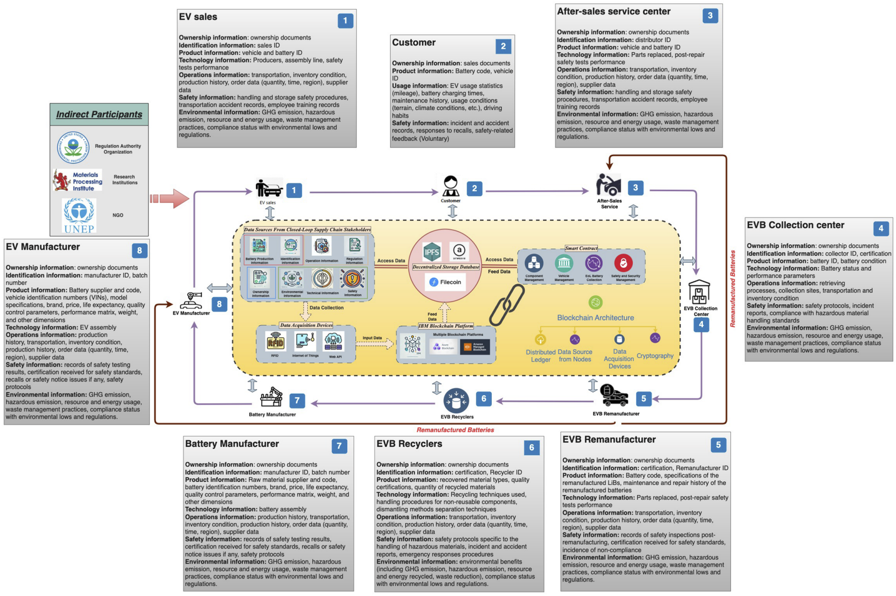

Figure 5. Blockchain-based CLSC for EVBs. (Source: Authors' own work)

This intricate system, facilitated by blockchain technology, allows for a highly efficient, secure and transparent handling of all data relevant to the lifecycle of EVBs. It supports the traceability of materials and components, ensures compliance with safety and environmental standards and fosters a collaborative ecosystem among various stakeholders. The integration of such technology into the EVB supply chain not only enhances operational efficiencies but also plays a crucial role in the promotion of sustainable practices and the circular economy within the automotive industry.

6. Implications and limitations

6.1 Theoretical implications

By integrating insights from case study participants, we provide a nuanced understanding of current remanufacturing strategies within the case company and the potential applications for remanufactured EVBs. This perspective is particularly valuable given the rapid expansion of the electric vehicle sector and the subsequent focus on environmentally sound end-of-life battery practices.

First, our research augments existing models of EVB CLSCs by considering the influence of regulatory factors, a frequently overlooked aspect in studies such as those by Zhao *et al.* (2021), Liu *et al.* (2023) and Chai *et al.* (2024).

Second, understanding the specific regulatory contexts of China's policies and legal frameworks allows our study to not only clarify how existing networks are configured but also to emphasize the importance of robust data-sharing mechanisms. This understanding is crucial because, while prior research by Gao *et al.* (2022), Rufino *et al.* (2022) and Niu (2023) has suggested standardization and communication protocols as means to enhance information flow across supply chains. However, as Silva *et al.* (2023) pointed out, there is a risk that such standardization could stifle innovation. Our findings bridge this gap by showcasing how blockchain can support innovative data sharing without constraining technological progress,

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

particularly through its capacity for tracing individual battery components and enhancing lifecycle transparency.

Third, by addressing consumer trust issues, a major barrier to the acceptance of remanufactured products highlighted by Zhang *et al.* (2023a, b) and Li *et al.* (2023), our study underscores the potential of blockchain to improve product traceability and thereby increase consumer confidence. As supported by research from Cole *et al.* (2019) and Zanoletti *et al.* (2024), blockchain's features, such as decentralized ledgers and smart contracts, enable enhanced cooperation among stakeholders, facilitating a peer-to-peer network that ensures secure, real-time verification and communication. This network not only mitigates concerns over product quality but also aids in overcoming competitive pressures from unregulated recycling channels.

Fourth, the enhanced tracking capabilities provided by blockchain, as noted in our findings and supported by Schmidt and Wagner (2019) and Kampker *et al.* (2021), can effectively address legal and economic challenges within the remanufacturing sector, such as liability issues and conflicts of interest. This dovetails with Dai *et al.*'s (2019) concerns about the environmental impacts of remanufacturing, suggesting that blockchain's ability to enforce regulatory compliance and streamline operations could significantly reduce both legal risks and environmental burdens. Our study proposes an integrated system that combines an updated CLSC framework with blockchain technology, emphasizing critical data sharing at each juncture of the supply chain. This proposal not only extends existing theoretical frameworks but also provides practical pathways for implementing sustainable practices in the remanufacturing of EVBs.

6.2 Practical implications

Remanufacturing end-of-life EVBs presents significant challenges, including information asymmetries among supply chain participants, complex regulatory frameworks and low consumer trust in remanufactured products. Blockchain technology, characterized by its decentralized, transparent and traceable networks, offers substantial potential to enhance collaboration and data sharing across the supply chain. Despite this, research on designing a CLSC for EVB remanufacturing within China's unique regulatory context, applying blockchain technology to address data sharing and collaboration issues, remains limited. This supply chain model highlights the critical role of collaborative remanufacturing and data sharing in addressing quality and safety concerns, thereby potentially facilitating broader adoption of remanufactured EVBs and supporting the growth of the remanufacturing industry.

The proposed CLSC integrates blockchain technology to enhance data sharing, tracking and coordination within the supply chain. Blockchain's tamper-evident, decentralized and traceable characteristics enable reliable product information traceability and promote close collaboration among diverse stakeholders, contributing to the development of an intelligent and informative supply chain. Theoretically, the proposed CLSC and blockchain architecture offer guidance for organizations involved in blockchain ecosystem design and the circular economy of electric vehicles and aim to establish a robust social system and technology infrastructure that supports secure data sharing and multi-participant cooperation.

To further enhance the application of blockchain in EVB remanufacturing, it is crucial to explore its integration with advanced technologies like artificial intelligence (AI) and the Internet of Things (IoTs). AI could be used to analyze data collected via blockchain to optimize supply chain operations and predict maintenance needs, while IoT devices can provide real-time data to blockchain networks, ensuring more dynamic and responsive SCM. We envisage that future research should investigate the scalability of blockchain solutions in large-scale operations and their interoperability with existing IT systems within the EVB industry. These explorations will not only refine the effectiveness of blockchain in EVB remanufacturing processes but also pave the way for innovative practices in the sustainability and circularity of EV ecosystems.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

6.3 Limitations

The focus on Tesla in China as a case study influences the findings in several key respects and has implications for their generalizability. First, Tesla is a leader in EVB technology and remanufacturing, particularly noted for its innovative practices and the integration of advanced technologies like blockchain. Studying Tesla allows for an in-depth examination of cutting-edge practices in a real-world setting, which can provide valuable insights into how blockchain can enhance the remanufacturing processes. This context-specific approach means that the findings might have captured nuanced details of Tesla's operational strategies and technological implementations that may not be present in other companies. Second, China's stringent environmental regulations and policies supporting the recycling and remanufacturing of EVBs provide a unique regulatory backdrop that significantly influences Tesla's operational decisions. This particular regulatory environment can affect the extent to which the findings can be applied to other regions or countries with different regulatory frameworks. Third, while the case study provides deep insights into Tesla's specific practices, these findings might not be fully generalizable to other EV manufacturers or regions without adaptations. Tesla's role as a technology leader and its specific business and operational models may differ significantly from those of other manufacturers, especially smaller or less technologically advanced companies. The unique aspects of Tesla's approach, including its scale and the specific technologies it employs, may not be directly applicable to other settings.

However, despite these limitations, the study's findings can still offer valuable lessons for other manufacturers and regions. For example, how blockchain technology is integrated into Tesla's EVB CLSC for tracking and data sharing can serve as a model for other companies looking to enhance transparency and efficiency in their EVB remanufacturing processes. The study can also highlight challenges and opportunities that other companies might face, thereby contributing to broader strategic discussions within the industry. Finally, by documenting the practices of a leading company in a leading market, our study sets the stage for further research that could explore similar implementations in different contexts. It encourages additional case studies and comparative analyses across different geographic and regulatory environments, which could help in assessing the scalability and adaptability of the findings.

7. Conclusions

The rapid expansion of EVs generates a substantial increase in the production and disposal of EVBs. To make EVs truly sustainable, there is a need for an increased focus on repurposing practices like remanufacturing. In response, researchers have advocated for the development of a CLSC for EVBs, which facilitates the recovery of components and materials from used EVBs. However, information asymmetry, safety concerns, technological barriers and customer scepticism create substantial obstacles to the growth and adoption of EVB remanufacturing.

Blockchain technology, with its inherent features such as decentralization, transparency and immutability, has been identified as a viable solution to address these challenges. Drawing upon the literature on blockchain and the circular economy of EVBs and insights from key industry players, we propose a blockchain-based CLSC for used EVBs. Our study presents an original and comprehensive blockchain-based CLSC system that permits collaboration between key stakeholders across the entire supply chain, clearly identifying their information needs.

The system identifies two main practical paths within the current regulatory and business contexts of China: maintenance and warranty services and the production of internal fleet vehicles. Significantly, the system ensures equal participation and transparent information sharing with the help of blockchain. It is expected that this blockchain-based CLSC can better address the safety and quality concerns of the remanufactured EVBs, improve consumer trust

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

toward remanufactured EVBs and finally contribute to the sustainable development of the EVB remanufacturing operations.

We also explored the limitations of this study, which examines Tesla in China as a case study to understand the integration of blockchain in EVB remanufacturing. Focused on a leader in the field known for its innovative use of technology, the study provides a detailed look at advanced practices within a specific regulatory and operational context. While offering in-depth insights into Tesla's approach, the findings highlight the role of China's strict environmental policies in shaping these practices, suggesting that the results may not be directly generalizable to other manufacturers or regions without modification. Despite this, the study still outlines valuable lessons for other companies, particularly in utilizing blockchain for enhanced supply chain transparency and efficiency. It also sets a foundation for future research, advocating for further case studies to explore the adaptability of these practices across diverse regulatory and geographic landscapes, thereby broadening the understanding of blockchain's potential in EVB remanufacturing.

Moreover, the proposed CLSC and blockchain architecture presuppose cooperative stakeholder engagement. Future research should investigate incentivization mechanisms to motivate participation and align actions with the network's best interests. In addition, the complex relationships between supply chain participants and the unclear economic benefits of the CLSC require further theoretical exploration. To promote the broader adoption of blockchain technologies in the circular economy of EVBs, addressing key challenges such as optimizing cost structures for profit maximization is essential. We also advocate for cross-disciplinary research that integrates information technologies, battery and vehicle engineering, operational management and occupational health, among others, to comprehensively address safety and sustainability concerns in the CLSC.

Building on the foundational insights from this study, future research should explore a range of strategic areas to deepen the understanding of blockchain's role in enhancing EVB remanufacturing. Proposed directions include developing incentivization mechanisms to encourage stakeholder collaboration within the blockchain-enabled CLSC and conducting economic analyses to clarify cost structures and financial benefits. In addition, integrating cross-disciplinary expertise from information technology, engineering and operational management could foster a more resilient remanufacturing ecosystem. Longitudinal studies could further assess the long-term impacts of blockchain integration, while investigations into regulatory changes would provide insights into legal influences on CLSC operations. Lastly, studies focused on enhancing consumer trust through transparent blockchain operations could significantly increase market acceptance and penetration of remanufactured EVBs, advancing the sector's growth and sustainability.

Acknowledgement

We acknowledge that certain materials included in this work are the intellectual property of third parties. Every effort has been made to identify and appropriately credit these materials to their respective copyright holders. Use of these materials has been secured through proper channels, including written permission where required and complies with all relevant copyright laws.

If we have inadvertently failed to acknowledge any third-party copyright materials or obtained permissions, we encourage the copyright holders to contact us at g.pang.1@bham.ac.uk so that appropriate corrections or permissions can be arranged.

Ethical considerations and privacy protection for interviewees: In conducting this research, ethical considerations and the protection of interviewee privacy are of utmost importance. The following measures have been implemented to ensure the highest standards of ethical conduct and confidentiality.

Informed consent: Voluntary Participation: All interviewees participated voluntarily. They were informed about the nature and purpose of the research, the topics to be discussed and their right to withdraw from the study at any time without any consequences.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Consent forms: Prior to each interview, participants were provided with a detailed consent form outlining the research objectives, methods, potential risks and benefits. They signed the consent form to indicate their willingness to participate.

Privacy and confidentiality: Anonymity: To protect the identity of the participants, any future research results published based on this will not display private information such as the real names and contact information of the interviewees.

Data security: All data collected during the interviews, including audio recordings and transcripts, are stored securely on password-protected devices and encrypted storage systems. Access to this data is restricted to authorized research team members only.

Confidentiality agreements: Researchers involved in this project have signed confidentiality agreements, ensuring that all information disclosed during the interviews is kept strictly confidential.

Ethical approval: Institutional Review Board (IRB) Approval: This study has received approval from the IRB of the University of Birmingham, which ensures that the research complies with ethical standards and guidelines.

Compliance with ethical standards: The research adheres to the ethical standards set forth by the IRB, including respect for persons, beneficence and justice.

Interview process: Respectful Interaction: Interviews were conducted in a respectful and non-intrusive manner, allowing participants.

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

References

Belbağ, A.G. and Belbağ, S. (2023), "Remanufactured products: a systematic review from the consumer perspective", *Journal of Remanufacturing*, Vol. 13 No. 2, pp. 207-241, doi: 10.1007/s13243-023-00125-0.

Berg, B.L. and Lune, H. (2012), *Qualitative Research Methods for the Social Sciences*, 8th ed., Pearson Education, London.

Brian, T. (2024), "BASF starts up battery recycling plant in German", *Recycling Today*, available at: https://www.recyclingtoday.com/news/basf-schwarzheide-germany-battery-recycling-lithium-nickel-cobalt/ (accessed 21 February 2025).

Chai, J.W., Qian, Z.F., Wang, F. and Zhu, J. (2024), "Process innovation for green product in a closed loop supply chain with remanufacturing", *Annals of Operations Research*, Vol. 333 Nos 2-3, pp. 533-557, doi: 10.1007/s10479-020-03888-y.

Chen, Z.W., Sarkis, J. and Yildizbasi, A. (2024), "Digital transformation for safer circular lithium-ion battery supply chains: a blockchain ecosystem-data perspective", *International Journal of Production Research*, Vol. 63 No. 5, pp. 1585-1606, doi: 10.1080/00207543.2024.2381224.

Chinen, K., Matsumoto, M., Tong, P.S., Han, Y.S. and Niu, K.H.J. (2022), "Electric vehicle owners' perception of remanufactured batteries: an empirical study in China", *Sustainability*, Vol. 14 No. 17, 10846, doi: 10.3390/su141710846.

Chinese Government (2024), "The provisional measures on the recycling and repurposing of EV power storage batteries", available at: https://www.gov.cn/xinwen/2018-02/26/content_5268875.htm (accessed 20 September 2024).

Christian, D., Dempsey, H. and Bushey, C. (2023), "Why the electric vehicle battery race needs a recycling revolution", available at: https://www.ft.com/content/73138e84-701a-4e75-9ca8-7725d0867eb5 (accessed 11 August 2024).

Chun, Y.Y., Chinen, K. and Matsumoto, M. (2023), "How to attract newness-conscious consumers to a circular electric vehicle economy", *Sustainable Production and Consumption*, Vol. 40, pp. 147-158, doi: 10.1016/j.spc.2023.06.018.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Cole, R., Stevenson, M. and Aitken, J. (2019), “Blockchain technology: implications for operations and supply chain management”, *Supply Chain Management*, Vol. 24 No. 4, pp. 469-483, doi: 10.1108/SCM-09-2018-0309.

Dai, Q., Kelly, J.C., Gaines, L. and Wang, M. (2019), “Life cycle analysis of lithium-ion batteries for automotive applications”, *Batteries*, Vol. 5 No. 2, p. 48, doi: 10.3390/batteries5020048.

Duan, K.R., Pang, G. and Lin, Y. (2023), “Exploring the current status and future opportunities of blockchain technology adoption and application in supply chain management”, *Journal of Digital Economy*, Vol. 2, pp. 244-288, doi: 10.1016/j.jdec.2024.01.005.

Ellerbeck, S. (2023), “Electric vehicle sales leapt 55% in 2022 – here’s where that growth was strongest”, available at: https://www.weforum.org/stories/2023/05/electric-vehicles-ev-sales-growth-2022/ (accessed 25 April 2025).

Flyvbjerg, B. (2006), “Five misunderstandings about case-study research”, *Qualitative Inquiry*, Vol. 12 No. 2, pp. 219-245, doi: 10.1177/1077800405284363.

Gao, Y.H., Liu, Y.D., Tan, Z.X. and Li, Z.D. (2022), “Analysis of cooperation equilibrium of participants in power battery recycling chains considering information barrier”, *Chinese Journal of Population, Resources and Environment*, Vol. 20 No. 2, pp. 159-167, doi: 10.1016/j.cjpre.2022.06.006.

Global Times (2024), “Chinese ministry issues standards for utilization of used NEV batteries”, available at: https://www.globaltimes.cn/page/202408/1318043.shtml (accessed 18 August 2024).

Grati, R., Loukil, F., Boukadi, K. and Abed, M. (2024), “A blockchain-based framework for circular end-of-life vehicle processing”, *Cluster Computing*, Vol. 27 No. 1, pp. 707-720, doi: 10.1007/s10586-023-03981-4.

Gu, X.Y., Ieromonachou, P., Zhou, L. and Tseng, M.L. (2018), “Optimising quantity of manufacturing and remanufacturing in an electric vehicle battery closed-loop supply chain”, *Industrial Management and Data Systems*, Vol. 118 No. 1, pp. 283-302, doi: 10.1108/IMDS-04-2017-0132.

Gu, X.Y., Zhou, L., Huang, H.F., Shi, X.T. and Ieromonachou, P. (2021), “Electric vehicle battery secondary use under government subsidy: a closed-loop supply chain perspective”, *International Journal of Production Economics*, Vol. 234, 108035, doi: 10.1016/j.ijpe.2021.108035.

Harley, B. and Cornelissen, J. (2022), “Rigor with or without templates? The pursuit of methodological rigor in qualitative research”, *Organizational Research Methods*, Vol. 25 No. 2, pp. 239-261, doi: 10.1177/1094428120937786.

Hastig, G.M. and ManMohan, S.S. (2020), “Blockchain for supply chain traceability: business requirements and critical success factors”, *Production and Operations Management*, Vol. 29 No. 4, pp. 935-954, doi: 10.1111/poms.13147.

Hazen, B.T., Boone, C.A., Wang, Y.C. and Khor, K.S. (2017), “Perceived quality of remanufactured products: construct and measure development”, *Journal of Cleaner Production*, Vol. 142, pp. 716-726, doi: 10.1016/j.jclepro.2016.05.099.

Huster, S., Rosenberg, S., Hufnagel, S., Rudi, A. and Schultmann, F. (2024), “Do consumers want reconditioned electric vehicle batteries? - a discrete choice experiment”, *Sustainable Production and Consumption*, Vol. 48, pp. 446-459, doi: 10.1016/j.spc.2024.05.027.

Kampker, A., Wessel, A., Fiedler, F. and Maltoni, F. (2021), “Battery pack remanufacturing process up to cell level with sorting and repurposing of battery cells”, *Journal of Remanufacturing*, Vol. 11, pp. 1-23, doi: 10.1007/s13243-020-00088-6.

Kirchherr, L., Piscicelli, R., Bour, E., Kostense-Smit, J., Muller, A., Huibrechtse-Truijens, M. and Hekkert, J. (2018), “Barriers to the circular economy: evidence from the European Union (EU)”, *Ecological Economics*, Vol. 150, pp. 264-272, doi: 10.1016/j.ecolecon.2018.04.028.

Kshetri, N. (2018), “Blockchain’s roles in meeting key supply chain management objectives”, *International Journal of Information Management*, Vol. 39, pp. 80-89, doi: 10.1016/j.ijinfomgt.2017.12.005.

Kumar, A., Huyn, P. and Vennelakanti, R. (2023), “A digital solution framework for enabling electric vehicle battery circularity based on an ecosystem value optimization approach”, *Materials Sustainability*, Vol. 1 No. 1, pp. 1-15, doi: 10.1038/s44296-023-00001-9.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Li, L., Dababneh, F. and Zhao, J. (2018), "Cost-effective supply chain for electric vehicle battery remanufacturing", *Applied Energy*, Vol. 226, pp. 277-286, doi: 10.1016/j.apenergy.2018.05.115.

Li, J.Z., Liu, F.B., Zhang, J.Z., Li, L.Y. and Ferreira, J. (2024), "Forward–reverse blockchain traceability: promoting electric vehicles with battery recycling in the presence of subsidy", *Annals of Operations Research*, Vol. 415, doi: 10.1007/s10479-024-06108-z.

Liu, Y. and Wang, Q. (2024), "Blockchain for supply chain: performance implications and contingencies", *Industrial Management and Data Systems*, Vol. 125 No. 1, pp. 364-383, doi: 10.1108/IMDS-05-2024-0457.

Li, Z.H., Zhong, X.B. and Xu, X.Y. (2023), "The mechanism of retired power batteries recycling through blockchain token incentives", *Journal of Cleaner Production*, Vol. 415, 137560, doi: 10.1016/j.jclepro.2023.137560.

Liu, F., Li, J., Zhang, J., Tong, Z. and Ferreira, J. (2023), "Optimal strategy for secondary use of spent electric vehicle batteries: sell, lease, or both", *Annals of Operations Research*, doi: 10.1007/s10479-023-05380-9.

Lochmiller, C. (2021), "Conducting thematic analysis with qualitative data", *Qualitative Report*, Vol. 26 No. 6, pp. 2029-2044, doi: 10.46743/2160-3715/2021.5008.

MIIT (2024), "Draft industry standards on the comprehensive utilization of used new-energy vehicle (NEV) batteries to boost the development of the NEV sector", available at: https://jx.ah.gov.cn/group6/M00/0B/98/wKg8Bma9tkSAN2BLAAYaDMXJXnw215.pdf (accessed 18 August 2024).

Milios, L. and Matsumoto, M. (2019), "Consumer perception of remanufactured automotive parts and policy implications for transitioning to a circular economy in Sweden", *Sustainability*, Vol. 11 No. 22, 6264, doi: 10.3390/su11226264.

Muhammet, D., Vladimir, S. and Ali, E.T. (2021), "Remanufacturing facility location for automotive Lithium-ion batteries: an integrated neuromorphic decision-making model", *Journal of Cleaner Production*, Vol. 317, 128438, doi: 10.1016/j.jclepro.2021.128438.

Nath, S.D., Khayer, A., Majumder, J. and Barua, S. (2022), "Factors affecting blockchain adoption in apparel supply chains: does sustainability-oriented supplier development play a moderating role?", *Industrial Management and Data Systems*, Vol. 122 No. 5, pp. 1183-1214, doi: 10.1108/IMDS-07-2021-0466.

Neumann, J., Petranikova, M., Meeus, M., Gamarra, J.D., Younesi, R., Winter, M. and Nowak, S. (2022), "Recycling of lithium-ion batteries—current state of the art, circular economy, and next generation recycling", *Advanced Energy Materials*, Vol. 12 No. 17, doi: 10.1002/aenm.202102917.

Niese, N., Pieper, C., Arora, A. and Xie, A. (2020), "The case for a circular economy in electric vehicle batteries", available at: https://www.bcg.com/publications/2020/case-for-circular-economy-in-electric-vehicle-batteries.

Niu, Y.H. (2023), "How can China address its EV battery-recycling challenge?", available at: https://dialogue.earth/en/pollution/how-can-china-address-its-ev-battery-recycling-challenge/ (accessed 17 September 2024).

Nurdiawati, A. and Agrawal, T.K. (2022), "Creating a circular EV battery value chain: end-of-life strategies and future perspective", *Resources, Conservation and Recycling*, Vol. 185, 106484, doi: 10.1016/j.resconrec.2022.106484.

Parviziomran, E. and Elliot, V. (2024), "Barriers to circular economy: insights from a small electric vehicle battery manufacturer", *Journal of Purchasing and Supply Management*, Vol. 30 No. 2, doi: 10.1016/j.pursup.2024.100905.

Peter, F., Roger, G. and Martyn, H. (2000), *Case Study Method: Key Issues, Key Texts*, SAGE, London.

Rufino, J.C.A., Sanseverino, E.R., Gallo, P., Koch, D., Schweiger, H.G. and Zanin, H. (2022), "Blockchain review for battery supply chain monitoring and battery trading", *Renewable and Sustainable Energy Reviews*, Vol. 157, 112078, doi: 10.1016/j.rser.2022.112078.

Schmidt, C.G. and Wagner, S.M. (2019), "Blockchain and supply chain relations: a transaction cost theory perspective", *Journal of Purchasing and Supply Management*, Vol. 4 No. 25, 100552, doi: 10.1016/j.pursup.2019.100552.

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026

Shoaib, M., Lim, M.K. and Wang, C. (2020), “An integrated framework to prioritize blockchain-based supply chain success factors”, *Industrial Management and Data Systems*, Vol. 120 No. 11, pp. 2103-2131, doi: 10.1108/IMDS-04-2020-0194.

Silva, E.R., Lohmer, J., Rohla, M. and Angelis, J. (2023), “Unleashing the circular economy in the electric vehicle battery supply chain: a case study on data sharing and blockchain potential”, *Resources, Conservation and Recycling*, Vol. 193, 106969, doi: 10.1016/j.resconrec.2023.106969.

Tesla (2023), “Impact report”, available at: https://www.tesla.com/en_gb/impact (accessed 15 November 2024).

Tracy, S.J. (2010), “Qualitative quality: eight ‘big-tent’ criteria for excellent qualitative research”, *Qualitative Inquiry*, Vol. 16 No. 10, pp. 837-851, doi: 10.1177/1077800410383121.

Transport Environment (2024), “From waste to value: the potential for battery recycling in Europe”, available at: https://www.transportenvironment.org/articles/from-waste-to-value-the-potential-for-battery-recycling-in-europe (accessed 22 February 2025).

Wang, C., Feng, X.T., Woo, S., Wood, J. and Yu, S.H. (2023), “The optimization of an EV decommissioned battery recycling network: a third-party approach”, *Journal of Environmental Management*, Vol. 348, 119299, doi: 10.1016/j.jenvman.2023.119299.

Xiong, S.Q., Ji, J.P. and Ma, X.M. (2020), “Environmental and economic evaluation of remanufacturing lithium-ion batteries from electric vehicles”, *Waste Management*, Vol. 102, pp. 579-586, doi: 10.1016/j.wasman.2019.11.013.

Xu, W., Yan, W., Song, B. and He, J. (2023), “Blockchain adoption and strategic contracting in a green supply chain considering market segmentation”, *Industrial Management and Data Systems*, Vol. 123 No. 10, pp. 2704-2732, doi: 10.1108/IMDS-02-2023-0080.

Yadav, G., Luthra, S., Jakhar, S.K., Mangla, S.K. and Rai, D.P. (2020), “A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: an automotive case”, *Journal of Cleaner Production*, Vol. 254, 120112, doi: 10.1016/j.jclepro.2020.120112.

Yin, R. (2018), *Case Study Research and Applications: Design and Methods*, Sage Publication, London.

Zanoletti, A., Carena, E., Ferrara, C. and Bontempi, E. (2024), “A review of lithium-ion battery recycling: technologies, sustainability, and open issues”, *Batteries*, Vol. 10 No. 38, pp. 1-31, doi: 10.3390/batteries10010038.

Zhang, X.G., Feng, X.B., Jiang, Z.G., Gong, Q.S. and Wang, Y. (2023a), “A blockchain-enabled framework for reverse supply chain management of power batteries”, *Journal of Cleaner Production*, Vol. 415, 137823, doi: 10.1016/j.jclepro.2023.137823.

Zhang, X.M., Zheng, H.D. and Zheng, X.X. (2023b), “Impact of government fund policy and blockchain technology on closed-loop supply chains in textile and apparel industry”, *Journal of Cleaner Production*, Vol. 434 No. 1, 140037, doi: 10.1016/j.jclepro.2023.140037.

Zhang, C., Li, J.C., Tian, Y.X. and Li, H.S. (2024), “Decisions on blockchain adoption and echelon utilization in the closed-loop supply chain for electric vehicles under carbon trading policy”, *Information Sciences*, Vol. 681, 121247, doi: 10.1016/j.ins.2024.121247.

Zhao, X., Peng, B.H., Zheng, C.Y. and Wan, A. (2021), “Closed-loop supply chain pricing strategy for electric vehicle batteries recycling in China”, *Environment, Development and Sustainability*, Vol. 24 No. 6, pp. 7725-7752, doi: 10.1007/s10668-021-01755-9.

Supplementary material

The supplementary material for this article can be found online.

Corresponding author

Gu Pang can be contacted at: g.pang.1@bham.ac.uk

For instructions on how to order reprints of this article, please visit our website:
www.emeraldgrouppublishing.com/licensing/reprints.htm
Or contact us for further details: **permissions@emeraldinsight.com**

Downloaded from http://ftp.nowpublishers.com/imds/article-pdf/125/7/2321/9766862/imds-11-2024-1137.pdf by guest on 05 August 2026