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Blockchain EV Payment Systems: A Systematic Literature Review in Retail Energy Trading

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Abstract

This study provides a systematic literature review of blockchain technology for the electric vehicle industry using a retail business-process lens. Based on a final sample of twenty-one publications, primary and sub-themes representing the body of work are identified, implications and applications are discussed. Literature-informed future research directions are proposed. Blockchain features, smart contracts, and electric vehicle charging systems are the emergent key themes in this study. The findings suggest that digitalizing electric vehicle networks with blockchain technology may benefit from operationalization and scalability.

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Introduction

Blockchain Technology (BT) has grown in popularity providing security and anonymity without requiring a third-party organization to oversee the transactions (Zhang et al., 2020). BT oversees transaction recording and asset tracking in a specific network (Nakamoto, 2008). BT maintains data-record consistency in the nodes operating in a decentralized network. These characteristics suggest trustworthiness and a safer option to use BT in the electric vehicle (EV) retail market. While BT payment systems are most prevalent in cryptocurrency applications (Taleb, 2019; Tama et al., 2017), the EV charging industry may benefit from process adoption as there is a growing importance of building safe and efficient EV payment systems (Khan et al., 2021). The emergence of BT has gained adoption in different industries and the technology should create business value (Yang et al., 2021). While BT faces technical challenges and limitations in

practice; BT as a process requires extensive knowledge for businesses to fully understand how to leverage and utilize its capabilities to facilitate safe and efficient transactions (Kim et al., 2021).

Existing research identifies the challenges and limitations associated with BT (Abdella et al., 2021; Baza, Amer et al., 2021; Niu et al., 2022). Exploring security and privacy effectiveness, and market positions such as BT scalability in the EV charging industry is suggested to be of importance (Abdella et al., 2021). Current prototypes and models in the EV charging business lack adequate implementation methods to demonstrate its operationalization (Turjo et al., 2021; Wang et al., 2019). This study explores the utilization of BT payment systems by identifying themes within the literature, determining sub-themes and utilizing past research to draw upon BT value as a process for the EV charging business.

A systematic literature review (SLR; Kowalczyk et al., 2013) was performed to uncover emergent themes, diagnose links to practice, and identify future directions. The research objectives are: a) identify primary and sub-themes of BT in the EV payment systems literature, b) examine the implications and applications of BT regarding EV payments systems, and c) propose literature-informed future research directions for the advancement of science in this research domain. The research questions are:

- *RQ1: What are the key themes and sub-themes regarding BT integration in the electric vehicle charging payments systems?*
- *RQ2: What are BT's practical implications and applications in EV charging payments systems?*
- *RQ3: What are the key research deficits in BT in EV charging payments systems research?*

Methodology

This study follows a cohesive and reliable SLR (*see* Xiao, Y., & Watson, M., 2019). Parameters for inclusion and exclusion of the literature are clearly established to provide replicable results following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA, Moher et al., 2009). A thematic analysis classifies and identifies research trends and themes. A machine learning technique minimizes subjective errors. Lastly, Watkins (2017) Rigorous and Accelerated Data Reduction (RADaR) technique is applied to examine research gaps and investigate future direction and literature-driven recommendations.

Scopus and Web of Science (WoS) databases were selected for their high-quality and relevant papers (Mongeon & Paul-Hus, 2016). In the databases, a keyword search was conducted in title, abstract, and specifically keywords on a broad BT and EV literature with the following query:

`"blockchain" OR "digital ledger" AND "payment system*"`

The keywords were selected based on a literature overview coupled with industry expertise. Due to the novelty of the topic, the researchers were adamant about using keywords that limit the exclusion of possibly relevant articles in the initial stages. The initial search returned 919 papers. Non-English Articles resulted in excluding 21 papers. After removing the duplicates, 773 papers remained. ASReview – an artificial intelligence software was trained to further validate studies for

relevancy in an objective and replicable way (Hindriks, 2020; Van de Schoot et al., 2020), using the naïve Bayes approach (Kadhim, 2019). The machine was initially trained via coding based on:

- *Q1) Is the paper related to the EV charging industry? (Yes, Maybe, No)*
- *Q2) Does the paper discuss BT? (Yes, Maybe, No)*
- *Q3) Does the paper discuss the utilization of BT in the EV charging payment systems? (Yes, Maybe, No)*

To limit bias and errors, the research team trained the machine independently, removed articles that all researchers deemed irrelevant, kept the ones that all researchers deemed relevant and aligned on the “maybe” articles. In total, 729 articles were further excluded from this process. Lastly, the researchers conducted a full-paper review and manually removed 23 articles based on the inclusion/exclusion criteria. The final sample included 21 papers.

The thematic approach allows for article categorization based on primary and secondary themes (Boyatzis, 1998; Taylor and Taylor, 2009). To limit researcher bias, the research team utilized Leximancer, an artificial intelligence text analysis software. Leximancer highlights the key themes based on concept occurrence and co-occurrences (Leximancer, 2019). This analysis aimed to identify guiding categories in which the discovery of themes can be further interpreted. The papers were compiled by compressing the folder containing all 21 papers. Then, the stoplist function was used to remove irrelevant words such as “ https/figure/www.” Next, other unrelated words such as “by/or/if” were removed manually. The analysis revealed three central concepts based on top-concept occurrence: a) blockchain features, b) electric vehicle charging systems, and c) smart contracts. Some key concepts that stood out were anonymity, decentralization, energy trading, Ethereum, privacy protection, secure communication, validation and automation.

Following the thematic classification, the articles were categorized into primary themes. The**Blockchain Features** (6 occurrences) outlines characteristics of BT systems such data decentralization and data integrity, availability and security. The **Charging System** (11 occurrences) outlines types of centralized or manual systems versus decentralized or integrated systems. The **Smart Contract** (16 occurrences) outlines mechanisms that enact transactions between the energy providers and retail consumers. The thematic distribution was examined over time indicating that research on smart contracts has gained traction and increased interest in recent years. The review suggests that in the past year, more research focused on Blockchain features examining the characteristics and technical aspects of BT systems.

The primary themes were subsequently examined for research impact based on average citations received to date. The average citations were calculated to demonstrate impact and relevance: blockchain Features (mean=116.25), charging system (mean=149.75), and smart contracts (mean=150.75).

Emerging sub-themes were reviewed and subsequently organized to make sense of the themes as a process. The theme ‘Ethereum’ (14 occurrences) outlines the platform that is prominently being adopted as a ‘decentralization’ method (5 occurrences) for ‘energy trading’ (9 occurrences) in the EV charging market. The themes of ‘secure communication’ (3 occurrences) and ‘validation & automation’ (11 occurrences) are enacted by having anonymity (5 occurrences) and ‘privacy protection’ (6 occurrences). Therefore, a focus on *‘anonymity’* and *‘privacy protection’* is provided as these themes appear to be key drivers of the parent’ *energy trading’* theme.

Discussion

The demand and supply of energy involves various echelons between the distribution network and the retail consumer. Energy trading in the EV business raises compliance requirements for protecting the anonymity and privacy of the consumer (Turjo et al., 2021). The rapid rise of EV charging adoption is driven by regulatory requirements and technological advancement requiring an EV charging system' infrastructure that is not only efficient but that also safeguards the privacy (Baza, Sherif et al., 2021; Khan et al., 2021; Niu et al., 2022) and anonymity (Hatefi et al., 2022; Lin et al., 2020; Niu et al., 2022) of the consumer (Kim et al., 2021). A balance of accountability between the provider and the consumer (Hatefi et al., 2022) needs to be attained for ensuring that personal transaction information is secure, private, and compliant to regulatory requirements (Hong et al., 2021).

The proliferation of the EV technology and rapid adoption (Khan et al., 2021) by consumers requires infrastructure for longer distances. Several types of energy sources have been identified in the literature such as: a) solar, b) charging stations, and c) vehicle-to-vehicle (Baza, Sherif et al., 2021). Trading systems have emerged offering consumers price bid alternatives where suppliers and consumers are connected through centralized or decentralized systems that make use of payment technology (Abdella et al., 2021). The payment technology enables transaction bidding, account reconciliation and balances facilitated by cryptocurrency platforms operationalized by a BT model (Baza, Amer et al., 2021) such as, Ethereum. These platforms operate using smart-contracts (Zhang, 2022) for buying, selling, and obtaining account balances (Coll-Mayor et al., 2019). Current energy trading systems appear to lack transparency in the process (Abdella et al., 2021); whereby, the central operator may have access to sensitive transactional information that is required to organize the trading of energy between providers and consumers, including, EV identification, driver identification, banking information, location and time (Baza, Sherif et al., 2021). The lack of transparency in transactional information available by the providers operating the BT platforms raises questions on anonymity and privacy protection for the EV energy trade process of consumer information.

Privacy and security are fundamental for the availability, integrity, and confidentiality of information systems (Abdella et al., 2021; Hatefi et al., 2022). Decentralized systems require privacy solutions that provide assurance on the security of the digital assets and the management of the information (Lin et al., 2020). While solutions with a decentralized approach to privacy concerns are offered (Erdin et al., 2018), trust and privacy are of concern (Khan et al., 2021). Baza, Amer et al. (2021) argue that few studies have addressed privacy and security that are specific to energy trading; while, Erdin et al. (2018) claim that there aren't any studies that address privacy and the exposure to payment data such as location and user data. Abdella et al. (2021) proposed integrating BT with anonymous messaging and multi-signature technology to achieve security and privacy; however, Baza, Sherif et al. (2021) suggest that anonymization isn't sufficient to maintain privacy of information such as, locations visited by the EV consumers. This in-turn hinders the potential for scalability of EV infrastructure and its operations as the assurance of privacy to consumers against misuse of data becomes an increasing regulatory requirement (Erdin et al., 2018). Research has focused on the design of enhancing privacy solutions at the protocol level (Lin et al., 2020); where, smart contract authentication solutions such as using 'pseudonym ID' and 'zk-SNARKs' (Gabay et al., 2020) appear successful at the expense of inefficient verification cycles (Kim et al., 2021).

Zhang (2022) suggest that a trust-less application for practical implementation isn't available and privacy measures remain outstanding.

Anonymity in the transaction process of BT systems aims to preserve the privacy of legitimate users (Lin et al., 2020) by allowing information authentication without disclosure of personal details (Abdella et al., 2021; Sarkar et al., 2020). Anonymity disables the transaction tracing of information to the real identity of the consumer, contributing to the protection of privacy (Hong et al., 2021); however, this may facilitate a system for illegal activity to take place (Hatefi et al., 2022). For example, the tracking of transaction records for tax compliance hindered by the lack of transaction traceability (Niu et al., 2022). Kim et al. (2021) proposed a model where EVs make use of the same token repeatedly – enabling a system to learn the identification of the EV to determine duplication in a verification process; however, Lin et al. (2020) suggest that there are limitations and boundaries that need to be considered such as the computational complexity and higher than normal waiting times in the transaction verification process. *While anonymity in BT and EV systems is of importance, the literature reviewed suggests that providing perfect anonymity isn't a widely adopted practice.*

Directions for future research

Recommendations were developed by reviewing all included papers (Watkins, 2017). This study recommends future research that provide proof of concept for privacy and security of BT systems in the retail EV charging industry. Critically, privacy and security appear to be imperative for enabling BT systems that are able to reach operational status while enabling scalability within the markets. Table 1 provides an overview of research deficits based on included papers.

Table 1. Future directions based on included papers

Reference	Research Deficit
Niu et al. (2022)	Higher Security
Baza, Sherif et al. (2021)	Privacy Energy Trading
Hatefi et al. (2022)	Malicious User Tracing
Yang et al. (2021)	Battery Energy Storage
Kim et al. (2021)	Anonymity and Traceability
Hong et al. (2021)	Secure multiparty computation cryptographic techniques
Abdella et al. (2021)	Scalability and efficiency
Wang et al. (2019)	Reputation of provider
Shaikh et al. (2018)	Confidentiality & integrity
Pee et al., 2019	Energy use Efficiency & Security Solutions
Khan et al. (2021)	Machine Learning Approach
Erdin et al. (2018)	large-scale formation of the payment network topology
Lin et al. (2020)	customize proposal and deploy
Coll-Mayor et al. (2019)	Tested in real environment
Kim et al. (2022)	Competitive advantage
Radi et al., 2019	EV driver privacy
Kim et al. (2022)	Evaluation of suitable blockchain technologies
Zhang (2022)	Reduce delay of blockchain transactions
Sarkar et al. (2020)	Improved charging system
Turjo et al. (2021)	Off-chain architecture

Limitations & implications

Given the databases selection (WoS and Scopus), the researchers may have missed articles that can possibly be relevant; however, the selectivity with databases was undertaken to maintain quality and relevancy. This study is industry focused (Booth, 2006; Snyder, 2019), being less applicable to other industries. While machine learning was used to reduce researcher bias and reduce manual errors, its use may lack context and depth; however, theoretical and practical implications were drawn from the review.

Considerations should be given to a) the rapid proliferation of the technology coupled with the rising adoption of EV in the marketplace, b) regulatory requirements for maintaining privacy and anonymity while attaining efficient transaction information flows, c) disruption of scalability requirements that arise from transactional boundaries of privacy and anonymity, and d) potential risks that arise from scalability and operations of BT and EV systems that may incentivize illegal and fraudulent transactions.

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Declaration of Generative AI and AI-assisted Technologies

During the preparation of this work the authors used ASReview and Leximancer software in order to satisfy the relevancy of the literature and derive themes of interest. After using this software tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Conflict of Interest

The authors of this publication declare there is no conflict of interest.

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