


Blockchain-Enhanced Smart Contract for Cost-Effective Insurance Claims Processing

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ABSTRACT

Blockchain-enabled smart contracts have revolutionized the insurance industry due to their potential to streamline backend operations, mitigate fraudulent claims, and enhance data security and transparency. Guided by the design science methodology, the authors propose two specific smart contract frameworks to enhance insurance claims processing related to vehicle damage claims and personal injury claims. These proposed frameworks can improve the overall efficiency and effectiveness of insurance claims processing by automating claims submission, review, analysis, and payment, while reducing fraud and data leakage, by merging various data sources and disintermediation. Furthermore, the authors design a smart contract template supported by eight operational algorithms to facilitate the processing of insurance claims with the help of smart contracts. This template provides practitioners with a standardized prototype for the development of secure and efficient insurance applications.

KEYWORDS

Blockchain, Design Science, Fintech, Insurance Claims Processing, Smart Contract

BLOCKCHAIN-ENHANCED SMART CONTRACT FOR COST-EFFECTIVE INSURANCE CLAIMS PROCESSING

Insurance is a longstanding concept in human society; however, at present, the insurance sector faces an array of challenges due to the major economic transformations of the past few decades. These challenges encompass both macro factors, such as economic instability and regulatory pressures (Anne, 2016), and micro factors, such as distrust, high transaction costs, frequent data leaks, and numerous fraudulent activities (Zhang et al., 2022). These issues have had a profound impact on the insurance sector. To adapt and thrive in this changing landscape, insurance companies are actively seeking new strategies to address these challenges.

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Technology is a key driver for the revitalization of the insurance sector in the coming years. According to a survey conducted by Upskill, a leading provider of augmented reality software, 80% of insurance providers consider innovation as a decisive factor in their future corporate success. Furthermore, 60% identify technology as one of the major opportunities for their organizations.

Blockchain, a disruptive technology that enables the decentralized distribution of digital information (Buthelezi et al., 2022), is poised to revolutionize the insurance industry. The inherent qualities of decentralization, immutability, transparency, and validity offered by blockchain hold immense promise for overcoming the challenges faced by the insurance industry (Huang et al., 2022; Zhang et al., 2021). Smart contracts, which are self-executing protocols running on blockchain networks, ensure automated, irreversible, transparent, and traceable transactions. By leveraging blockchain-enhanced smart contracts, insurance companies can streamline backend operations, reduce manual processes, and detect and deter fraudulent claims. As a result, companies can offer more cost-effective strategies, enhance the customer experience, and achieve a stronger competitive position. Although the broader financial services sector is actively exploring blockchain and smart contracts, their application in the insurance field remains in its infancy (Gatteschi et al., 2018). However, the alliance of big data, digital technologies, and insurance provides a robust foundation for the integration of blockchain and its innovations.

This study focuses on the claims settlement process in car insurance, which is one of the most common forms of insurance. The authors provide three distinct contributions. First, following the proposed by Gregor and Hevner (2013) and Hevner et al. (2004) design science research methodology, the authors adopt transaction cost economics (TCE) as the kernel theory to develop two smart contract-based frameworks for claims processing in the insurance industry. These frameworks enhance the overall efficacy and efficiency of car insurance claims processing while ensuring data security and transparency. In particular, the first framework explores potential improvements in vehicle damage claims processing and the second framework highlights possible enhancements in personal injury claims processing through the use of smart contracts. The authors validate the applicability and feasibility of these frameworks through in-depth interviews with key stakeholders, including three insured parties, two claims adjusters, an IT manager, and a car insurance director, from a large insurance firm in China. Second, the authors create another design artifact—an adaptable smart contract template tailored specifically to car insurance claims processing. To achieve this, the researchers identify eight essential activities involved in vehicle underwriting and claims processing, and they develop corresponding smart contract algorithms. This contribution provides a standardized prototype for secure and efficient insurance applications. Third, the authors' proposed smart contract-based frameworks and template offer practical guidance to practitioners in developing robust systems for insurance applications. By leveraging these frameworks, practitioners can benefit from a standardized approach that ensures security, efficiency, and transparency in the car insurance claims settlement process.

The rest of the paper is organized as follows. The second section includes an overall examination of the insurance industry and the major challenges that it faces. The third section provides an extensive literature review on the subject. The fourth section presents the authors' two proposed smart contract frameworks for the rapid processing of vehicle damage and personal injury claims, along with a smart contract template for insurance claims. The fifth section evaluates the applicability of our proposed smart contract frameworks. Finally, the authors provide concluding remarks and highlight potential avenues for future research in the sixth section.

RESEARCH CONTEXT

Overview of the Insurance Industry

According to McKinsey & Company's (2022) report, in 2020, the global insurance industry experienced only a slight increase in gross premiums, growing by 1.25% to reach USD5.99 trillion.

This growth rate represented a slowdown, compared with the 3.34% increase witnessed in 2019. The industry's sluggish expansion can be attributed to persistent low interest rates and a host of major challenges. Furthermore, the insurance industry is currently undergoing a profound transformation driven by the emergence of innovative technologies.

Challenges in the Insurance Industry

Lack of Trust

The insurance sector faces a major challenge characterized by a lack of mutual trust between insurers and the insured. This lack of trust stems from insurers' inability to adequately assess all risks upfront, leading to suspicions of fraudulent claims submitted by insured parties. A report from the Coalition Against Insurance Fraud (2022), an America's only anti-fraud alliance, estimated that fraudulent claims in the United States accounted for 10% of all claims costs in 2021. Conversely, insured individuals may also struggle to prove their innocence and may have concerns about not receiving proper compensation. This can create frustration and dissatisfaction among the insured, eroding their trust in the insurance industry as a whole. In summary, the lack of mutual trust between insurers and the insured has detrimental effects for both parties.

Manual Claims Processing

Advancements in science and technology have yielded a diverse range of claims processing systems, which aim to reduce labor costs while enhancing the efficiency of claims management. However, two challenges need to be addressed. First, existing claims processing systems are unable to meet the increasingly complicated demands of customers and struggle to keep pace with product iterations. Second, numerous crucial steps within the process still rely on manual intervention. Presently, claims adjusters are required to manually review, analyze, and submit claims, as well as request additional documentation from insured parties, validate loss coverage, and conduct loss assessments. Consequently, the operational costs associated with these tasks remain considerably high.

Fragmented Data Sources

Data play a vital role in the insurance sector, as they serve as a crucial asset. Insurers rely heavily on large amounts of data and information to evaluate risks, determine insurance premiums, and validate coverage. However, these data are often sourced from multiple and disparate sources. This introduces several challenges, such as potential degradation of data quality and increased risk of manual errors, counterfeiting, and fraudulent activities during underwriting and claims processing (Deloitte, 2020). Moreover, the use of fragmented data sources can give rise to disputes over data ownership and raise concerns regarding data security.

Lack of Transparency in Insurance Pricing and Claims Processing

The lack of transparency in insurance pricing and claims processing is another problem in this industry (Vo et al., 2017). A recent report by the GAP Institute highlighted that insurers' methods for pricing their products and handling claims are often concealed from clients (JAUNTIN, 2022). This lack of transparency not only fosters a sense of mistrust, but also hinders the growth and progress of the insurance industry as a whole.

LITERATURE REVIEW

Overview of Blockchain Technology and Smart Contracts

Blockchain technology has emerged as a revolutionary concept in the field of distributed ledgers, incorporating both static and dynamic transaction data within a peer-to-peer network. Originally developed by Satoshi Nakamoto under a pseudonym in 2008, it was initially intended to satisfy

the transactional requirements of the cryptocurrency known as Bitcoin. Unlike traditional ledgers, blockchain possesses several distinctive characteristics, including decentralization, immutability, consensus, and anonymity (Wang et al., 2019). Decentralization is a fundamental feature of blockchain, as it eliminates the need for a central authority or intermediary, resulting in reduced transaction costs and minimized risks associated with centralized data storage. Immutability ensures that, once data are recorded on a block, they become resistant to modification, falsification, and deletion. Consensus algorithms play a crucial role in fostering trust among participants by establishing predefined rules and agreements. The anonymity aspect of blockchain technology ensures the privacy and security of every node involved (Li et al., 2020; Wang et al., 2020).

The unique characteristics of blockchain have garnered considerable attention worldwide, leading to its integration with other emerging technologies such as artificial intelligence (AI), the Internet of things, and robo-advisors. This convergence has the potential to revolutionize various industries, including banking and financial services, public goods, and healthcare. The insurance industry is also beginning to welcome these innovations, which hold tremendous promise for its transformation.

The concept of smart contracts was initially introduced by Nick Szabo in 1994. It can be separated into the terms “smart” and “contract.” Similar to a traditional legal contract, the “contract” in this case involves parties reaching a consensus on specific rules through a series of promises. “Smart” refers in particular to self-executing contracts that are written by “programmable codes” and stored on the blockchain network. Therefore, smart contracts can be distinguished by their self-executing nature. This fundamental quality makes this type of contract much more difficult to alter or falsify than traditional contracts.

Smart contracts possess two essential features that contribute to their transformative potential in the insurance industry: Automation and enforceability. The automation feature of smart contracts streamlines processes, leading to reduced transaction completion times and increased operational efficiency (Hamledari & Fischer, 2021). By automating tasks and eliminating the need for manual intervention, smart contracts eliminate human errors and delays, ensuring the swift and accurate execution of transactions. Furthermore, the enforceability of smart contracts ensures that all parties involved adhere to the agreed terms and prevents breaches of contract. It provides a high level of trust and reduces the need for intermediaries to oversee and enforce the terms of the agreement. By embedding the agreed rules directly into the code, smart contracts provide a reliable and tamper-proof framework for transactional activities. In the insurance industry, the potential impact of smart contracts is significant. By replacing traditional paper insurance policies with code-based contracts operating on decentralized networks, they can realize various benefits (Qi et al., 2021).

Blockchain and smart contracts revolutionize the distribution of interests and responsibilities among participating entities in a decentralized environment (Tapscott & Tapscott, 2016; Upadhyay et al., 2021; Wang & Xu, 2022). They have the potential to significantly reduce bureaucracy and costs by circumventing the need for traditional intermediaries (Daniel & Guida, 2019).

Literature on Blockchain-Enhanced Smart Contracts

Although the smart contract is a concept that predates blockchain technology, blockchain provides the underlying infrastructure to enhance the implementation of smart contracts in an immutable, transparent, decentralized, and trustless manner (Alharby et al., 2018; Wang et al., 2019). Specifically, blockchain’s immutability ensures the security and trustworthiness of the smart contract. Moreover, blockchain provides all participants in the network with a clear view of the smart contract’s code and its execution. This transparency increases accountability and reduces the potential for fraud or manipulation. Also, the decentralized nature of blockchain enhances the resilience and fault tolerance of the smart contract system. Besides, smart contracts on a blockchain enable parties to engage in transactions without the need to trust each other explicitly. The execution of the contract is governed by predefined rules and consensus mechanisms built into the blockchain, ensuring fair and unbiased

outcomes. In the authors' work, the term "blockchain-enhanced smart contract" refers to the use of blockchain technology to enhance the capabilities and functionalities of traditional smart contracts.

In addition, the creation of smart contracts extends the scope of the Bitcoin blockchain from achieving consensus on data streams to achieving consensus on a computational level. Smart contracts play a pivotal role in the blockchain ecosystem, providing a flexible programming mechanism that empowers static block data. Smart contracts serve as the foundation for blockchain 2.0. Moreover, the inherent automation and programmability of smart contracts enable them to function as software agents in the virtual realm. By integrating smart contracts, decentralized applications and decentralized autonomous organizations can realize the use of AI (Balcerzak et al., 2022).

The literature exploring the intersection of smart contracts and blockchain technology is extensive and highlights their combined potential. Smart contracts, when integrated with blockchain, offer a range of benefits and introduce new avenues for research and development. Researchers have explored the various applications of blockchain-enhanced smart contracts across diverse industries. From supply chain management (Wang et al., 2019) to healthcare (Khatoun, 2020), finance (Peters & Panayi, 2016), and beyond, researchers have identified numerous use cases in which smart contracts can streamline processes, eliminate intermediaries, enhance security, and improve efficiency. For instance, Wang et al. (2019) proposed blockchain-empowered smart contracts to enhance efficiency and prevent counterfeiting in distributor-to-consumer transaction processing within the consumer electronics industry. In the development of PuRSCA, a peer-to-peer purchase and rental application for Android devices, Niya et al. (2018) explored the integration of smart contracts and the Ethereum platform. Their research demonstrated the potential of smart contracts to facilitate secure and transparent transactions between users, thereby enabling a decentralized marketplace. Khatoun (2020) developed a blockchain-based smart contract system to improve data management in the healthcare ecosystem.

Despite the rapid development and increasing adoption of smart contracts, it is important to acknowledge that they are still in their early stages, and various challenges and barriers need to be addressed. These challenges span technological, regulatory, and organizational aspects and have prompted researchers to express concerns about the widespread adoption of smart contracts. Cuccuru (2017) underscored several challenges associated with smart contracts, including issues related to their ease of understanding, the rigidity imposed by code, and the potential risks arising from decentralization. The automated execution of predefined algorithms in smart contracts upon product delivery may lead to unintended consequences. Additionally, the involvement of external programs called "oracles" to monitor off-blockchain events introduces the risk of falsified information. Cuccuru suggested that the diffusion of smart contracts should achieve a balance between the efficiency gained from decentralization and the regulatory oversight provided by offline legal systems. Peters and Panayi (2016) emphasized the need to address certain issues before smart contracts can achieve widespread adoption. Scalability emerges as a concern, as not every node is capable of handling the increasing volume of transactions associated with the growing number of smart contracts and users. The accuracy of the code is crucial and must be guaranteed by both the participants and developers. Additionally, the convergence of technical and legal aspects poses a major challenge when disputes arise between contracting parties. At least one person involved should possess a detailed understanding of both the technical and legal ramifications, which is not always feasible. Addressing privacy and security concerns during transactions, Kosba et al. (2016) proposed Hawk, a blockchain model that combines cryptography and privacy-preserving smart contracts, to ensure transactional privacy from the public. The Hawk compiler simplifies the process of integrating cryptography into smart contracts, enabling even amateur programmers to develop programs on Hawk without the need for extensive cryptography knowledge.

In summary, research on blockchain-based smart contracts can be broadly categorized into two main areas: The advantages of smart contracts in specific business scenarios and the concerns surrounding their adoption. However, most studies have been performed at the conceptual level, either describing the potential innovations of smart contracts in various business domains or

discussing general issues without specific implementation details. Academic research on smart contract-enabled insurance is still underdeveloped (Gatteschi et al., 2018; Vo et al., 2017; Zhou et al., 2018). Gatteschi et al. (2018) generally discussed the potential of blockchain and smart contracts in peer-to-peer insurance and pay-per-use-insurance. Vo et al. (2017) proposed a blockchain-based architecture for a pay-as-you-go car insurance application. Zhou et al. (2018) proposed MIStore, a blockchain-based system for the secure storage of patients' data in medical insurance. Sheth and Subramanian (2020) built an Ethereum-based smart contract system tailored to the insurance industry and proposed an economic model illustrating how smart contract systems can enhance social welfare by reducing transaction costs and reshaping supply and demand dynamics. More recently, Huang et al. (2022) developed a personalized car insurance scheme using smart contracts to address privacy and transparency concerns related to data collection. However, to the best of the authors' knowledge, there are no detailed smart contract templates specifically addressing insurance claims processing. Considering the current challenges and opportunities associated with blockchain and smart contracts, this paper aims to provide practical and actionable guidance to streamline the insurance claims process. The authors propose two multiparty frameworks and a smart contract template, offering insurers a step-by-step approach for the deployment of smart contracts to enhance the efficiency of insurance claims processing.

Transaction Cost Economics and the Potential of Blockchain for the Insurance Industry

The authors adopt TCE as the kernel theory to inform the design of blockchain-based artifacts for the insurance industry. TCE is a well-established economic theory that explains the costs involved in exchanging goods, services or information within an economic system (Williamson, 1979, 1985; Zhang et al., 2021). It has been widely applied in various fields, such as finance, management, and organizational economics. In recent years, TCE has also gained traction in information systems research, with scholars leveraging its theoretical perspectives to explain phenomena in offshore IT projects (Dibbern et al., 2008), contract design choices (Benaroch et al., 2016), and the impact of IT on firms' business strategies (Cao et al., 2022; Drnevich & Croson, 2013). Furthermore, TCE has been utilized as a kernel theory in design science research. For instance, Zhang et al. (2021) adopted TCE as a theoretical foundation to guide the development of a novel blockchain-based technical model for long-term car insurance. Drawing inspiration from Zhang et al. (2021), the authors utilize TCE as a kernel theory to inform the design of blockchain-based artifacts for car insurance claims processing.

In the insurance industry, transaction costs may arise from factors such as information asymmetry, opportunism, and fragmented data sources (Allen, 1991; Conner & Prahalad, 1996). In particular, in an economic transaction, *information asymmetry* refers to a situation in which one party has more information than the other party (Akerlof, 1970). Information asymmetry can thus lead to a lack of trust between parties, which, in turn, increases the transaction costs (Zhao, 2020), particularly those associated with negotiating policy terms, handling claims, and resolving disputes. Information asymmetry can also lead to a lack of transparency in both insurance pricing and claims processing. For instance, insurers may possess more information about the risks involved in the transaction than the insured party, which can create mistrust and uncertainty regarding the fairness and appropriateness of the premium being quoted. To reduce mistrust and the associated transaction costs, improved communication and transparency are necessary between insurers and insured parties. Ensuring that both parties have access to the same information and pricing models can foster greater trust, leading to more efficient and cost-effective transactions.

Opportunism occurs when one party in a transaction takes advantage of their position to exploit the other party (Williamson, 1985). In the insurance industry, opportunism can occur when either the insurer or the insured party acts in their own interest and against the interests of the other party. For example, on the one hand, an insurer may engage in opportunistic behavior by

denying a legitimate claim to avoid paying out benefits (Chalmers et al., 2002). This can lead to disputes and increased transaction costs associated with resolving the issue. On the other hand, an insured party may engage in opportunistic behavior by misrepresenting the risks involved in the transaction to secure a lower premium. This can lead to increased transaction costs associated with investigating and verifying the accuracy of the information provided. To mitigate opportunism and build trust between contracting parties, it is essential to establish a contract that addresses these issues (Zhang et al., 2021).

Fragmented data sources can also lead to increased transaction costs associated with data ownership disputes, security, management, analysis, and integration issues. When data are fragmented, it can be difficult to determine their owners and those responsible for their security. This can lead to disputes between insurers, insured parties, and other stakeholders over data ownership and access, which can be time-consuming and costly to resolve. Data security is also a concern regarding fragmented data sources. Data that are spread across different parties and systems may be vulnerable to unauthorized access, theft or loss. This can lead to data breaches, which can be costly to investigate and remediate and can result in reputational damage and legal liabilities. In addition, insurers and insured parties may need to invest in resources and technology to manage the data effectively, and data may need to be manually entered, cleaned, and standardized, which can be time-consuming and costly. To address these challenges, it is necessary to introduce technologies that allow the involved parties to collect, analyze, and integrate data from a variety of sources and establish clear data ownership and security protocols.

Blockchain and smart contracts can facilitate more efficient and cost-effective transactions in the insurance industry from the following perspectives.

Enhanced Transparency and Trust

Blockchain's inherent transparency and immutability enable all participants in the insurance ecosystem to access a shared and synchronized ledger. This transparency reduces information asymmetry, builds trust among stakeholders, and mitigates fraudulent activity. All relevant parties, including insurers, insured individuals, intermediaries, and regulators, can access and verify transactional data in real time, fostering a more transparent and trustworthy environment.

Streamlined Claims Processing

Smart contracts executed on the blockchain can automate and streamline the insurance claims process. By codifying predefined rules and conditions, smart contracts can automatically initiate claims settlements when specific criteria are met. This automation eliminates the need for manual intervention, reduces paperwork, and accelerates claims processing, leading to faster settlements for policyholders.

Improved Data Security and Privacy

Blockchain offers robust security features that protect sensitive insurance data from unauthorized access and tampering. The decentralized nature of blockchain ensures that data are distributed across multiple nodes, reducing the risk of a single point of failure. Additionally, advanced cryptographic techniques can be employed to encrypt and secure sensitive information, granting individuals greater control over their data and enhancing privacy protection.

Disintermediation and Automated Transactions

Blockchain serves as a platform for disintermediation (Chalmers et al., 2021), offering insurers the opportunity to bypass traditional intermediaries in the insurance industry. While intermediaries play a vital role in providing services such as distribution, claims management, and risk management, these services often carry high distribution costs, increased risks of fraud, and limited data transparency. With blockchain, insurers can leverage automated identity validation,

self-executed transactions, and decentralized consortia to reduce reliance on intermediaries and streamline operations.

Increased Efficiency and Effectiveness

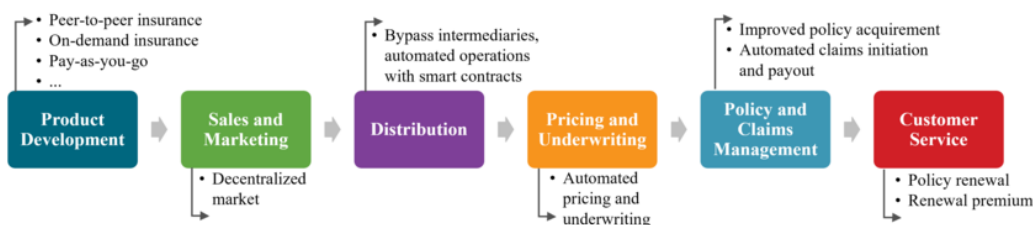
Blockchain enables the delivery of automated policies and enhances various activities within the insurance industry, such as speeding up and streamlining activities involved in underwriting, claims management, and fraud detection; reducing manual errors; lowering transaction costs; and avoiding data duplication. Moreover, blockchain provides a decentralized and unified platform for internal and external data, enabling the verification of personal identity, data ownership, policy reports, police reports, credit reports, claims histories, and subsequent policy trigger conditions. This unified platform also ensures the authenticity and integrity of data, allowing insurers to make informed decisions based on verified information.

Current Blockchain Use Cases in the Insurance Industry

The advantages mentioned above demonstrate the significant impact of blockchain technology on the entire insurance value chain (Figure 1). Recognizing the immense potential of blockchain, many insurance companies are collaborating with insurtech firms to explore its possibilities across various domains. Successful implementations have already been witnessed in car, health, life, and travel insurance. One notable example is InsurTETH, a UK-based fintech group that has successfully deployed a flight travel insurance solution using the Ethereum blockchain and smart contracts. This innovative approach enables automated claims initiation and compensation in the case of flight delays or cancellations. Another pioneering solution is Kasko2go, a mobile-based insurtech firm powered by AI and blockchain technologies, offering personalized pay-as-you-go car insurance (Peverelli & Feniks, 2021). By leveraging relevant data such as driver behavior, insurance history, road conditions, and weather statistics, the solution assesses claims quickly and provides refunds to drivers within only 15 minutes, a significant improvement over the traditional two-month process. This application not only enhances the customer experience, but also reduces insurance costs by up to 50% for those with safer driving practices. In addition, LumenLab, which is MetLife's innovation center, in collaboration with various insurtech partners, has developed the world's first blockchain-based health insurance product, called Vitana, specifically designed to address gestational diabetes (Marmur, 2018). This groundbreaking product leverages customers' electronic medical records, which are stored on their mobile devices, to issue policies within minutes. Automated payouts are triggered upon diagnosis, eliminating the need for lengthy claims processes. The introduction of Vitana improves the customer experience, reduces refund periods, and significantly enhances data security.

In summary, while insurers are actively testing blockchain technology, its implementation in the insurance industry is still in the early exploration phase. Current trials of blockchain-enabled insurance primarily focus on a limited range of insurance activities. Many of the proposed business models are still theoretical and lack empirical testing, making it challenging to assess their viability.

Figure 1. Blockchain use cases across the insurance value chain



DESIGN OF SMART CONTRACT-BASED FRAMEWORKS FOR COST-EFFECTIVE CAR INSURANCE CLAIMS PROCESSING

The aforementioned evidence strongly supports the idea that blockchain and smart contracts can serve as powerful catalysts to accelerate the transformation of the insurance sector (Sheth & Subramanian, 2020; Zhang et al., 2021). Taking car insurance as an example, the authors designed two explicit frameworks that outline blockchain-based workflows for automated claims processing. The first framework focuses on vehicle damage (Figure 2) and the second framework addresses accidental personal injuries (Figure 3). By integrating blockchain and smart contracts into car insurance claims processing, the authors sought to achieve two primary objectives. First, they aimed to reduce transaction costs by enhancing the overall efficiency and effectiveness of the claims settlement process through the automation of claims submission, review, analysis, and payment. Second, the authors aimed to ensure data security and transparency by merging various data sources and facilitating disintermediation.

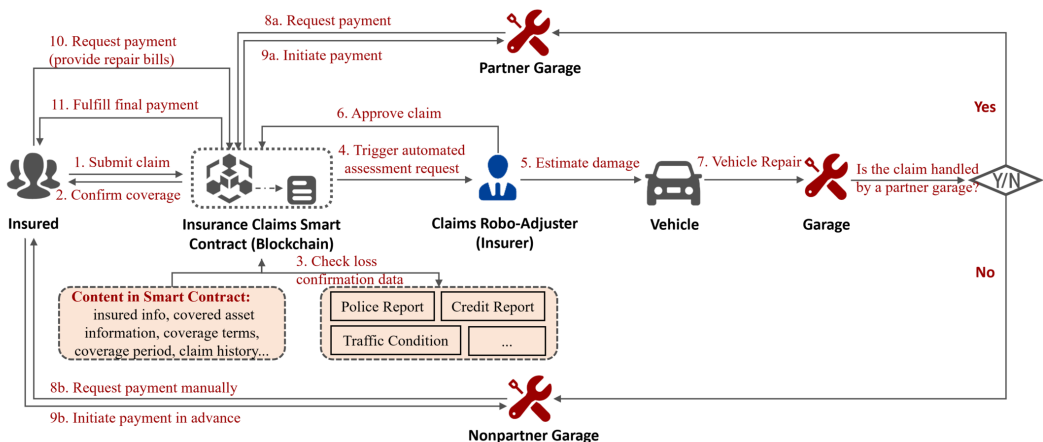
The Smart Contract-Based Framework for Vehicle Damage

Figure 2 presents an overview of the blockchain-based workflows utilized during the vehicle damage claims process. The framework outlines the key steps involved and the core stakeholders participating in the vehicle insurance claims process. In this scenario, the primary stakeholders are the insured, the insurer, the claims robo-adjuster, the vehicle, and the garage.

The procedures involved in the proposed framework are as follows:

1. Following a traffic accident, the insured party captures photos of the damage to the vehicle using a mobile app and uploads them to the blockchain, accompanied by a claim request.
2. A specific smart contract, previously agreed upon and signed by both the insured and the insurer, is triggered. The smart contract initiates a confirmation request to validate the insurance coverage with the insured.
3. Upon approval from the insured, oracles within the smart contract verify the authenticity and accuracy of the claim by consulting various external data sources, such as the police report, the insured’s credit report, and relevant data on traffic conditions and weather statistics.
4. If the evidence provided by the insured aligns with the predefined conditions in the smart contract, and the loss is confirmed based on the external data, an automated assessment request is sent to the insurer for further processing.

Figure 2. A smart contract-based framework for the workflows of vehicle damage claims



5. A claims robo-adjuster, belonging to the insurer, assesses the extent of damage to the vehicle using the uploaded photos and calculates the appropriate claim amount.
6. The claims robo-adjuster approves the claim based on the estimated damage and policy terms.
7. The vehicle is repaired by a trusted garage.
8. Payment is requested as follows:
 - a. If the vehicle is repaired at a garage from the insurer’s partner list, the partner garage uploads the relevant repair bills and requests automated payment through the blockchain.
 - b. If the vehicle is repaired at a nonpartner garage, the garage submits the relevant repair bills and requests manual payment from the insured.
9. Payment is initiated as follows:
 - a. The smart contract automatically initiates the payment, transferring the reimbursement directly to the partner garage.
 - b. The insured initiates payment to the nonpartner garage in advance.
10. If the insured pays for the repair in advance, they should provide repair bills to the blockchain to obtain the corresponding reimbursement from the smart contract.
11. The smart contract approves the request and transfers the corresponding reimbursement amount to the insured.

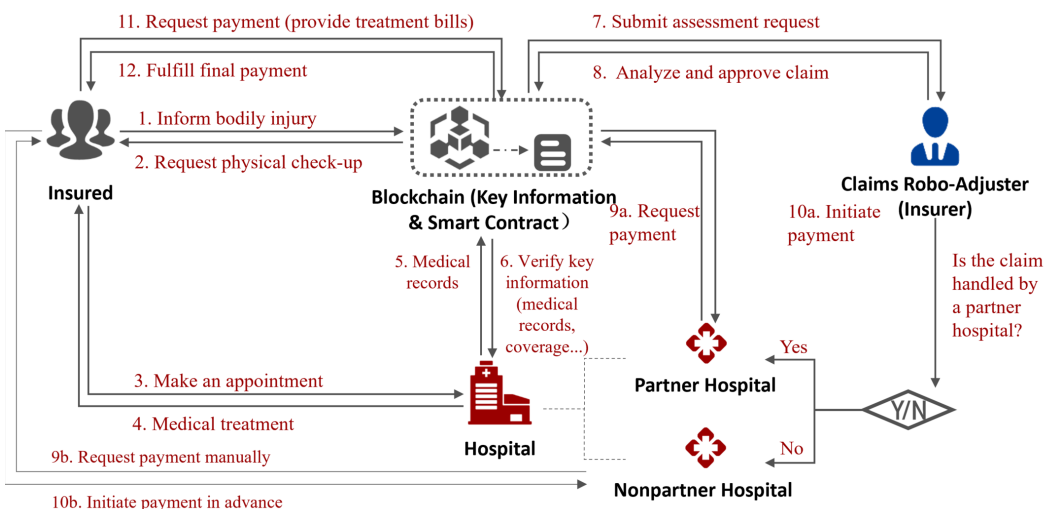
The Smart Contract-Based Framework for Bodily Injury

Figure 3 illustrates the blockchain-based workflows for bodily injury claims in the event of a traffic accident. This framework outlines the key steps involving the core stakeholders in the bodily injury claims process. The core stakeholders in this scenario are the insured, the insurer, the claims robo-adjuster, and the hospital.

The procedures involved in the proposed framework are as follows:

1. When the insured submits a claim for vehicle damage, they also report any bodily injury to the blockchain using a mobile app.

Figure 3. A smart contract-based framework for the workflows of personal injury claims



2. A specific smart contract is triggered, which verifies that the bodily injury is a result of the accident. The smart contract then prompts the insured to undergo a physical examination at a hospital.
3. The insured completes an online form and schedules an appointment with a designated hospital.
4. The insured undergoes an examination and receives the necessary medical treatment at the hospital.
5. The examination results and medical records are securely uploaded to the blockchain, triggering the execution of the smart contract.
6. The smart contract validates the examination and medical records against predefined conditions and verifies that the submitted claims fall within the insurance coverage.
7. If the medical records from the hospital and the loss confirmation data captured by the oracles align with the predefined conditions in the smart contract, an automated assessment request is sent to the insurer.
8. A claims robo-adjuster, belonging to the insurer, calculates the claim amount and approves the claim.
9. Payment is requested as follows:
 - a. If the insured receives treatment in a hospital from the insurer's partner list, the partner hospital uploads the treatment bills and requests automated payment through the blockchain.
 - b. If the insured receives treatment in a nonpartner hospital, the nonpartner hospital provides the treatment bills and requests manual payment from the insured.
10. Payment is initiated as follows:
 - a. The smart contract initiates an automatic payment, transferring the corresponding reimbursement directly to the partner hospital.
 - b. The insured initiates payment to the nonpartner hospital in advance.
11. If the insured pays the bill in advance, they should upload the treatment bills to claim the corresponding reimbursement from the smart contract.
12. The smart contract approves the reimbursement request and transfers the corresponding amount of money to the insured.

A Smart Contract Template for Insurance Claims

To enable the automated execution of smart contracts in real-world insurance claims processing, the authors present a smart contract template that facilitates interactions among the parties involved. The smart contract template encompasses eight carefully developed algorithms, each representing a critical operational mechanism within the insurance claims processing workflow. These algorithms are designed to reflect the specific steps and decision points that arise during the claims handling process. By implementing these algorithms as executable code within the smart contract, the researchers enable the automation of essential activities, ensuring efficiency, accuracy, and transparency throughout the claims processing procedure. Each algorithm within the template addresses a specific aspect of the claims process, such as claims submission, validation, and payment. For instance, one algorithm within the smart contract template is called "submitClaim," which is responsible for facilitating the submission of an insurance claim. The algorithm takes two inputs, namely the vehicle damage photos and the message sender. To initiate the claims submission process, the algorithm verifies whether the message sender has an active insurance policy. If the sender is insured, the algorithm proceeds to enable the uploading of the vehicle damage photos to the blockchain. This signifies that the insured individual has successfully submitted their claim to the blockchain, where it can be securely recorded and processed.

Another algorithm within the smart contract template is called "initiatePayment," which handles the payment process for damages in an insurance claim. The algorithm takes several inputs, including photos of the repair bill, the garage name, the claim amount, the garage account, and the insured account. When the algorithm is executed, it first verifies whether the garage specified in the claim

is partnered with the insurer. If the garage is a partner, the smart contract automatically triggers the payment process. As a result, the reimbursement amount is directly transferred from the insurer's account to the partner garage's account. This streamlined process ensures a seamless and efficient payment flow. However, if the garage is not a partner of the insurer, the algorithm follows an alternative approach. In this case, the insured individual is responsible for initiating payment to the nonpartner garage in advance. The smart contract facilitates this transaction, allowing the insured to transfer the reimbursement amount from their account to the garage's account. With the "initiatePayment" algorithm, the smart contract provides a flexible and adaptable solution to handle payment processes in insurance claims. It accommodates both partner and nonpartner garages, ensuring that payment is appropriately initiated based on the garage's status and the specific circumstances of the claim. The relevant sections of the smart contract template are presented in Table 1 of the Appendix. The finalized smart contracts are deployed on the Ethereum platform.

DESIGN EVALUATION

Following the design science methodology, the authors evaluated the applicability of their proposed smart contract-based frameworks for practitioners. In particular, they based the applicability evaluation on open- and closed-ended questions administered in semistructured face-to-face and Tencent meeting¹ interviews with three insured parties and four employees, including two claims adjusters, an IT manager, and a director, from a large car insurance firm in China. Due to geographic constraints, the authors conducted Tencent meeting interviews with the insured individuals, while they interviewed the rest of the participants face to face. Each interview was scheduled in advance and lasted between 20 and 50 minutes. Before the interviews, the authors provided each interviewee with a detailed description of the functionality and procedures of their smart contract-based frameworks. This preparatory step ensured that the participants had a clear understanding of the concepts and principles underlying the proposed frameworks.

The insured parties and the claims adjusters were the direct users of the authors' proposed frameworks. By conducting interviews with these users, the researchers gained valuable insights into the importance, necessity, and feasibility of the proposed frameworks from their perspectives. The three insured parties were customers using the car insurance product offered by the firm, and their information was provided by the insurance firm. They all had prior experience with car insurance claims, and one had also made bodily injury claims. These interviews had an average duration of 29 minutes. The researchers prepared the questions prior to the interviews. The questions covered:

1. How they felt about the existing processes involved in vehicle damage claims and bodily injury claims.
2. How they felt about the convenience and efficiency of the proposed smart contract-based frameworks applied during the insurance claims processes.
3. Whether the proposed frameworks helped them to establish trust with the insurance firm.
4. How they felt about the issues of data breach, theft or loss after the adoption of the proposed frameworks.

The feedback the authors received from these insured individuals strongly affirmed the value and importance of the proposed frameworks. They emphasized that the decentralized, autonomous, and automated nature of the smart contract-based frameworks significantly enhanced the overall efficiency of vehicle damage and bodily injury claims settlement. By automating the claims submission, review, analysis, and payment processes, these frameworks brought considerable convenience. Furthermore, the immutability and traceability of the frameworks alleviated their concerns regarding data leakage, tampering, and loss of information.

The two claims adjusters were deeply involved in the car insurance claims processes. The researchers conducted the interviews to understand their perspectives on the efficiency of the proposed frameworks. The close-ended questions covered (1) how they felt about the existing processes involved in vehicle damage claims and bodily injury claims in the firm and (2) how they felt about the effectiveness of the proposed smart contract-based frameworks during the process of handling insurance claims. Both claims adjusters agreed that the proposed frameworks had the potential to significantly improve their work efficiency. They highlighted the reductions in their manual workloads and the streamlining of tasks such as verifying policy coverage, assessing damages, and determining liability as key benefits of the frameworks. Additionally, one of the adjusters acknowledged that the proposed frameworks allowed for the storage of all relevant information, including policy details, accident reports, and damage assessments. They considered this enhanced storage capability valuable, as it improved trust and simplified the process of verifying and reviewing claims data.

The firm's IT manager was responsible for managing the information technology systems and infrastructure that supported the firm's business operations. Two specific key responsibilities of the IT manager were to ensure the security and confidentiality of the firm's data by implementing and maintaining appropriate data security measures and to monitor and maintain the firm's hardware and software systems to ensure their efficient and effective operation. The authors held an in-depth interview with the IT manager to understand the technical feasibility of their proposed frameworks. During the interview, the IT manager displayed significant interest in the researchers' proposed frameworks. The IT manager specifically highlighted the potential of our frameworks to maintain the integrity and immutability of data stored in smart contracts. Claims data, policy details, and other relevant information could be securely recorded on the blockchain, making them transparent, traceable, and resistant to tampering or unauthorized modification. Furthermore, the IT manager emphasized the importance of integrating external systems and data sources, such as vehicle databases, repair shops or accident reports, to gather relevant information for claims processing when designing smart contract-based frameworks. The IT manager noted that this integration was essential to the accuracy and efficiency of claims assessment and settlement.

The car insurance director was responsible for developing and implementing the firm's overall car insurance strategy and overseeing the day-to-day operations of the car insurance department. The director stated that incorporating blockchain and smart contracts into the car insurance product could give the company a competitive advantage. The adoption of these technologies was expected to improve operational efficiency, reduce transaction costs, mitigate the risk of fraud, and enhance the overall customer experience. While acknowledging the potential benefits, the director also raised a practical concern regarding the implementation of the authors' proposed frameworks. The director noted that, while the frameworks offer a promising long-term solution for cost-effective insurance claims processing, their successful integration will require the allocation of substantial human and financial resources. Educating participants about the new technology and integrating it with existing systems will require substantial investments during the early stages of implementation.

Overall, the interviewees considered the authors' proposed smart contract-based frameworks important, valuable, and viable enhancements to ensure an automated, irreversible, transparent, trackable, and trustworthy claims process in car insurance.

CONCLUSION

Theoretical and Management Implications

Driven by the design science research methodology, the authors designed and evaluated two frameworks and the related algorithms, leveraging blockchain and smart contract technologies for the processing of vehicle damage and personal injury claims.

This study makes three significant contributions to the literature.

First, the researchers employed TCE as the kernel theory to guide the design of two smart contract-based frameworks for car insurance claims processing. While previous research had applied TCE as a foundational theory for the design of IT artifacts in the insurance industry (Zhang et al., 2021), its application specifically for blockchain-based IT artifacts in car insurance has remained relatively unexplored. Therefore, the authors endeavored to bridge this research gap by adopting TCE as the theoretical basis to guide the development of two innovative smart contract-based frameworks for car insurance claims processing. The first framework focuses on potential enhancements in vehicle damage claims processing and the second framework highlights possible enhancements in personal injury claims processing through the use of smart contracts. To validate the practicality and feasibility of these frameworks, the researchers conducted in-depth interviews with key stakeholders from a prominent insurance firm in China. Compared with traditional claims processing, the proposed frameworks offer several benefits: They enhance the overall efficiency and effectiveness of the process by simplifying claims submission, automating time-consuming steps, reducing operational costs, and mitigating the risk of fraud; they ensure the secure, private, and transparent handling of client data by consolidating fragmented data sources into a unified blockchain database and eliminating intermediaries; and they foster mutual trust between insurers and insured parties by significantly reducing the risk of fraud for insurers while enabling prompt reimbursement for insured individuals. To the best of the authors' knowledge, their work is among the very few attempts to develop frameworks specifically tailored to car insurance claims processing.

Second, while the popularity of smart contract research has grown, a large number of studies on smart contracts have been limited to conceptual discussions, exploring potential innovations across various business domains or addressing general issues, without discussing specific implementation details (Gatteschi et al., 2018; Vo et al., 2017; Zhou et al., 2018). Academic research on operational smart contract-enabled insurance is still in the early stages of development. In this study, the authors created a new system supported by eight executable algorithms that significantly enhances the operational efficiency of smart contracts in real-world insurance claims processing. Their innovative smart contract template facilitates the automated execution of insurance claims, ensuring a standardized and secure process while optimizing costs. The authors' contribution offers a reliable prototype that streamlines insurance claims processing, benefiting both insurers and insured parties.

Third, the authors' proposed smart contract-based frameworks and template carry management implications for practitioners in the insurance industry. This industry has long struggled with management challenges that impede efficiency and transparency in insurance pricing, claims handling, and payment procedures. Additionally, a high level of distrust exists between insurers and policyholders. The researchers' proposed smart contracts present a practical solution to effectively address these issues. One of the key solutions offered by their smart contracts is the integration of operational algorithms into the contract template, enabling automated pricing and payment processes. This automation streamlines and expedites these crucial operations, reducing reliance on manual intervention and minimizing errors. By eliminating time-consuming and error-prone manual activities, smart contracts dramatically enhance the overall efficiency and effectiveness of insurance claims processing. Furthermore, using the authors' two smart contract frameworks helps to eliminate redundant intermediaries, resolving agency problems, which can hinder the smooth flow of insurance processes. As a result, these frameworks significantly improve the overall efficiency and effectiveness of insurance claims processing, fostering greater operational efficiency and reducing costs.

Potential Challenges in Framework Adoption

The authors' proposed frameworks may encounter several issues when tested by various practitioners, with the most prevalent challenges being regulatory and legal issues (Deloitte, 2018), potential security threats (Amponsah et al., 2021), integration concerns, and the high cost of early-stage development.

Regulatory and legislative aspects represent significant obstacles to the adoption of the authors' proposed frameworks. While blockchain and smart contracts have been decriminalized in many

countries, they still face strict oversight. Regulators and legislators primarily focus on the outcomes of technology rather than the technology itself, as they are driven by utilitarian considerations. They are hesitant to wait for blockchain and smart contracts to demonstrate significant improvements in insurance efficiency and effectiveness, which may take several years. Moreover, regulations and legislation are dynamic, often being changed or updated every few years, further hindering the immediate implementation of the researchers' proposed frameworks.

Cybersecurity remains a major concern for the successful implementation of their proposed frameworks. Recent security incidents have highlighted the vulnerability of blockchain networks, particularly as a small group of miners can launch a 51% attack². Unfortunately, there is currently no foolproof solution available to effectively mitigate the risk of such attacks.

The integration of the authors' proposed frameworks into the insurance industry will require significant changes and potentially even the complete replacement of existing systems. This aspect is expected to hinder the acceptance of the frameworks among stakeholders, as they will disrupt established processes and require extensive adaptation.

While the authors' blockchain-enhanced smart contracts offer an effective means of reducing insurance costs, their implementation will demand the investment of substantial human and financial resources. Organizations must dedicate significant efforts toward educating participants about the technology and ensuring seamless integration with existing systems. The associated costs could be considerable.

The ultimate adoption and utilization of the authors' proposed smart contract frameworks may take time. The researchers suggest that insurance practitioners maintain an optimistic outlook regarding the potential benefits offered by blockchain technology, while remaining cautious and mindful of the issues discussed above.

Implications for Future Research

This work is not without limitations. First, the authors validated the proposed two smart contract frameworks through interviews. Future research could integrate additional empirical methods such as mathematical analysis, simulation, and experiments. By incorporating these methods, a more comprehensive validation process could be achieved, ensuring the robustness and effectiveness of the proposed frameworks. Second, this study specifically focused on the claims processing of car insurance. Future research could exploit the potential of blockchain and smart contract technologies in other insurance domains, such as life, flight, and property insurance. Investigating the feasibility and practicality of these technologies across various insurance products would broaden current understanding of their potential benefits and challenges in the insurance industry as a whole. By conducting interviews with these users, the authors could gain valuable insights into the importance, necessity, and feasibility of the proposed frameworks from their perspectives.

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REFERENCES

- Akerlof, G. A. (1970). The market for “lemons:” Quality uncertainty and the market mechanism. *The Quarterly Journal of Economics*, 84(3), 488–500. doi:10.2307/1879431
- Alharby, M., Aldweesh, A., & Moorsel, A. v. (2018). Blockchain-based smart contracts: A systematic mapping study of academic research. In *Proceedings of the 2018 International Conference on Cloud Computing, Big Data, and Blockchain (ICCCBB)* (pp. 1-6). IEEE.
- Allen, D. W. (1991). What are transaction costs? *Review of Law & Economics*, 14, 1–18.
- Amponsah, A., Adekoya, A., & Weyori, B. (2021). Blockchain in insurance: Exploratory analysis of prospects and threats. *International Journal of Advanced Computer Science and Applications*, 12(1), 445–466. doi:10.14569/IJACSA.2021.0120153
- Anne. (2016,). *6 Biggest challenges for insurance companies*. Insurance Analysis. <http://insurance-analyzer-info.com/6-biggest-challenges-for-insurance-companies>
- Balcerzak, A. P., Nica, E., Rogalska, E., Poliak, M., Klieštík, T., & Sabie, O.-M. (2022). Blockchain technology and smart contracts in decentralized governance systems. *Administrative Sciences*, 12(3), 1–16. doi:10.3390/admsci12030096
- Benaroch, M., Lichtenstein, Y., & Fink, L. (2016). Contract design choices and the balance of ex ante and ex post transaction costs in software development outsourcing. *Management Information Systems Quarterly*, 40(1), 57–82. doi:10.25300/MISQ/2016/40.1.03
- Buthelezi, B. E., Ndayizigamiye, P., Twinomurinzi, H., & Dube, S. M. (2022). A systematic review of the adoption of blockchain for supply chain. *Journal of Global Information Management*, 30(8), 1–32. doi:10.4018/JGIM.297625
- Cao, C., Ray, G., Subramani, M., & Gupta, A. (2022). Enterprise systems and the likelihood of horizontal, vertical, and conglomerate mergers and acquisitions. *Management Information Systems Quarterly*, 46(2), 1227–1242. doi:10.25300/MISQ/2022/15631
- Chalmers, D., Matthews, R., & Hyslop, A. (2021). Blockchain as an external enabler of new venture ideas: Digital entrepreneurs and the disintermediation of the global music industry. *Journal of Business Research*, 125, 577–591. doi:10.1016/j.jbusres.2019.09.002
- Chalmers, J. M. R., Dann, L. Y., & Harford, J. (2002). Managerial opportunism? Evidence from directors’ and officers’ insurance purchases. *The Journal of Finance*, 57(2), 609–636. doi:10.1111/1540-6261.00436
- Coalition Against Insurance Fraud. (2022). *The impact of insurance fraud on the U.S. Economy*. Insurance Fraud. <https://insurancefraud.org/wp-content/uploads/The-Impact-of-Insurance-Fraud-on-the-U.S.-Economy-Report-2022-8.26.2022.pdf>
- Conner, K. R., & Prahalad, C. K. (1996). A resource-based theory of the firm: Knowledge versus opportunism. *Organization Science*, 7(5), 477–501. doi:10.1287/orsc.7.5.477
- Cuccuru, P. (2017). Beyond Bitcoin: An early overview on smart contracts. *International Journal of Law and Information Technology*, 25(3), 179–195. doi:10.1093/ijlit/eax003
- Daniel, F., & Guida, L. (2019). A service-oriented perspective on blockchain smart contracts. *IEEE Internet Computing*, 23(1), 46–53. doi:10.1109/MIC.2018.2890624
- Deloitte. (2018, August 27). *Deloitte’s 2018 global blockchain survey*. Deloitte. <https://www2.deloitte.com/content/dam/Deloitte/cz/Documents/financial-services/cz-2018-deloitte-global-blockchain-survey.pdf>
- Deloitte. (2022). *2022 insurance outlook*. Deloitte. <https://www2.deloitte.com/content/dam/Deloitte/cl/Documents/financial-services/cl-2020-insurance-outlook.pdf>
- Dibbern, J., Winkler, J., & Heinzl, A. (2008). Explaining variations in client extra costs between software projects offshored to India. *Management Information Systems Quarterly*, 32(2), 333–366. doi:10.2307/25148843

- Drnevich, P. L., & Croson, D. C. (2013). Information technology and business-level strategy: Toward an integrated theoretical perspective. *Management Information Systems Quarterly*, 37(2), 483–509. doi:10.25300/MISQ/2013/37.2.08
- Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaría, V. (2018). Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Internet*, 10(2), 1–16. doi:10.3390/fi10020020
- Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *Management Information Systems Quarterly*, 37(2), 337–356. doi:10.25300/MISQ/2013/37.2.01
- Hamledari, H., & Fischer, M. (2021). Role of blockchain-enabled smart contracts in automating construction progress payments. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 13(1), 04520038. doi:10.1061/(ASCE)LA.1943-4170.0000442
- Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *Management Information Systems Quarterly*, 28(1), 75–105. doi:10.2307/25148625
- Huang, C., Wang, W., Liu, D., Lu, R., & Shen, X. (2022). Blockchain-assisted personalized car insurance with privacy preservation and fraud resistance. *IEEE Transactions on Vehicular Technology*, 72(3), 1–16. doi:10.1109/TVT.2022.3215811
- JAUNTIN. (2022). *Leading the way in trust: How insurance providers can ensure transparency for customers*. Jauntin. <https://jauntin.com/insurance-providers-transparency/>
- Khatoun, A. (2020). A blockchain-based smart contract system for healthcare management. *Electronics (Basel)*, 9(1), 94. doi:10.3390/electronics9010094
- Kosba, A., Miller, A., Shi, E., Wen, Z., & Papamanthou, C. (2016). Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In *Proceedings of 2016 IEEE Symposium on Security and Privacy* (vol. 19, pp. 839–858). IEEE. doi:10.1109/SP.2016.55
- Li, P., Xu, C., Jin, H., Hu, C., Luo, Y., Cao, Y., Mathew, J., & Ma, Y. (2020). ChainSDI: A software-defined infrastructure for regulation-compliant home-based healthcare services secured by blockchains. *IEEE Systems Journal*, 14(2), 2042–2053. doi:10.1109/JSYST.2019.2937930
- Marmur, Y. (2018, August 20). MetLife's new blockchain health insurance product eliminates claims. *Business Wire*. <https://www.businesswire.com/news/home/20180820005644/en/MetLife%E2%80%99s-New-Blockchain-Health-Insurance-Product-Eliminates-Claims>
- McKinsey & Company. (2022). *Creating value, finding focus: Global insurance report 2022*. McKinsey & Company. <https://www.mckinsey.com/~media/mckinsey/industries/financial%20services/our%20insights/creating%20value%20finding%20focus%20global%20insurance%20report%202022/creating-value-finding-focus-global-insurance-report-2022-vf.pdf>
- Niya, S. R., Schüpfer, F., Bocek, T., & Stiller, B. (2018). A peer-to-peer purchase and rental smart contract-based application (PuRSCA). *Información Tecnológica*, 65(5-6), 307–320.
- Peters, G., & Panayi, E. (2016). Understanding modern banking ledgers through blockchain technologies: Future of transaction processing and smart contracts on the internet of money. In P. Tasca, T. Aste, L. Pelizzon, & N. Perony (Eds.), *Banking Beyond Banks and Money* (pp. 239–278). Springer International Publishing. doi:10.1007/978-3-319-42448-4_13
- Peverelli, R., & Feniks, R. (2021, December 30). *Kasko2go: AI-based risk assessment for car insurance. Now the whole story*. ITCDA Europe. <https://www.itcdiaeuropa.com/featured-insurtechs/ai-based-risk-assessment-for-car-insurance-now-the-whole-story>
- Qi, H., Wan, Z., Guan, Z., & Cheng, X. (2021). Scalable decentralized privacy-preserving usage-based insurance for vehicles. *IEEE Internet of Things Journal*, 8(6), 4472–4484. doi:10.1109/JIOT.2020.3028014
- Sheth, A., & Subramanian, H. (2020). Blockchain and contract theory: Modeling smart contracts using insurance markets. *Managerial Finance*, 46(6), 803–814. doi:10.1108/MF-10-2018-0510
- Tapscott, D., & Tapscott, A. (2016). *Blockchain revolution: How the technology behind Bitcoin is changing money, business, and the world*. Portfolio.

- Upadhyay, A., Mukhuty, S., Kumar, V., & Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. *Journal of Cleaner Production*, 293, 126130. doi:10.1016/j.jclepro.2021.126130
- Vo, H. T., Mehedy, L., Mohania, M., & Abebe, E. (2017). Blockchain-based data management and analytics for micro-insurance applications. In *Proceedings of the 2017 ACM on Conference on Information and Knowledge Management* (pp. 2539-2542). ACM. doi:10.1145/3132847.3133172
- Wang, F., Shan, G. B., Chen, Y., Zheng, X., Wang, H., Mingwei, S., & Haihua, L. (2020). Identity authentication security management in mobile payment systems. *Journal of Global Information Management*, 28(1), 189–203. doi:10.4018/JGIM.2020010110
- Wang, Q., Lau, R. Y. K., & Mao, X. (2019). Blockchain-enabled smart contracts for enhancing distributor-to-consumer transactions. *IEEE Consumer Electronics Magazine*, 8(6), 22–28. doi:10.1109/MCE.2019.2941346
- Wang, X., & Xu, F. (2022). The value of smart contract in trade finance. *Manufacturing & Service Operations Management, Articles in Advance*, 1–18. 10.1287/msom.2022.1126
- Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations. *The Journal of Law & Economics*, 22(2), 233–261. <https://www.jstor.org/stable/725118>. doi:10.1086/466942
- Williamson, O. E. (1985). *The economic institutions of capitalism: Firms, markets, relational contracting*. Free Press.
- Zhang, G., Zhang, X., Bilal, M., Dou, W., Xu, X., & Rodrigues, J. J. P. C. (2022). Identifying fraud in medical insurance based on blockchain and deep learning. *Future Generation Computer Systems*, 130, 140–154. <https://doi.org/https://doi.org/10.1016/j.future.2021.12.006>. doi:10.1016/j.future.2021.12.006
- Zhang, W., Wei, C.-P., Jiang, Q., Peng, C.-H., & Zhao, J. L. (2021). Beyond the block: A novel blockchain-based technical model for long-term care insurance. *Journal of Management Information Systems*, 38(2), 374–400. doi:10.1080/07421222.2021.1912926
- Zhao, L. (2020). The analysis of application, key issues and the future development trend of blockchain technology in the insurance industry. *American Journal of Industrial and Business Management*, 10(2), 305–314. doi:10.4236/ajibm.2020.102019
- Zhou, L., Wang, L., & Sun, Y. (2018). MISStore: A blockchain-based medical insurance storage system. *Journal of Medical Systems*, 42(8), 149. doi:10.1007/s10916-018-0996-4 PMID:29968202

ENDNOTES

- ¹ Tencent Meeting is a video conferencing software program that has gained widespread popularity and adoption in China. It provides users with high-definition audio and video conferencing, meeting recording, screen sharing, and real-time instant messaging functions.
- ² A 51% attack is executed by a group of miners on a blockchain by controlling over 50% of a network's mining hash rate.

APPENDIX

Table 1. Segments of the smart contract template for car insurance claim processing

<p>function isInsured</p> <p>//Checks if a policy holder is currently insured INPUT: policyHolder (contains lastPayment, policyValid, numAccidents, banned) OUTPUT: policyValid //true or false 1. client <- policyHolder 2. if client.policyValid == true and 3. client.banned == false and 4. client.lastPayment + paymentPeriod >= current time then: 5. return true 6. else: 7. return false</p>
<p>function getRecord</p> <p>//Allows an insurer to retrieve the claim record for the insured INPUT: claimRecordID, claimRecordSet, insuredAddress OUTPUT: claimRecord (contains insuredAddress, insurerAddress, claimDate, claimAmount, and accidentDetails) 1. claimRecord <- claimRecordSet[claimRecordID][insuredAddress] 2. return claimRecord</p>
<p>function submitClaim</p> <p>//Submits a claim INPUT: vehicle damage photos, message.sender OUTPUT: submissionSuccess//true or false 1. client <- message.sender 2. if isInsured(message.sender) == true then: 3. uploadPhotos<- vehicle damage photos 4. return true 5. else: 6. return false</p>
<p>function initiateConfirmationRequest(insuredAccount, insurerAccount)</p> <p>// Initiates a confirmation request to validate the insurance coverage with the insured INPUT: insuredAccount, insurerAccount OUTPUT: confirmationRequestSent // true or false 1. smartContract <- getAgreedSmartContract(insuredAccount, insurerAccount) 2. if smartContract is not null then: 3. sendConfirmationRequest(smartContract, insured) 4. return true 5. else: 6. return false</p>
<p>function verifyClaim(approvalFromInsured)</p> <p>// Verify the authenticity and accuracy of the claim INPUT: approvalFromInsured OUTPUT: claimVerificationResult // true or false 1. if approvalFromInsured == true then: 2. if verifyClaimWithOracles() then: 3. return true 4. else: 5. return false 6. else: 7. return false</p>

continued on following page

Table 1. Continued

<p>function assessClaim</p> <p>//Assesses a claim INPUT: evidence, lossConfirmation OUTPUT: assessmentRequestSent // true or false 1. if evidenceMatchesConditions(evidence) AND lossConfirmed(lossConfirmation) then: 2. sendAutomatedAssessmentRequestToInsurer() 3. return true 4. else: return false</p>
<p>function isPartnered</p> <p>//Checks whether the provided garage has a partnership with the insurer</p> <p>INPUT: garageName, the insurer's partner garage set $\{g_i \in G\}$ OUTPUT: garageisPartnered //true or false 1. for i = 0 to n do 2. if garageName == g_i then: 3. return true 4. return false</p>
<p>function initiatePayment</p> <p>//Initiates damage payment INPUT: repair bill photos, garageName, claimAmount, garageAccount, insuredAccount 1. uploadPhoto <- repair bill photos 2. damagePayment <- claimAmount 3. if isPartnered(garageName) == true then: 4. garageAccount += damagePayment 5. else: 6. insuredAccount -= damagePayment 7. garageAccount += damagePayment</p>

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