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Insured? Good! Designing a Blockchain-based Credit Default Insurance System for DeFi Lending Protocols

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Abstract

The rising popularity of blockchain has cleared the path for developing numerous decentralized finance (DeFi) applications. However, insurance solutions for DeFi applications are still missing. Therefore, this article presents a smart contract-based P2P credit default insurance solution using the Design Science Research Method. The design presents an approach to decentralize insurance systems by reducing the number of intermediaries. The evaluation of the artifact shows that blockchain and smart contracts can provide financial inclusion, reduce costs and automate processes in insurance processes.

Keywords: Decentralized Finance, Design Science Research, Financial Inclusion, Smart Contract

Introduction

Nearly one-third of the global population, particularly from emerging and developing countries, have no access to basic financial services like bank accounts, loans, or insurances. According to a World Bank Group study (World Bank Group 2018), the main reasons for this deficiency mainly include a lack of trust in financial institutions by individuals, too expensive accounts, and missing infrastructures. In this light, the United Nations set sustainable development goals to foster the underserved population's financial inclusion (UNCDF 2021).

The tension between individuals and institutions that offer financial services is based on the prevailing conflict of objectives. More precisely, consumers aim at reducing their risk and seek protection while the financial industry seeks to maximize profits (Chen and Bellavitis 2020). Traditional financial intermediaries such as banks, brokers, or insurance companies, have inefficient, costly, lengthy, and opaque processes (Gatteschi et al. 2018; Schär 2020; Zetzsche et al. 2020). In this light, a blockchain-based financial system promises to bring various benefits like efficiency, integrity, and transparency, ultimately granting individuals access to decentralized financial (DeFi) services (Chen and Bellavitis 2020; Schär 2020; Zetzsche et al. 2020).

DeFi is a movement that facilitates financial inclusion through seamless access to financial markets and services using blockchain technology and smart contracts (Chen and Bellavitis 2020; Schär 2020; Zetzsche et al. 2020). DeFi does not rely on intermediaries and central institutions but promotes an open, democratic, and censorship-free financial infrastructure (Schär 2020). DeFi offers a broad spectrum of financial services like the conventional financial system, including loans, payments, decentralized markets, or derivatives (Schär 2020). Specifically, the DeFi ecosystem enables peer-to-peer (P2P) lending and borrowing services for crypto assets through dedicated platforms, e.g., Aave, Maker, or Compound (Manda

and Yamijala 2019; Schär 2020). At present, the DeFi-based P2P lending market comprises the largest DeFi application area, with a total value of over USD 82bn[1].

However, one problem that arises with DeFi-based P2P lending is that unless there is sufficient collateral, loans are unsecured, and the lender is not repaid in the event of default (Grigo et al. 2020). Even in cases of sufficient collateral locked in a smart contract, decentralized lending platforms can become the target of exploitation attacks. An example of such an attack involved the DAO hack, in which exploitable flawed smart contracts led to the loss of a large amount of funds (Destefanis et al. 2018; Sayeed et al. 2020). Thus, credit default and code risks prevail in DeFi-based P2P lending.

Developing blockchain-based credit default insurances (CDIs) for DeFi-based P2P lending can solve this problem. While insurance companies already offer protection against unsecured loans in the traditional financial system (Bolton and Oehmke 2011), CDI services in the DeFi ecosystem do not exist. The insurance industry faces numerous challenges, and some could be better met through simpler and less expensive processes, higher automation, and better digitalization measures (Schmidt et al. 2017). A way to achieve these improvements could be by using blockchain technology to develop an insurance system that directly integrates within the DeFi space (Borselli 2020; Gatteschi et al. 2018).

Although the literature highlights the potentials of integrative blockchain-based insurance systems for the DeFi ecosystem (Borselli 2020; Gatteschi et al. 2018; Hans et al. 2017; Tasca 2019), there is a lack of IS research on how such a system should be designed and developed to lever both the DeFi ecosystem and design theory. Thus, we raise the following research question:

> **RQ:** *How can an effective blockchain-based credit default insurance for DeFi-based P2P lending be designed?*

To answer the research questions, we design a blockchain-based CDI system for lending and borrowing services in the DeFi ecosystem. We follow a rigor Design Science Research (DSR) approach (Peffers et al. 2007). The objectives of our research are to uncover currently existing problems and untapped potentials of the traditional insurance industry and to develop and propose an architecture of a DeFi-based CDI that will serve as a blueprint for future approaches. The number of intermediaries is to be reduced using smart contracts.

Foundations

Insurance

Insurance companies are financial intermediaries that offer services to provide protection and financial coverage against unforeseen events by transferring a large number of similar risks into a common pool and managing the payout process within that pool (Thoyts 2010). In this light, Rejda and McNamara (Rejda and McNamara 2017) characterize the concept of insurance as follows:

- *Pooling of risks*: Risks of an individual are spread across a group, and the individual only must pay the average loss in a lump sum
- *Risk transfer*: The final risk is no longer borne by an individual but by the insurer.
- *Indemnification*: In the event of a loss, the individual is compensated in whole or partially for the loss incurred.

An insurance contract is based on two elements. The insurance premium to be paid by the insurance seeker and the compensation due with a certain probability of a loss (Borch et al. 1990). To cover the costs occurring by the insured event, the insurer charges a risk premium, usually an equitably premium. The equitably premium represents the financial equivalent of the degree of risk that customers transferred into the pool (Thoyts 2010). In addition, the total premium includes a portion to cover administrative costs incurred primarily in the insurer's risk management (Thoyts 2010).

Since customers pay the premiums in advance, the insurance company can invest the pooled funds to generate additional income. This approach increases the security deposit for new policies and makes the insurance more attractive to new customers (Rejda and McNamara 2017). The insurance premium should

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[1] See https://defipulse.com/, data as of August 25, 2021

always be high enough to cover all costs yet low enough to compete with other insurers (Rejda and McNamara 2017). Thus, the insurance company needs to diligently assess and manage the risks that may occur. Against this backdrop, insurance companies follow the law of large numbers to mitigate risks. By adding many customers, the insurer's risk increases, but disproportionately to the insurance fees paid. Thus, by spreading the risk to many people, insurance companies reduce their overall risk (Rejda and McNamara 2017).

Thoyts (2010) defines the role of the insurer holistically and outlines seven tasks the insurer is involved: (i) controlling pool, (ii) calculating an equitable premium, (iii) arranging reinsurances, (iv) improving risk management, (v) investing funds, (vi) controlling claim payments, and (vii) guaranteeing solvency of the pool.

A specific type of insurance includes the market for CDIs that has rapidly grown in the past years (Luo et al. 2017). CDIs transfer credit default risks from the creditor to a third party, commonly to a credit default insurer (Bolton and Oehmke 2011). In such an insurance contract, a protection seeker and the insurance company agree that in the event of a default by the borrower, default insurance will cover the loss incurred by the creditor (Luo et al. 2017).

Blockchain, Smart Contracts and DeFi

Blockchain is a public ledger in which transaction data is stored in blocks. Each block is linked to the next block by cryptographic mechanisms (Zheng et al. 2017). The data is replicated on every node that participates in the network (Swan 2015). Thus, a blockchain can be described as a distributed ledger on which decentral nodes validate transactions. Distributed, in this case, means that the verification of information takes place under the avoidance of central decision-makers and that there is no central data handling (Zetzsche et al. 2020). In summary, blockchain offers a decentralized, tamper-proof and transparent infrastructure to exchange transaction data (Zetzsche et al. 2020).

While the first generation of blockchains, e.g., Bitcoin, was limited to financial transactions, the following generation allowed the implementation of business logic through smart contracts (Beck et al. 2016; Buterin 2014). A smart contract is a piece of code stored on the blockchain and executed by a triggering event (Beck et al. 2016). As such, smart contracts do not require central authorities to enforce the rules of a business logic (Zetzsche et al. 2020). Most smart contracts are built on the Ethereum blockchain and allow the creation of digital tokens, decentralized applications (Dapps), and decentralized autonomous organizations (DAOs). Thus, smart contracts enable innovative application opportunities in various industries (Beck et al. 2016; Schär 2020).

DeFi aims to unleash the potential of combining blockchain technology and smart contracts to create an open financial infrastructure (Grigo et al. 2020; Schär 2020). Specifically, the building blocks of DeFi include the settlement layer, asset layer, protocol layer, application layer, and aggregation layer (Schär 2020). Thus, DeFi constitutes an integrative system for financial services and inherits large efficiency of transactions, low costs, high automation, and elimination of counterparty risk (Chen and Bellavitis 2020; Schär 2020). By doing so, DeFi creates a borderless, censorship-free ecosystem where no centralized entities or governments can intervene (Schär 2020; Zetzsche et al. 2020). Thus, DeFi represents a completely separate decentralized financial ecosystem without the necessity of intermediaries (Zetzsche et al. 2020).

A particular field of application for DeFi is DeFi-based P2P lending. In general, P2P lending describes loans granted directly by private individuals to other individuals as personal loans, where no financial institution, such as a bank, acts as an intermediary (Schär 2020). Smart contracts manage lending and borrowing processes and build the underlying infrastructure for a DeFi-based system (Chen and Bellavitis 2020; Manda and Yamijala 2019). However, while smart contracts provide a deterministic and trustless environment to perform DeFi-based P2P lending, credit default risk can prevail.

To mitigate this specific risk, appropriate insurance products are required. The idea of a P2P-insurance system lies in sharing risk with the community, thus reducing the individual's risk (Tasca 2019). Using blockchain technology facilitates the original idea of P2P insurance (Tasca 2019), as the network is decentralized and transactions are recorded transparently, thereby establishing trust (Beck et al. 2016; Pilkington 2016). In P2P insurance, policyholders self-organize and pool capital, while the decision to take on a certain risk is made within a system of interconnected smart contracts through majority voting of the

pool participants (Borselli 2020; Manda and Yamijala 2019). Conventional CDIs can be replicated in the DeFi ecosystem and protect unsecured loans and attacks in DeFi-based P2P lending applications (Manda and Yamijala 2019).

Methods
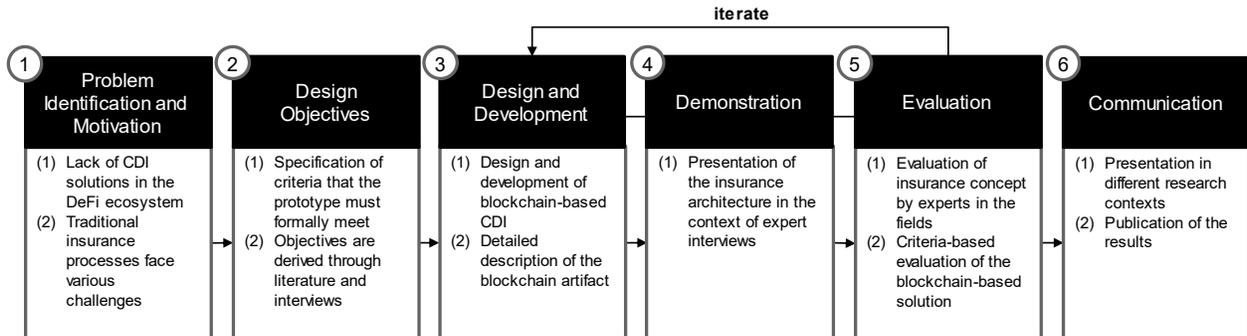
Figure 1 Research Process (adapted from Peffers et al. (2007))

We follow the DSR approach (March and Smith 1995) to design and develop a CDI architecture based on blockchain technology. We find DSR as a suitable approach for our research endeavor as it provides guidelines that aim to solve known problems by building and evaluating solutions in information technology (Hevner et al. 2004). DSR is used to derive generally applicable artifacts and verify their effectiveness (Peffers et al. 2007). In particular, we chose the DSR method, according to Peffers et al. (2007).

The research processes comprise six steps, which are depicted in Figure 1. First, we analyzed the existing real-world problems. We find an imminent problem of unbacked loans in DeFi-based P2P lending, and no protection or insurance solution for unsecured loans in DeFi-based P2P lending exists yet. Also, no design theory on how to develop such a system is present. Second, to solve the problems identified in the first step, we define objectives that the CDI solution should meet. These individual objectives are developed based on blockchain, DeFi, and insurance literature and the insights of expert interviews. Third, considering these objectives, we then developed our DeFi-based insurance system. In particular, we chose the Ethereum platform for the solution's infrastructure, as it offers the best developer environment and is also leading in terms of smart contract platforms (Schär 2020). Fourth, to comply with the chosen research method, repeated end-to-end executions were conducted. Thus, we demonstrated and discussed the solution with various experts along the development process. Fifth, we evaluated the solution against the pre-established criteria. Again, we used literature and interviews to derive our conclusions. Finally, the results are discussed and presented in this paper.

Problem Identification and Design Objectives

Although DeFi offers P2P solutions for lending and borrowing crypto assets, no adequate protection solution exists in the event of default or exploitation(al) attacks. For example, if a lending protocol lacks sufficient collateral, loans remain unsecured, thus, increasing counterparty risk and default (Grigo et al. 2020). However, even in cases of sufficient collateral locked into a smart contract, decentralized lending platforms face human errors resulting in code flaws or can become the target of exploitation(al) attacks (Destefanis et al. 2018; Gatteschi et al. 2018; Sayeed et al. 2020). Smart contract exploits can have severe financial damages for users and negatively affect the overall acceptance of DeFi-based applications (Mehar et al. 2019; Sayeed et al. 2020). While the literature mentions the theoretical potentials of blockchain-based insurances (Gatteschi et al. 2018; Grigo et al. 2020; Schär 2020), it does not provide any architectural solutions. Specifically, design theory for CDI, to bridge the gap between conventional insurances and the DeFi ecosystem, is missing.

Besides, the literature depicts the deficits of the current insurance industry and acknowledges the merits of decentralized insurance services (Borselli 2020; Hans et al. 2017; Schmidt et al. 2017; Tasca 2019). Insurance processes are generally characterized by information asymmetry between the insurance company and the policyholder, as business processes remain opaque (Gatteschi et al. 2018; Tasca 2019). However, in the event of a claim, the insured person needs to trust the insurance company that the damage is reasonably assessed (Hans et al. 2017; Tasca 2019). Also, the insurer faces information asymmetries regarding unjustified, fraudulent, and exaggerated claims, which make up nearly ten percent of all claims (Lorenz et al. 2016; Rejda and McNamara 2017).

Furthermore, most processes, such as payouts in the event of a claim, are still carried out manually (Hans et al. 2017; Tasca 2019) and involve paper-based documentation (Eling and Lehmann 2018). As such, the financial compensation of policyholder's claims typically takes time, which leads to costly processes and negatively affects customer experience (Gatteschi et al. 2018; Tasca 2019). In addition, banks are largely involved in managing financial transactions, e.g., payment settlements, compensation payouts, and asset management, resulting in large fees yet reducing efficiency (Rejda and McNamara 2017). In summary, existing insurance solutions show limitations that can be addressed by blockchain-based solutions (Gatteschi et al. 2018; Tasca 2019).

We analyzed the relevant literature on insurance to derive the requirements for a blockchain-based insurance concept. Specifically, we aim to better understand the main objectives towards an improved CDI. To further ensure the validity of our requirement set, we used insights from our interviews with experts in the DeFi and insurance industry. Those findings are combined to determine nine design objectives that we later use to measure the effectiveness of the artifact. Table 1Figure 2 describes each objective in detail and states its evaluation criteria.

Design Objectives	Description	Evaluation
Low costs	Traditional insurance companies incur high costs for their business model, which are transferred to the end-users. These administrative costs should be avoided by the blockchain architecture (Cohn et al. 2017).	Comparison of costs
Short transaction times	As soon as a compensation payment is approved, it should be paid out immediately, avoiding longer processing times of conventional insurance (Cohn et al. 2017).	Evaluation of transaction times
Data persistency	Traditional insurance companies often struggle with efficient data management (Schmidt et al. 2017). It must be possible to store the data immutably and permanently.	Evaluation of fulfillment
Automated processes	Processes should be as automated as possible to make them more efficient and less susceptible to manipulation. The automated flow of smart contracts should accelerate processes while mitigating the lack of human resources (Gatteschi et al. 2018).	Evaluation of automation
Trust and reliable transaction processing	Transactions and processes must be traceable to foster trust in the system (Tasca 2019). In addition, the insured must rely on an assured payout in the event of an approved claim (Tasca 2019). Therefore, the architecture should reduce the number of intermediaries, lower the power of a central institution, and instead empower the users.	Evaluation of trust
Provide suitable protection solutions	The insurance system should provide effective means to protect insurance seekers against credit default risk.	Evaluation of protection
Enhanced transparency	Currently, insurance processes are very opaque. In order to evaluate the security of an insurance policy, the user should be provided with as much transparency as possible (Tasca 2019).	Evaluation of transparency
Financial inclusion	A DeFi-based insurance service should grant individuals and small businesses, particularly from emerging and developing countries, access to insurances from everywhere, anytime (24/7), without discrimination, and censoring by higher	Evaluation of financial inclusion

	authors and thus should be built on permissionless and public blockchains (Zetzsche et al. 2020).	
Asset management	The insurance solution should allow for the dedicated investment management of the collected premium (Rejda and McNamara 2017). These funds should be seamlessly invested within the DeFi ecosystem to generate additional revenues.	Evaluation of investment options

Table 1 Design Objectives

Development

The design objectives were used as guidelines for the development of the blockchain-based CDI system. The Ethereum blockchain serves as the underlying infrastructure in building the insurance platform, as it offers a mature development environment and yet prospering ecosystem (Schär 2020). In addition, we rely on a stable cryptocurrency, i.e., stablecoin, as a medium to pay the premium to mitigate the risk of exchange rate volatility of cryptocurrencies to classic Fiat currencies (Berentsen and Schär 2019). From an architectural perspective, the lending protocol that our DeFi-based CDI solution aims to protect is independent of other lending protocols. This means that each lending protocol has its own CDI smart contract that manages the insurance logic for a dedicated lending protocol. Overall, the proposed architecture is modular and flexible, allowing changes to be made quickly to the system.

Description of the architecture

The artifact proposes an architecture to mitigate the risk of unsecured loans in DeFi-based P2P lending and represents a decentralized marketplace for CDIs based on blockchain technology and smart contracts. Figure 2 depicts the architecture of the insurance system.
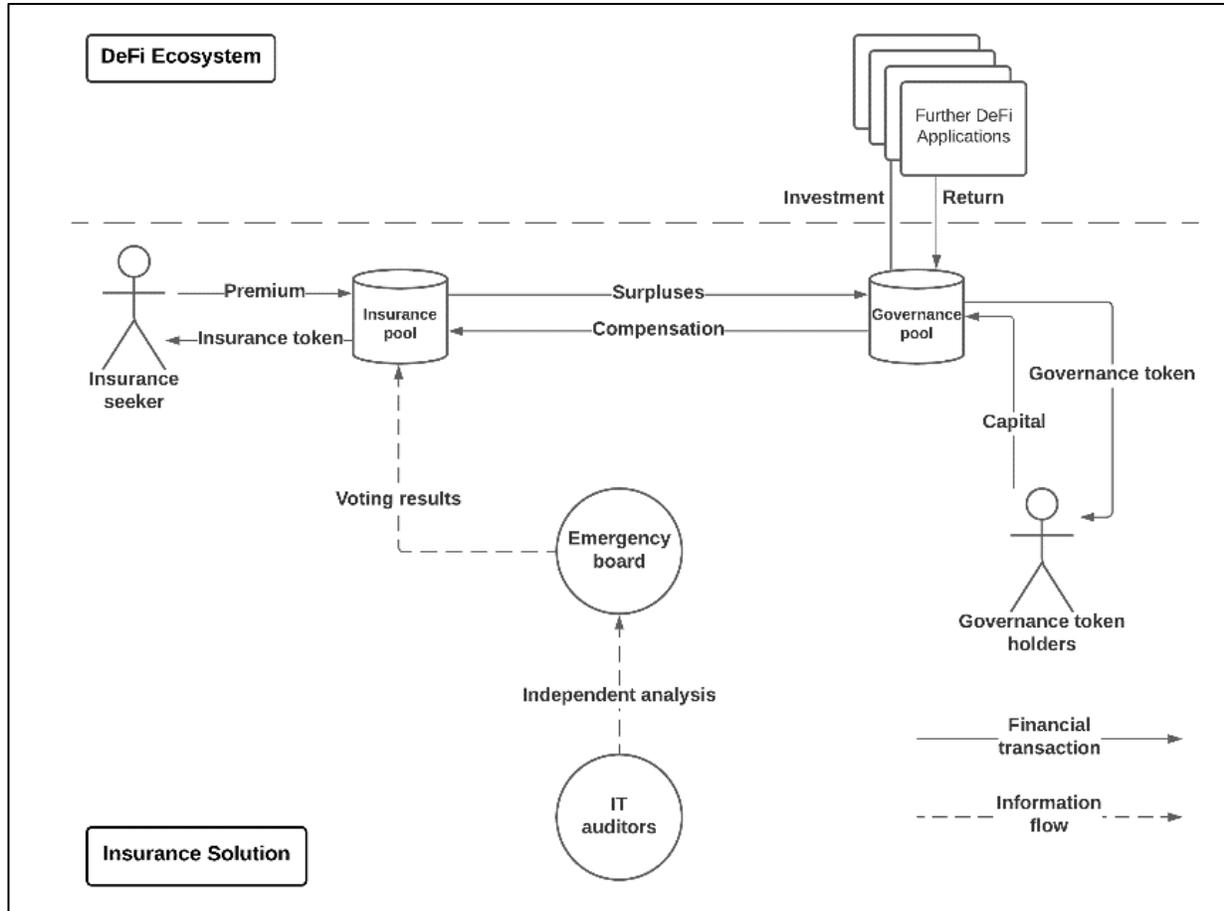
Figure 2 Smart Contract-based Insurance System Architecture

The P2P CDI system is based on two different tokens. First, an individual can protect their investment by buying an insurance token. This token represents all the processes and transactions associated with the usual operations of an insurance company. The price for an insurance token is composed of the risk premium and administration fee. The risk premium represents the risk portion of the insurance premium, while the administrative fee is to operate the system and stabilize the governance pool. Second, a governance token grants the owner various voting rights, thereby allowing them to actively engage in management decisions and the project's future (Jensen et al. 2021). In addition, governance token holders also receive a share in the success of the protocol through the returns achieved. Users can acquire governance tokens either by participating in the processes of the insurance system or by financial investments. For example, investors can generate additional returns by providing capital to the pool, thus participating in the platform's economic success. Besides, governance token holders can decide how and where to invest the funds locked within the governance pool in other DeFi applications to generate income.

In conjunction with these tokens, the P2P insurance system requires both an insurance and a governance pool to separate the people seeking insurance protection and investors. On the one hand, the insurance pool manages the creation and issuing of insurance tokens. It holds a certain amount of cryptocurrency, acting as a source of liquidity to be able to settle claims at short notice. The governance pool allocates any surpluses from the insurance pool and provides additional capital in emergency cases.

In addition to the insurance and the governance pool, an emergency board is established. The emergency board, at best, consists of experts either from the insurance or smart contract auditing industry. Those experts should be independent of each other and can be voted out and replaced at any time. However, the final decision on who represents the emergency board is taken by the governance token holder who are entitled to cast their vote in the election of the emergency board. Since their stake of coins is directly affected by negative long-term decisions of the emergency board, this incentivizes them to choose competent members. To also incentivize the emergency board to provide truthful and accurate decisions concerning claims processes, the members themselves also have a stake in the governance token. All participants are rewarded with governance tokens if their vote is in line with the consensus result.

To ensure usability for all participants, we propose a web-based dApp. This dApp displays the data on the project's status, such as the transaction volumes, number of outstanding claims, and capitalization ratio at any time. This application allows customers and investors to better assess the project and offers functionality for managing claims and performing votes.

Design Decisions

Start of the project: Starting the project and providing enough capital within the insurance pool for settlement payments is challenging. Moreover, the question of distributing tokens arises. To this end, an initial coin offering (ICO), in which people receive the governance tokens in return for a payment. Besides believing in the future success of the project, their incentive to do so is also to gain a large share (the supply of governance tokens is capped) of the project while it is still undervalued (Li and Mann 2018). Executing the ICO, it is important to set maximum limits for the purchase of coins to prevent any concentrations of power in the voting systems from the start, which is a common problem in DeFi projects (Jensen et al. 2021). Later, governance tokens can be purchased from decentralized marketplaces at any time. In this light, the price is determined by the currently mapped risk, funding level and expected returns of the project.

Risk assessment and insurance fee management: The underlying risk assessment and management determines the required insurance fee payment amount. Due to the novelty of DeFi-based P2P lending, there is no literature on default rates for calculating the cost of the insurance policies. These data are elementarily important for the determination of the risk and an appropriate height of the fee. Especially since the security and stability of each lending protocol are highly individual and can vary greatly, this fee is quite challenging to price. Lending pools that are more reputable and have been in existence for a longer period can be assumed to have a higher level of security and can charge a lower fee. If more claims occur in a particular lending pool, the insurance fee for that pool should be adjusted immediately.

One approach could be that community voting determines the insurance fees. Then, through the implemented incentive system, the community will, assuming the effectiveness of the market, vote for an appropriate fee. An appropriate fee is neither too high, as otherwise no contracts will be signed, nor too low either, as then the risk of loss is too great.

To ensure a secure and sustainable business model and prevent insolvency, the minimum capital requirements common in the traditional insurance industry are followed. These have been set out in the Solvency II supervisory system in Article 101. A confidence level of 99.5% must be achieved for the probability of meeting payment obligations over the period of one year. The respective coverage ratio results from the ratio between the capital required in the worst possible scenarios compared to the project's own funds. A coverage ratio of 100% means that there are sufficient capital reserves to always cope with negative scenarios (Eling et al. 2007). Therefore, the minimum capital requirements of the solution are set to 100% as well, meaning the insurance grants a 100% coverage ratio to each person buying the insurance.

Claims and entitlement management: In the event of a claim, the process shown in Figure 3 is initiated. The person who suffered the damage of the credit default must report a claim on the website. Making a claim requires a fee to counteract spamming or unlawful claims. However, in case of a successful application, the fee will be refunded. The fee is based on a percentage of the claim but also on the valuation process the injured party chooses. Option one entails a relatively small fee for which the case is brought to the other insurance pool participants for community voting. The applicant can skip the community voting and forward the case directly to the emergency board by paying a higher fee by choosing option two.

If a consensus of more than 75% for a payout is reached in the community voting, payment is initiated. In the event of an approved claim, the insured will then receive entitlement to the amount of their awarded claim in the form of a payout from the insurance pool directly into their wallet. If option one is chosen, but the community voting among insurance pool participants does not approve the claim with at least 75% of the votes, the injured party must go through the emergency board if they insist on compensation. Otherwise, the applicant must accept non-payment. If the emergency board cannot come to a decision, they can consult external IT-audit experts who conduct an independent analysis. The emergency board is the last instance, and its decision is final. To prevent exploitation of the governance pool, claims above the value of the insurance pool must necessarily go through the emergency board to prevent fraudulent collusion within the insurance pool.

Guidelines for successful claims: We decided on a deadline for reporting a claim of seven days. This gives the injured parties enough time to report the damage. Damages covered by the insurance are besides
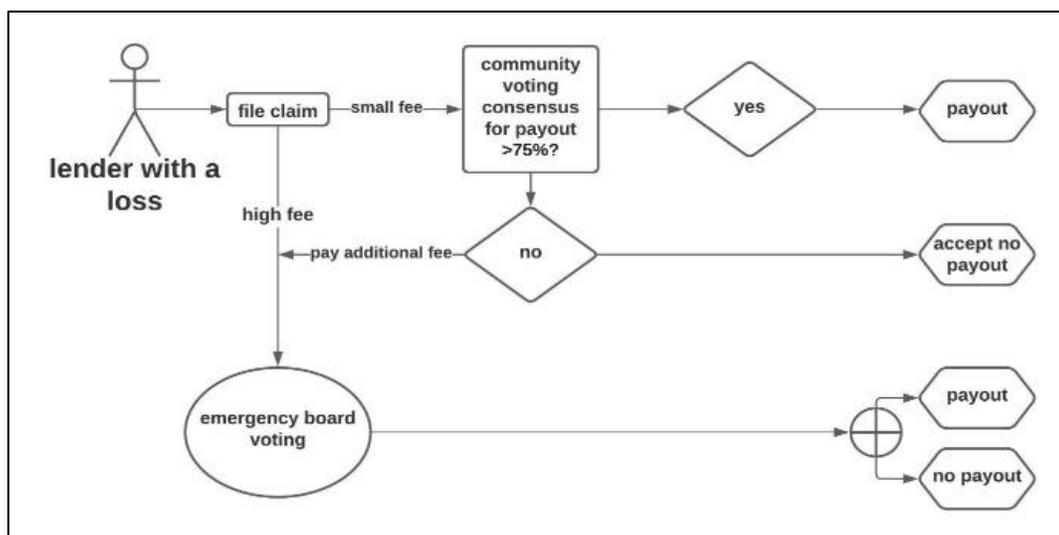
Figure 3 Insurance Claim Process

credit defaults themselves, hacks, code errors or manipulations since they have the same effects as a default, i.e., capital loss. Not covered is the loss of the private key and thereby loss of control over the wallet, which means that the owner cannot sign transactions anymore. To claim the losses, one must first prove to own the private key, which belongs to the respective wallet address. This is done by signing a transaction with a certain code. To prevent fraud and collusion, a reputation system should be implemented (Cohn et al.). Additionally, due to the transparent character of the blockchain, such fraudulent activities can generally be identified easily (Pilkington 2016).

Investments with project funds: Part of the business model of an insurance company is to generate a return on the capital accumulated through fees and business success. In this way, the company generates an additional income stream (Rejda and McNamara 2017). In the case of the DeFi-system, there are several ways to do this. For example, the collected project's funds could be used to also lend it as liquidity in a lending pool and earn interest on it. However, this might be critical since it would increase the business risk by potentially losing the collateral needed for settlement payments. The largest part of a traditional insurance company's investment portfolio is usually in bonds, which present lower risk (Rejda and McNamara 2017). However, since no bonds are available in DeFi, a similar risk profile should be achieved, the pool's funds could be staked in parts in the proof-of-stake (POS) algorithm to generate additional income (Tschorsch and Scheuermann 2016). However, it has to be considered that staking in POS algorithms still bears risks (Vukolić 2016). The additional capital generated can be used to reduce fees or be distributed to governance token holders. The best fit would be a mix of both options to attract more customers through lower fees and to create higher incentives to hold governance tokens for the long term. The decision on the allocation of funds should be made by governance token holders.

Governance: The possibilities and rights that the governance token provides are manifold. These token holders can actively shape the insurance protocol through voting and are responsible for economic success. Also, this token offers an incentive to hold the in the long term, benefiting from price increases. In the beginning, it would also be possible to enable an emergency stop of the project if one of our smart contracts gets exploited. The governance token holders would then initiate this emergency stop by voting. However, we argue that this option should not be possible to comply with the Code is Law paradigm (DeFilippi and Hassan 2018).

Evaluation of the solution

To evaluate our blockchain solution, we perform a multi-methodological approach (Hevner et al. 2004). We base our evaluation on relevant literature within the field of insurances and DeFi. In addition, we use insights from several interviews with experts presented in Table 2. All interviews were conducted in a structured way: First, a brief introduction of the interviewees took place, followed by questions regarding the currently existing problems of the traditional insurance industry. Second, we talked about the potentials of decentralized applications in the insurance sector in more general. Third, we presented our concept of a DeFi-based CDI architecture. Finally, we asked the interviewees to evaluate our concept and provided room for further feedback on the artifact. At any time, interviewees had the opportunity to contribute their own ideas and suggestions for further improvement of the concept.

Expert ID	Title	Organization	Area of Expertise
Expert 1	Senior Consultant	Consultancy firm	DeFi & Insurance
Expert 2	Head of Digital & Emerging Tech	Consultancy firm	DeFi & Technology
Expert 3	Partner	Consultancy firm	DeFi & Technology
Expert 4	Consultant	Insurance company	DeFi & Insurance
Expert 5	Researcher	Research institution	DeFi & Technology

Table 2 Overview of Interview Expert

The developed blockchain-based solution for CDIs reduces the number of intermediaries compared to traditional insurance systems. In addition, it addresses the problem of unsecured loans in DeFi-based P2P lending, for which no solutions are offered by the traditional insurance industry (Expert 1). A general evaluation of the concept is derived from the literature research and the expert interviews (see Table 3).

Objective	Blockchain-based Solution
Low costs	Costs, in general, are reduced since there is no human involvement in selling and managing data of the insurance product (Expert 1, 4, 5). In addition, lower costs through improved capital efficiency and intelligent liquidity management (Expert 5).
Short transaction times	When the claim is approved, the payment is settled instantly via smart contracts (Schär 2020). However, the voting processes represent a strong inefficiency and delay (Expert 2).
Data persistency	Due to the nature of blockchain, all data is stored immutably and permanently (Beck et al. 2016; Zheng et al. 2017). Security of system and thus smart contract protocols are high due to underlying blockchain infrastructure (Expert 5).
Automation of processes	More automated processes, such as paying out damage settlements, are mostly automated (Expert 2, 4). Decision-making is done via crowdsourcing. The community voting and the escalation board require human actions, which hinder fully automated processes (Expert 2).
Trust and reliable transaction processing	The goal to reduce the number of intermediaries is met since there is no need for a bank handling settlement payment (Expert 2). Overall, the solution partially decentralizes insurance. However, full decentralization is not reached yet, due to the community voting and emergency board (Expert 3, 5).
Provide suitable protection solution	The blockchain solution offers the possibility to protect against losses on the most common lending protocols (Expert 1, 2, 3, 4).

Enhanced Transparency	Transparency is one of the key characteristics of blockchain technology (Pilkington 2016). For better use experience, a dashboard on the website of the project allows to get an overview of the funding status at any time. Other key figures such as outstanding claims are also displayed transparently (Expert 4).
Financial inclusion	Accessing new customer segments particularly the underserved population. Thus, the solution can solve superordinate social problems (Expert 4).
Asset management	Capital can be used multiple times and on the same platform to achieve higher capital returns since premiums are locked in Ethereum-based smart contracts (Expert 4, 5). The asset management is managed by governance token holders, e.g., excess liquidity can be used in staking protocols or liquidity mining (Expert 4, 5).

Table 3 Evaluation of the Blockchain-based CDI Solution

In traditional insurance systems, dependencies, information inefficiencies and intermediaries play a major role (Gatteschi et al. 2018; Tasca 2019). In contrast, the blockchain-based solution does not require a central authority and offers the potential to reduce costs and further automate processes (Beck et al. 2016; Zetzsche et al. 2020), which are often slow in traditional insurances. However, the artifact does not entirely meet the requirements of a completely decentralized application due to crowd voting (Expert 3). Entities such as the emergency board and the community voting can still be regarded as not fully decentralized authorities (Expert 1,2). To still achieve a high number of participants and, thus, decentralization, the community voting should be easy to use, and the claim process should be standardized (Expert 4).

The solution provides insurance seekers the opportunity to become a part of the community (Expert 4). A significant advantage of blockchain insurance over traditional insurance prevails in asset management since the locked surpluses and external funds can be seamlessly invested in other DeFi applications (Expert 4 and 5). In this light and according to Expert 1, 4, and 5, smart liquidity management is a central factor for the success of an insurance business model.

While the presented insurance architecture is highly scalable, Expert 5 outlines that processes will rather be implemented on second-layer solutions or sidechains in the long term.

Ultimately, the developed CDI facilitates access to financial services, creating an open, social, and sustainable financial market for insurances, thus leveraging financial inclusion (Expert 4).

Discussion

Our smart contract-based solution introduced an innovative way for an automated, secure, efficient, and reliable CDI protocol on the Ethereum blockchain. In this light, we contribute to the literature on emerging DeFi-based applications (Schär 2020; Zetzsche et al. 2020). The evaluation of the architecture shows that DeFi approaches in the insurance industry might enable several improvements for different stakeholders.

First, creating an insurance system that is entirely blockchain- and smart contracts-based lowers the costs compared to the traditional insurance industry, where each process requires human resources. The automation of processes due to smart contracts makes those processes of an insurance system more efficient and faster (Gatteschi et al. 2018). Moreover, the responding times of an algorithm are quicker and are available at any time compared to the normal banking hours in traditional finance. Payout processes are facilitated due to predefined rules in the smart contract (Tasca 2019).

Second, blockchains provide a secure and immutable infrastructure, which helps the parties involved in the blockchain insurance system rely on non-duplicate and correct data stored on a tamper-proof blockchain (Tasca 2019). In addition, the insurance policy, which is stored on the blockchain and shared publicly, protects against fraud, as there can be no ambiguity during a claim (Gatteschi et al. 2018).

Third, another benefit is enhanced transparency, which lowers information asymmetries normally existing between the insurance company and the person seeking insurance. All transactions fulfilled can be traced since they are recorded publicly on the blockchain (Tasca 2019). Through the blockchain-based architecture, the insurance processes become more transparent. However, it is questionable whether this transparency is perceived as an advantage by all users. Some users might find it uncomfortable that their transactions are stored on the blockchain and are visible to other users (Expert 2).

Overall, we redesign the traditional concept of insurance and its roles as defined by Thoyts (Thoyts 2010) by introducing a blockchain and smart contract-based CDI solution. Thus, we extend the existent insurance literature by demonstrating how traditional tasks of insurance companies can be seamlessly executed through blockchain and smart contract technology (see Table 4). In summary, all activities can either be managed by smart contracts or through the employment of the crowd.

Role of Traditional Insurer	Smart Contract-based Insurance Protocols
Controlling membership of the pool	Managed by the insurance pool's smart contract
Calculation of equitable premium	Calculation based on voting by governance token holders
Arrangement of reinsurances	Occurrence of additional losses ensured by governance pool
Risk improvement	Decide and managed by governance token holders
Investments of the pool funds	Fund allocation by governance pool while investment decision by governance token holders
Control of claim payments	Control via consensus by community voting, an emergency board, and auditors
Guaranteeing the solvency of the pool	Managed by governance pool and external investors

Table 4 Transformation of Traditional Roles of the Insurer to Smart Contract-based Protocols

Eventually, we extend the insurance model Thoyts (Thoyts 2010) proposed using smart contract technology (see Figure 4). As the individual insurance seeker shares similar risks, i.e., default risks caused by technological flaws, fraudulent behavior, or human errors, the risk can be pooled together. The common pool is identical to the case for CDI seekers in the DeFi ecosystem. However, the main difference to Thoyts' (Thoyts 2010) insurance concept includes the automated management functions enabled by smart contracts through blockchain technology. In addition, we differentiate between the intents of both the insurance and governance pool. The former automatedly administrates the underwriting process while the latter, governed by the platform's token holders, decide on the general premium calculation enforced into code executed by the smart contract. Thus, these token holders' overall management on the strategical level is carried out via votes on protocol changes.

By presenting this research article, our contribution is threefold. First, we describe a specific design for implementing an effective blockchain-based CDI system. Practitioners and researchers can use the architecture as a blueprint to implement their own instances of a CDI. Second, we also contribute to the DeFi and insurance literature by discussing the benefits of using blockchain and smart contracts for implementing insurance solutions. Third, we redesign the conventional insurance model defined by Thoyts (Thoyts 2010), replacing the insurance company management with smart contracts.
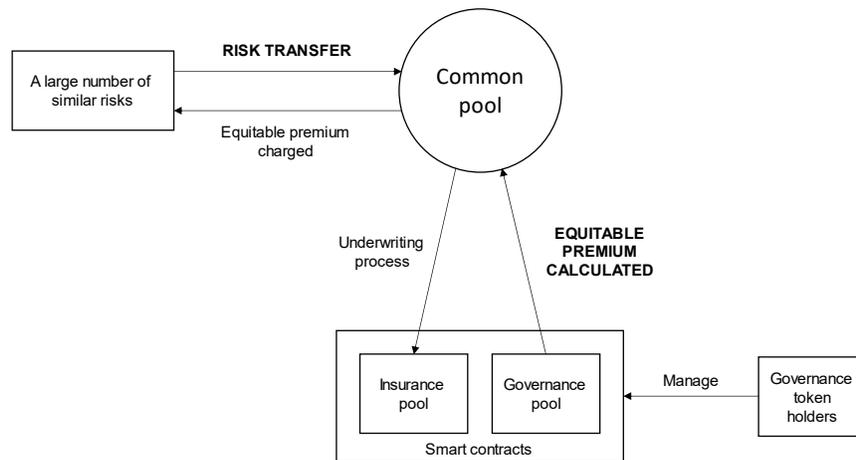
Figure 4 The Smart Contract-based Insurance Concept based on Thoyts (2010)

Conclusion

This paper demonstrates a decentralized insurance architecture to mitigate the risk of credit default and hacks in the DeFi--based P2P lending market. The evaluation of the artifact shows that blockchain-based insurances can efficiently replicate traditional insurances, specifically in the realm of CDI. Thus, our architecture reduces the number of intermediaries, lowers costs and automates processes. We redesign the insurance concept by replacing major components of the conventional insurance model with blockchain technology and smart contracts. Thus, we also provide a design for an open and integrative insurance system, levering financial inclusion.

Conversely, the architecture shows that a trade-off between high automation and governance is required. In addition, other blockchains in the DeFi ecosystem should be examined, e.g., Algorand, Binance, or Polkadot. The asset management process can be improved by automated processes using artificial intelligence. Also, regulatory uncertainty prevails in jurisdictions. Concluding, DeFi promises great potential, particularly for financial inclusion and process efficiency.

References

Beck, R., Czepluch, J. S., Lollike, N., and Malone, S. (eds.) 2016. *BLOCKCHAIN – THE GATEWAY TO TRUST-FREE CRYPTOGRAPHIC TRANSACTIONS*.

Berentsen, A., and Schär, F. 2019. Stablecoins: The quest for a low-volatility cryptocurrencypp. 65-71.

Bolton, P., and Oehmke, M. 2011. Credit Default Swaps and the Empty Creditor Problem*Review of Financial Studies* (24:8), pp. 2617-2655 (doi: 10.1093/rfs/hhr002).

Borch, K. H., Sandmo, A., and Aase, K. K. 1990. *Economics of Insurance*, Amsterdam, The Netherlands: Elsevier.

Borselli, A. 2020. Smart Contracts in Insurance: A Law and Futurology Perspective(1), pp. 101-125 (doi: 10.1007/978-3-030-27386-6_5).

Buterin, V. 2014. A next-generation smart contract and decentralized application platform

Chen, Y., and Bellavitis, C. 2020. Blockchain disruption and decentralized finance: The rise of decentralized business models*Journal of Business Venturing Insights* (13), e00151 (doi: 10.1016/j.jbvi.2019.e00151).

Cohn, A., West, T., and Parker, C. 2017. Smart after all: blockchain, smart contracts, parametric insurance, and smart energy grids*Georgetown law technology review* (1:2), pp. 273-304.

DeFilippi, P., and Hassan, S. 2018. Blockchain Technology as a Regulatory Technology: From Code is Law to Law is Code(21:12).

Destefanis, G., Marchesi, M., Ortu, M., Tonelli, R., Bracciali, A., and Hierons, R. 2018. Smart contracts vulnerabilities: a call for blockchain software engineeringin *2018 IEEE 1st International Workshop on Blockchain Oriented Software Engineering (IWBOSE)*: *Proceedings : March 20, 2018, Campobasso, Italy*, R. Tonelli, S. Ducasse, G. Fenu and A. Bracciali (eds.), Campobasso. 3/20/2018 - 3/20/2018, Piscataway, NJ: IEEE, pp. 19-25.

Eling, M., and Lehmann, M. 2018. The Impact of Digitalization on the Insurance Value Chain and the Insurability of Risks*The Geneva Papers on Risk and Insurance - Issues and Practice* (43:3), pp. 359-396 (doi: 10.1057/s41288-017-0073-0).

Eling, M., Schmeiser, H., and Schmit, J. T. 2007. The Solvency II Process: Overview and Critical Analysis*Risk Management & Insurance Review* (10:1), pp. 69-85 (doi: 10.1111/j.1540-6296.2007.00106.x).

Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., and Santamaría, V. 2018. Blockchain and Smart Contracts for Insurance: Is the Technology Mature Enough*Future Internet* (10:2), p. 20 (doi: 10.3390/fi10020020).

Grigo, J., Hansen, P., Patz, A., and van Wachter, V. 2020. "Decentralized Finance (DeFi) – A new Fintech Revolution?" Bitkom.

Hans, R., Zuber, H., Rizk, A., and Steinmetz, R. (eds.) 2017. *Blockchain and smart contracts: Disruptive technologies for the insurance market,* Boston.

Hevner, A. R., March, S. T., Park, J., and Ram, S. 2004. Design Science in Information Systems Research*MIS Quarterly* (28:1), p. 75 (doi: 10.2307/25148625).

Jensen, J. R., Wachter, V. v., and Ross, O. 2021. How Decentralized is the Governance of Blockchain-based Finance: Empirical Evidence from four Governance Token Distributions

Li, J., and Mann, W. 2018. Initial Coin Offering and Platform Building*SSRN Electronic Journal* (doi: 10.2139/ssrn.3088726).

Lorenz, J.-T., Münstermann, B., Higginson, M., Olesen, P. B., Bohlken, N., and Ricciardi, V. 2016. Blockchain in insurance – opportunity or threatMcKinsey&Company.

Luo, C., Wu, D., and Wu, D. 2017. A deep learning approach for credit scoring using credit default swaps*Engineering Applications of Artificial Intelligence* (65), pp. 465-470 (doi: 10.1016/j.engappai.2016.12.002).

Manda, V. K., and Yamijala, S. P. 2019. Peer-to-peer lending using blockchain*International Journal of Advance and Innovative Research* (6:1).

March, S. T., and Smith, G. F. 1995. Design and natural science research on information technology*Decision Support Systems* (15:4), pp. 251-266 (doi: 10.1016/0167-9236(94)00041-2).

Mehar, M. I., Shier, C. L., Giambattista, A., Gong, E., Fletcher, G., Sanayhie, R., Kim, H. M., and Laskowski, M. 2019. Understanding a Revolutionary and Flawed Grand Experiment in Blockchain*Journal of Cases on Information Technology* (21:1), pp. 19-32 (doi: 10.4018/JCIT.2019010102).

Peffers, K., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. 2007. A Design Science Research Methodology for Information Systems Research*Journal of Management Information Systems* (24:3), pp. 45-77 (doi: 10.2753/MIS0742-1222240302).

Pilkington, M. 2016. Blockchain technology: principles and applicationsin *Research Handbook on Digital Transformations*, F. Olleros and M. Zhegu (eds.), Edward Elgar Publishing, pp. 225-253.

Rejda, G. E., and McNamara, M. J. 2017. *Principles of risk management and insurance*, Boston: Pearson.

Sayeed, S., Marco-Gisbert, H., and Caira, T. 2020. Smart Contract: Attacks and Protections*IEEE Access* (8), pp. 24416-24427 (doi: 10.1109/ACCESS.2020.2970495).

Schär, F. 2020. Decentralized Finance: On Blockchain- and Smart Contract-based Financial Markets(doi: 10.13140/RG.2.2.18469.65764).

Schmidt, R., Möhring, M., Bär, F., and Zimmermann, A. 2017. The Impact of Digitization on Information System Design - An Explorative Case Study of Digitization in the Insurance Business(303), pp. 137-149 (doi: 10.1007/978-3-319-69023-0_13).

Swan, M. 2015. *Blockchain*: *Blueprint for a new economy*, Sebastopol, CA: O'Reilly Media, Inc.

Tasca, P. 2019. Insurance under the Blockchain Paradigmpp. 273-285 (doi: 10.1007/978-3-319-98911-2_9).

Thoyts, R. 2010. *Insurance*: *Theory and practice*, London, New York: Routledge.

Tschorsch, F., and Scheuermann, B. 2016. Bitcoin and Beyond: A Technical Survey on Decentralized Digital Currencies*IEEE Communications Surveys & Tutorials* (18:3), pp. 2084-2123 (doi: 10.1109/COMST.2016.2535718).

UNCDF 2021. *Financial Inclusion and the SDGs - UN Capital Development Fund (UNCDF)*. https://www.uncdf.org/financial-inclusion-and-the-sdgs. Accessed 16 June 2021.

Vukolić, M. 2016. The Quest for Scalable Blockchain Fabric: Proof-of-Work vs. BFT Replication(9591), pp. 112-125 (doi: 10.1007/978-3-319-39028-4_9).

World Bank Group 2018. The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech RevolutionInternational Bank for Reconstruction and Development/The World Bank (ed.).

Zetzsche, D. A., Arner, D. W., and Buckley, R. P. 2020. "Decentralized Finance (DeFi)," *Journal of Financial Regulation* (6:2), pp. 172-203 (doi: 10.2139/ssrn.3539194).

Zheng, Z., Xie, S., Dai, H., Chen, X., and Wang, H. (eds.) 2017. *An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends,* Honolulu.