Innovative User Incentive Models in Blockchain-Based Dockless Bike Sharing Systems

MSc Research Project

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TING YI LIU
Student ID: X21177899

School of Computing

National College of Ireland
Supervisor: Theo Mendonca

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School of Computing

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Innovative User Incentive Models in Blockchain-Based Dockless Bike Sharing Systems

Ting Yi Liu
x21177899

Abstract:

In cities all across the world, bike sharing programs have grown in popularity as a method to lessen traffic congestion and enhance air quality. Traditional dockless bike sharing systems, however, have a variety of issues, including theft, vandalism, and improper usage of the bikes. By creating a platform for bike sharing that is more safe and transparent, blockchain technology has the potential to solve some of these issues. Blockchain may also be utilized to develop novel user incentive models that will motivate more individuals to use bike sharing systems. This paper discusses how blockchain technology may boost the efficacy and efficiency of bike sharing systems. The article also offers some innovative user incentive schemes that may be utilized to promote the adoption of bike sharing systems.

Keywords: Blockchain, Smart Contract, Bike Sharing, Incentive Models, sharing economy, Dockless

1. Introduction

Due to the development in environmental consciousness in recent years, green and sustainable transport policies have become a crucial policy direction for transportation authorities in many nations. Additionally, mobility systems like bike-sharing, car-sharing, and electric vehicle-sharing are becoming more important and are being promoted globally as a result of the thriving sharing economy.

Marcus Felton and Joe Spaeth first proposed the idea of the sharing economy in 1978 (Felson and Spaeth , 1978), and it focused on individuals pooling their resources or commodities. The sharing economy is becoming more and more prevalent in people's everyday lives as technology advances, including in the areas of transportation (including ride-sharing and taxis), labor services (as well as skill sharing), housing and food sharing. In these versions of the sharing economy, vendors rent out different spare resources and distribute them to those in need, therefore boosting economic gains.

With the advent of dockless bike sharing programs, rider now have easy and adaptable mobility alternatives, revolutionizing urban transportation. These systems enable better accessibility and convenience by allowing user to hire and return bicycles without the requirement for fixed docking stations. These systems, however, confront a number of difficulties, including bike theft, poor parking, and low user interest. Blockchain technology has drawn interest recently due to its potential to overcome these issues and improve the effectiveness and dependability of bike sharing systems. It is now feasible to make transparent and secure transactions, track bike usage, and reward users to actively engage in the system by taking advantage of blockchain's decentralised and immutable characteristics.The goal of this paper is to investigate the usage of blockchain technology in dockless bike sharing systems with a particular emphasis on user incentives. The introduction of incentives is essential for promoting user adoption and involvement in the bike sharing program.

This research investigation intends to answer the following issues by using blockchain technology into the user incentive design:

● How can blockchain technology be used in dockless bike sharing systems to produce transparent and unchangeable records of user behavior and incentive distributions?

● What are the various incentive systems that may be applied using blockchain smart contracts?

● How might user incentives be created to encourage virtuous actions like cautious driving, considerate parking, and active participation?

● What possible advantages and difficulties may blockchain-based user incentives in dockless bike sharing systems bring about?

2. Related Work

2.1. Overview of Systems for Dockless Bike Sharing

A new generation of bike sharing systems that do not require docking stations has arisen, known as dockless bike sharing (Shen et al., 2018). This innovative business model has significantly increased globally and transformed the conventional bike sharing sector (Chen, Z et al., 2020). In a number of cities, including Singapore (Shen et al., 2018) and Nanjing (Ma et al., 2019), the use of dockless bike sharing programs has been researched. One study done in Singapore sought to comprehend how the city's dockless bike sharing systems were used. Urban planners, decision makers, and practitioners in the transportation industry might benefit from the study's ideas on how to develop bike sharing systems while assuring their sustainability.

By providing a versatile and practical means of transportation, dockless bike sharing systems have changed urban mobility. Dockless bike sharing systems do not require fixed docking stations where users must pick up and return bicycles, in contrast to conventional station-based bike sharing systems. Instead, customers may use a smartphone app to find and unlock bikes, ride them to their destination, and then park them in specified spots or public locations. The infrastructure and operating model are what distinguish dockless systems from station-based ones. For station-based systems, users must pick up and drop off their bikes at real docking stations that have been carefully positioned across the city. Users are constrained by the availability of bikes at particular stations, which reduces the system's flexibility and coverage area. The users of dockless bike sharing systems, in contrast, may locate and unlock bikes from any position within the service area thanks to the usage of GPS and mobile technology. The software allows users to find nearby bikes, unlock them with a code or QR code, and begin riding. When they get at their destination, they may lock the bike and properly store it, capping the rental period. The bicycles may be kept at authorized parking areas, public bike racks, or other suitable places.

2.2. The benefits of dockless bike sharing systems

Firstly, for quick travels, dockless bike sharing offers a practical and adaptable form of transportation. Instead of searching for and returning bikes to particular docking stations, users may quickly identify and unlock bikes using smartphone applications (Shang et al., 2023). Greater accessibility and convenience are made possible by this flexibility, particularly for first and last mile rides and in locations where conventional bike sharing systems would not be appropriate (Chen et al., 2020). Second, dockless bike sharing may lessen the need for automobiles and ease traffic congestion. In particular for short-distance rides, studies have demonstrated that the availability of dockless bikes can cause a modal shift from private vehicles to bikes (Ma et al., 2019). This change may lower carbon emissions and enhance air quality in cities (Li, 2023). Furthermore, the integration of dockless bike sharing with public transportation systems further lowering the dependency on private automobiles (Chen et al., 2020).

Additionally, dockless bike sharing encourages exercise and enhances public health. The accessibility of bike promotes people to use active transportation, which can raise physical activity levels and have a positive impact on health (Ma et al., 2019). In light of sedentary lifestyles and the increased incidence of chronic illnesses, this is especially crucial (Mi & Coffman, 2019). In term of urban planning, dockless bike sharing may help to improve the built environment and create bicycle infrastructure. According to studies, the use of dockless bikes is favourably impacted by the provision of supportive cycling infrastructure including bike lanes and parking spaces (Shen et al., 2018). This can encourage communities to invest in cycling infrastructure and cultivate a more bike-friendly atmosphere, both of which support sustainable transportation and urban livability.

2.3. The challenge of dockless bike sharing systems

In many different situations, the use of dockless bike sharing systems has been researched. The capacity and occupancy of bike sharing docking stations in conventional systems have received the majority of attention in prior studies (Shen et al., 2018). To analyze the mobility patterns of dockless bikes, these research methodologies, however, have certain drawbacks (Shen et al., 2018). Bike sharing markets have been transformed by the introduction of dockless bike sharing systems, which have experienced significant development and expansion globally (Chen et al., 2020). Since the first dockless bike sharing operation began in 2016 in China, the country's total number of shared bikes has surged to nearly 23 million in just one year (Guo et al., 2022). Comparing dockless bike sharing systems to conventional docked ones, there are a number of advantages. Users may easily access and ride bikes without being constrained by specific docking stations due to the varied mobility choices they offer (Shang et al., 2021). The user experience and satisfaction have both improved as a result of this flexibility (Chen et al., 2020). Furthermore, dockless bike sharing programs may help to promote environmental sustainability by lowering traffic, pollution, and fuel consumption (Shang et al., 2021). A seamless choice for first and last mile trips, dockless bike sharing has been proven to be more effective than standard public bikes when combined with public transportation (Chen et al., 2020).

However, the fast expansion of dockless bike sharing programs has also brought forth other difficulties. The issue of incorrect parking practices, when bikes are left in haphazard areas, disrupting public spaces and annoying walkers, is one of the main challenges (Jia et al., 2022). Numerous tactics have been used to solve this issue, including the installation of parking infrastructures, geo-fences, and electric fences (Schnieder et al., 2021). These actions seek to guarantee effective management of bike distribution and availability while directing users to store bicycles in authorized areas (Jia et al., 2022). Furthermore, fleet management and the usage of public areas have grown to be crucial factors in dockless bike sharing systems functioning (Kondor et al., 2022). In conclusion, dockless bike sharing programs have significantly altered urban mobility by providing flexible and practical means of transportation. By reducing traffic, pollutants, and fuel consumption, these devices might help maintain the environment. However, the fast expansion of dockless bike sharing programs has also brought many difficulties, including the necessity for efficient fleet management and incorrect parking habits. To deal with these issues, tactics including parking infrastructures and the usage of geo-fences have been put into place.

2.4. Applications of blockchain technology in the sharing economy

Several facets of the sharing economy might be revolutionised by blockchain technology. Peer-to-peer transactions may be made more secure by using it, which is decentralized and transparent (Huurne et al., 2017). Decentralized collaboration is one of the main uses for blockchain in the sharing economy. Blockchain can help participants in sharing economy platforms cooperate and build trust, allowing for the efficient and safe sharing of resources and services (Xu et al., 2019). Blockchain technology can provide stakeholders in the context of mobile crowdsensing systems a transparent and secure environment that promotes resource and service sharing (Capponi et al., 2019). This may result in the growth of a device-to device market for services, increasing the efficacy and efficiency of crowsensing applications. Healthcare record management is a significant area where blockchain technology is being used in the sharing economy. Blockchain technology can make it possible for many parties to securely share healthcare data while maintaining the privacy and provenance of the data. This may enable population health analytics to analyze data more effectively and provide more insightful findings (Mackey et al., 2019). Equity crowdfunding may use blockchain technology to provide investors and companies with a transparent and secure platform. In crowdfunding transactions, it can increase confidence and lessen knowledge asymmetry (Zhu & Zhou, 2016).

Blockchain technology can facilitate real-time information exchange among actors in the supply chain, lowering transaction costs and enhancing transparency (Liu et al., 2019). This can improve supply chain operations collaboration and risk mitigation. But there are difficulties and obstacles in the way of blockchain technology's acceptance in the sharing economy. AI-Breiki et al. (2020) list a few of these: the requirement for platform integration with other platforms, the reliance on external trustworthy actors, and the requirement to solve regulatory and legal challenges. Further investigation is also required to fully comprehend the possible used and restrictions of blockchain technology in the sharing economy (Bag et al., 2020). In a broader sense through improving trust, security, and coordination amongst participants, blockchain technology has the potential to alter a number of facets of the sharing economy. Blockchain can offer transparent and secure platforms for peer-to-peer transactions, from decentralized cooperation to healthcare record management and supply chain operations. For blockchain technology to be widely used in the sharing economy, there are several obstacles and problems that must be overcome.

2.5. Incentive models

In many areas, such as corporate governance, healthcare, consumer behavior, industrial growth, investment dynamics, energy sector management, and pro-social conduct, incentive models are essential. These models are intended to inspire people or groups to accomplish certain objectives or exhibit certain behaviors. The sort of incentives employed, the environment in which they are applied, and the characteristics of the individual or organization are some of the variables that affect how successful incentive models are. The purchase of green products can be encouraged by "soft" economic incentive policies in the context of consumer behavior (Wang & Li, 2022). Economic incentives like high-intensity and low-intensity subsidies as well as behavioral interventions like green emotions and social norms have a favorable impact on consumers' green consumption. In order to encourage green consumption, the combination of these intervention strategies is more successful than any one of them alone.

3. Applications of Blockchain Technology

3.1. The history and concept of Blockchain

History and Concept of Blockchain Byzantium, the capital of the Eastern Roman Empire, is geographically equal to Istanbul in contemporary Turkey. Due to the size of the Eastern Roman Empire in antiquity, every army was separated from one another for defensive reasons, and messengers were the sole means of communication between generals. When the generals came to an agreement, the result frequently did not reflect the views of the majority. When it became apparent that one of the generals had committed treason, the Byzantine Problem emerged as to how the other faithful generals could come to a decision without being swayed by the traitor. Blockchain was first introduced with Bitcoin, two weeks after Lehman Brothers' failure, which launched the global financial crisis. The concept of an electronic cash system based on P2P network technology, cryptography, time-stamping, blockchain, etc. was detailed in "Bitcoin: A Peer-to-Peer Electronic Cash System" by Satoshi Nakamoto on November 1, 2008. This was the first time the idea of a blockchain system was introduced. This was the beginning of Bitcoin. The first Bitcoin creation block with serial number 0 was created on 3 January 2009, two months after the idea was put into reality. Due to the use of cryptography, each block has a distinct hash value, making it impossible for data to be changed once it is written into the block and preventing tampering (Wang & Kogan, 2018). Blockchain is used to store transactions in each block, through a decentralized method, so that everyone jointly maintains a ledger and does not need to rely on a third party. These two features minimize the risk of tampering and forgery, allowing parties to achieve an agreement without the help of a third-party center on a network where trust connections cannot be built. In addition, the anonymity, traceability, and disintermediation characteristics of blockchain technology enable its use in a wide range of industries, including finance, supply chain management, and digital asset management.

3.2. Basic and characteristics of smart contracts

According to Grishchenko et al. (2018), smart contracts are computer programs that operate on the blockchains of cryptocurrencies like Ethereum and allow for financial transactions without the involvement of a reliable third party. They are created using programming languages like Solidity and run on the blockchain as bytecode (Grishchenko et al., 2018). Due to its capacity to carry out distributed transactions safely and effectively, smart contracts have grown in popularity (Pinna et al., 2019). When certain criteria are satisfied, smart contracts can automatically execute, which is one of its fundamental features (Haque et al., 2021). As a result, there is no longer a need for intermediaries like banks or attorneys, which lowers the possibility of fraud or manipulation (Haque et al., 2021). Decentralized refers to the fact that smart contracts are stored and performed over a network of computers rather than a single server (Kamal et al., 2022). Because of the capacity of all network users to check and validate transactions, this decentralization guarantees the contract's transparency and immutability (Kamal et al., 2022). Smart contracts must be secure since coding flaws or vulnerabilities might have disastrous results (Grishchenko et al., 2018). For thorough verification and analysis, it is necessary to formalise the semantics and security attributes of smart contracts (Grishchenko et al., 2018). Machine learning, symbolic execution, analysis, and other approaches have all been suggested by researchers as potential ways to find vulnerabilities in smart contracts (Wang et al., 2021). To stop monetary losses and protect the stability of the blockchain ecosystem, these techniques seek to locate and fix security problems (Wang et al., 2021).

Beyond financial transactions, smart contracts may be used in many more contexts. They may be used to a variety of fields, such as finance, trading, and healthcare (Bennacer et al., 2023; Susanto et al., 2022). By enabling more reliable and effective transactions, the implementation of smart contracts in various sectors can change procedures (Susanto et al., 2022). However, a number of obstacles, including legal complexities and regulatory concerns, prevent the implementation of smart contracts in businesses (Zhu, 2022; Ramadan et al., 2022). In this regard, smart contracts are software applications that enable safe and automated transactions on cryptocurrency blockchains. They are created in certain languages and run as bytecode. Transparency, automated execution, and decentralization are some traits of smart contracts. It is essential to ensure the security of smart contracts, and academics have suggested a number of techniques for vulnerability identification. Although smart contracts have uses across many sectors, adoption is hampered by problems including regulatory concerns.

3.3. Ethereum

The second-generation blockchain platform for smart contracts and decentralized apps is called as Ethernet. Programmers may create smart contracts using Turing-complete programming languages on Ethereum virtual machines (EVM), and the contracts' programmable logic can then be utilized to effect state changes on the blockchain. Ether's programmability enables developers to create a wide range of decentralized applications (Dapp), some of which have already been created. These applications include cryptocurrency wallets, financial apps, decentralized marketplaces, and games, among others. When compared to the Bitcoin blockchain, Ether is based on the account as the core, tracking each account's state conversion in the blockchain. The account state conversion is the currency and information between accounts, and the account is primarily split into two types: externally owned accounts (EOA) and contract accounts (CA), where the external account is controlled by the private key to decrypt data. The contract account is controlled by the contract code published by the external account, while the external account is controlled by the private key to conduct transactions and publish contracts (Fig. 1). The contract accounts can communicate with one another via message transmission (Ethereum whitepaper).

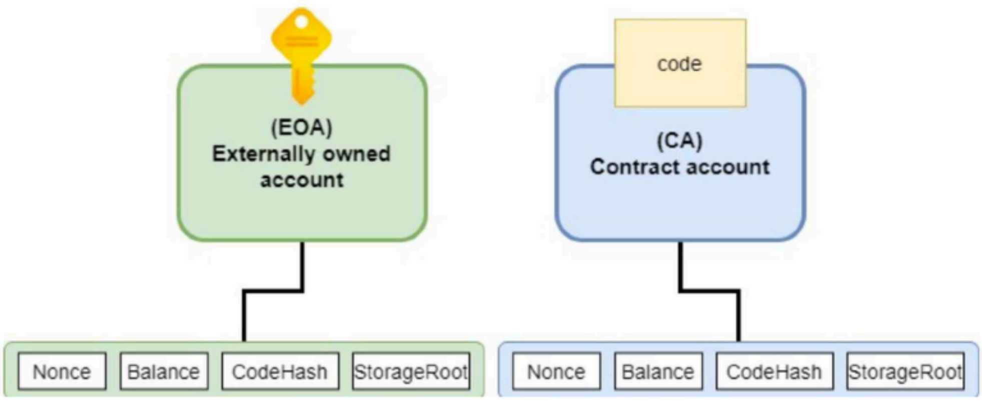

Figure 1: Externally owned accounts and Contract account (Kasireddy, 2019)

In Ether, gas charges are crucial ideas. Each node in the Ether blockchain receives or validates a transaction or message sent by an account, calculates the result using the EVM, and stores the amount of gas required to use the limit of gas set by the transaction's sender. The product of the gas limit and the gas price then represents the fee the sender is willing to pay for the transaction's execution, as shown in the Figure 2 where Wei is the smallest unit.

Figure 2: Schematic for calculating gas (Kasireddy, 2019)

A smart contract is a structure on the Ethereum blockchain that is part of a unique protocol that has code functions that allow for decision-making, data storage, ethereum transfer, and interaction with other contracts.

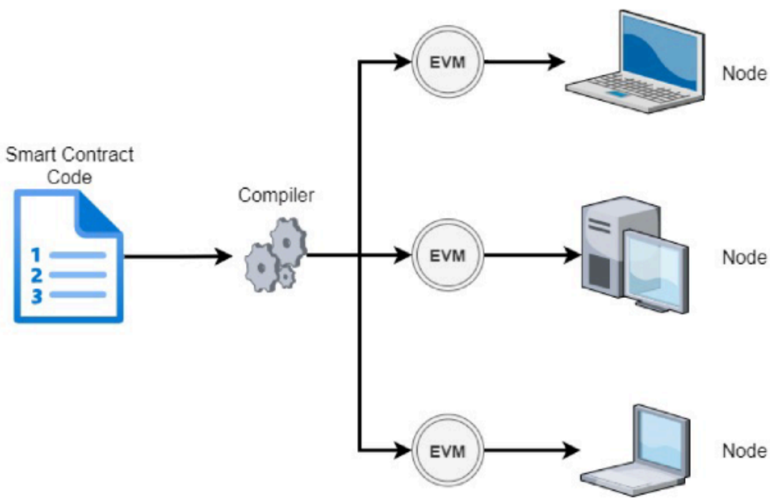

Figure 3: Ethereum Blockchain

3.4. Remix IDE

The contract content in this research is written in the contract-oriented language Solidity. A web-based Integrated Development Environment (IDE) called Remix IDE was created exclusively for creating Ethereum smart contracts (Figure 4). It is a strong tool that makes it simple and effective for developers to create, test, deploy, and debug smart contracts. Remix IDE was critical in easing smart contract creation and facilitating interface with the Ethereum network. Therefore, It is popular tool among Ethereum developers because of its powerful capabilities and simplicity (Remix IDE).

Solidity is a high-level programming language intended primarily for constructing smart contracts on multiple blockchain systems, the most popular of which being Ethereum. It is statically typed and contract-oriented, which means that developers may design and deploy self-executing contracts that let developers execute established rules and actions. Because of its syntax's resemblance to JavaScript, it is easier for developers who are already experienced with web programming to use.

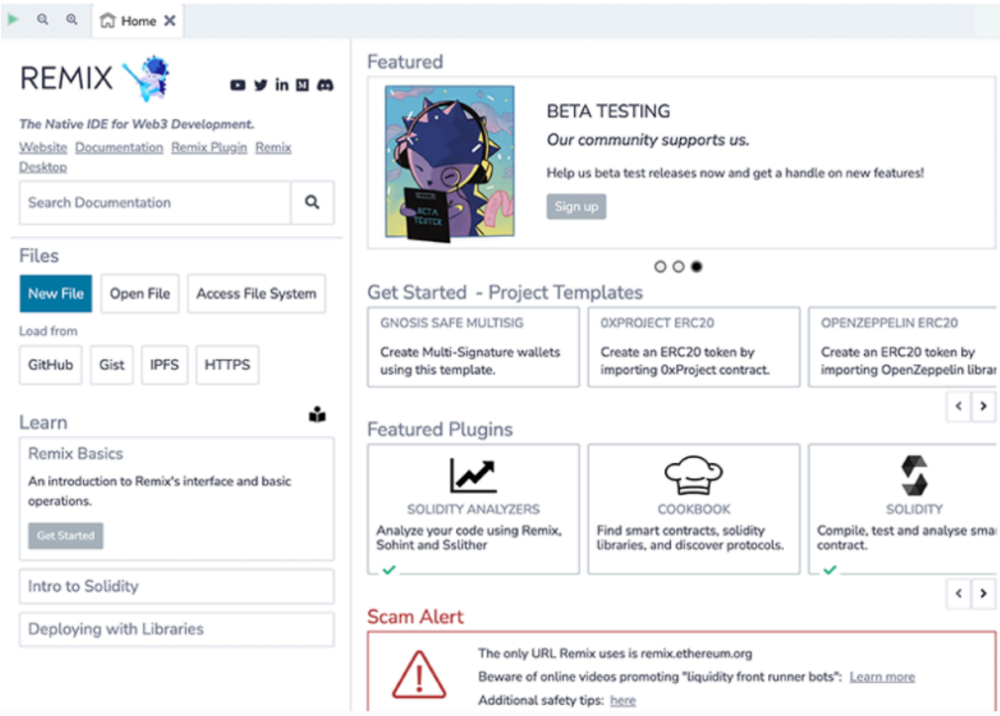

Figure 4: Remix IDE

3.5. Ganache

A well-liked software package called Ganache is frequently employed in blockchain development, particularly for Ethereum development. Developers may install, test, and debug smart contracts without having to communicate with the actual Ethereum network due to the local development environment that it offers. Deterministic behavior is ensured for dependable testing and debugging. Developers may monitor the performance of smart contracts under different mining situations using block mining control. Additionally, Ganache offers account management, making it simple to swap between roles and permissions when testing software. Its logging and debugging capabilities aid developers in quickly finding and fixing problems with their smart contracts.

In this research, using personal blockchain for Ethereum testing and development. How each component of the project will come together is shown in the flow chart below (Figure 5). The rules of our Smart Contract shall reside in our Smart Contract. Once these rules have been established, we need to employ Ganache to build the Smart Contract and set up some testing.

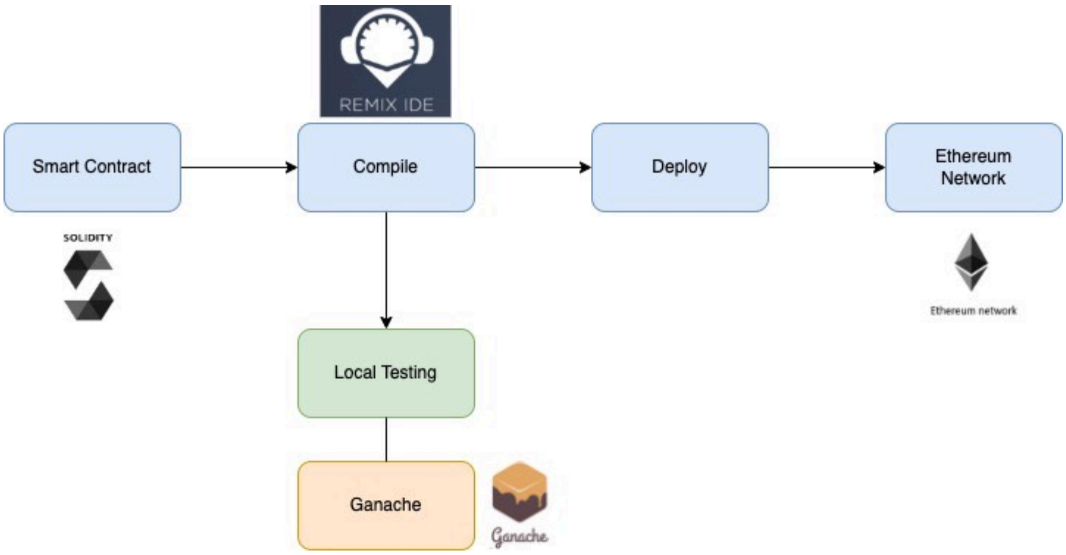

Figure 5: Research flow chart

Simply launch Ganache and select "Quick Start" to get started. You will then be given ten account addresses with 100 ETH each to test (Figure 6).

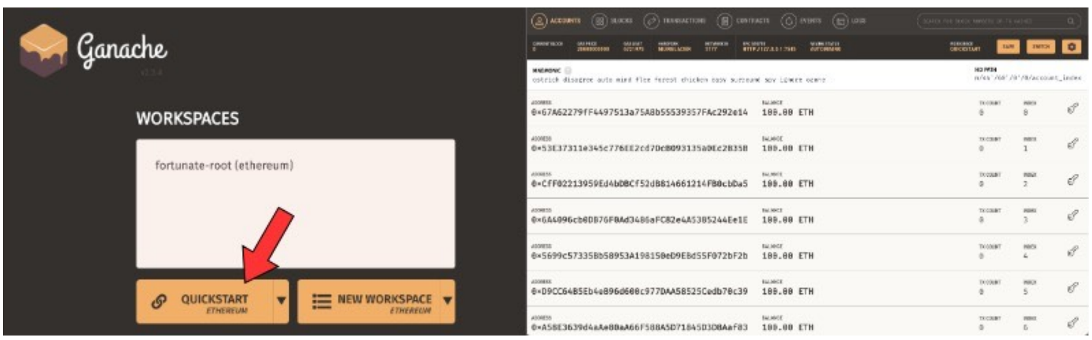

Figure 6: Ganache set up

4. Design and implement of smart contracts

4.1. Deploy bike sharing smart contract

Compile and deploy the Bike Sharing Smart Contract to the Ganache network using the Remix IDE development environment. Go to the "Deploy & Run Transactions" tab on the left-hand side. Under the "Environment" section, select "Dev - Ganache Provider" as the environment and enter the connection URL for Ganache (http://127.0.0.1:7545).

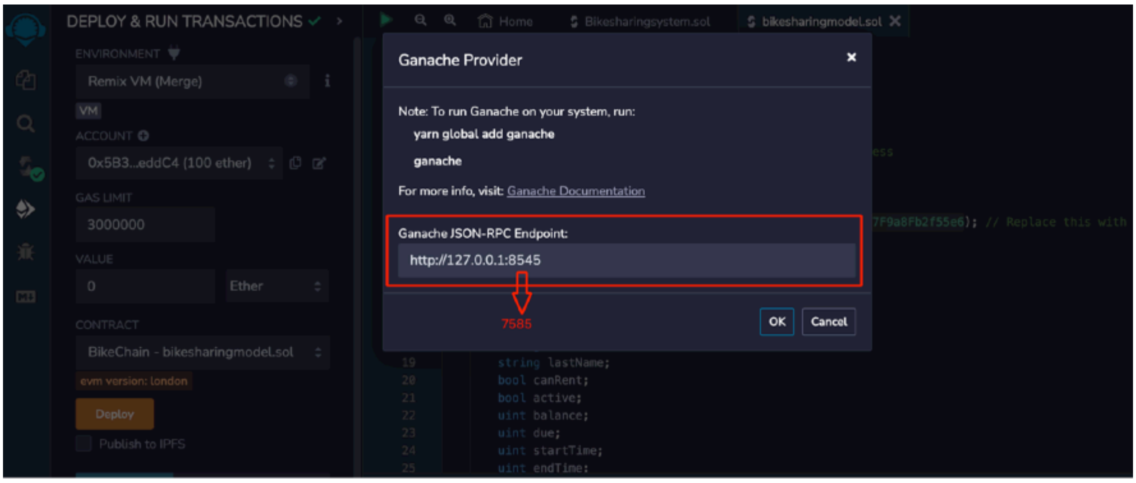

Figure 7: Set environment to "Ganache Provider"

This research is designed as a B to C (Business to Customer) model. In this model, the business (B) acts as the service provider or operator, while the customers (C) are the end-users who interact with the service. The goal is to create a bike-sharing platform where customers can rent bikes and earn rewards for their activities. In this research, the first test account Ganache provides is set as the user's wallet address, and the second test account is configured as the business's wallet address during the deployment of the smart contract on Ganache. In the smart contract system, these addresses are utilized to simulate the user and business roles (Figure 8).

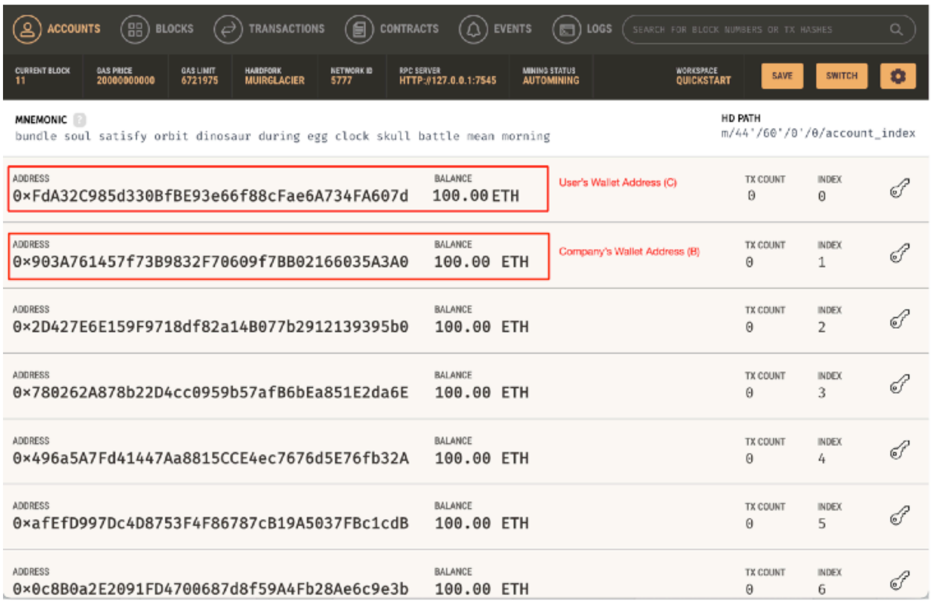

Figure 8: Ganache test account

Before deploy the contract we need to put company wallet address to the contract as shown Figure 9. Then we can start deploy the smart contract.

In Remix IDE, go to the "Solidity Compiler" tab and select the version of Solidity used in your smart contract. Then, navigate to the "Deploy & Run Transactions" tab again. Click "Deploy" to deploy the contract to the Ganache network.

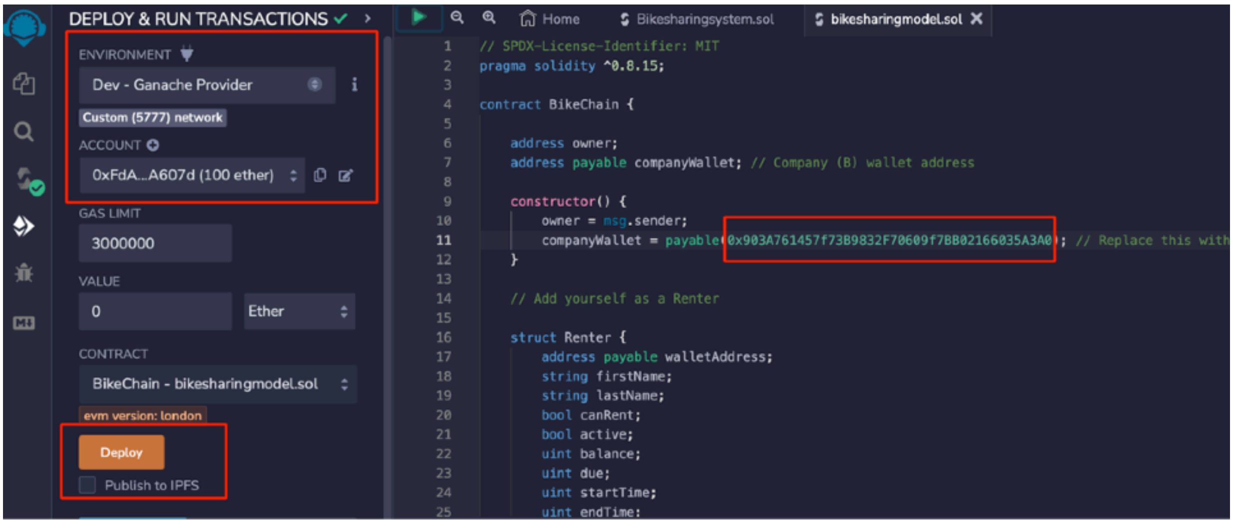

Figure 9: Deploy smart contract

After deploying a smart contract, your account balance will decrease slightly due to the gas fee required to execute the contract deployment transaction. Once the contract deployment transaction is complete, the contract address and other related information will appear below. This verifies that the contract was successfully deployed on the Ethereum blockchain and is now available for network interaction. The contract address may be used for a variety of tasks, including checking the contract's status, calling its functions, and sending money to it (Figure 10).

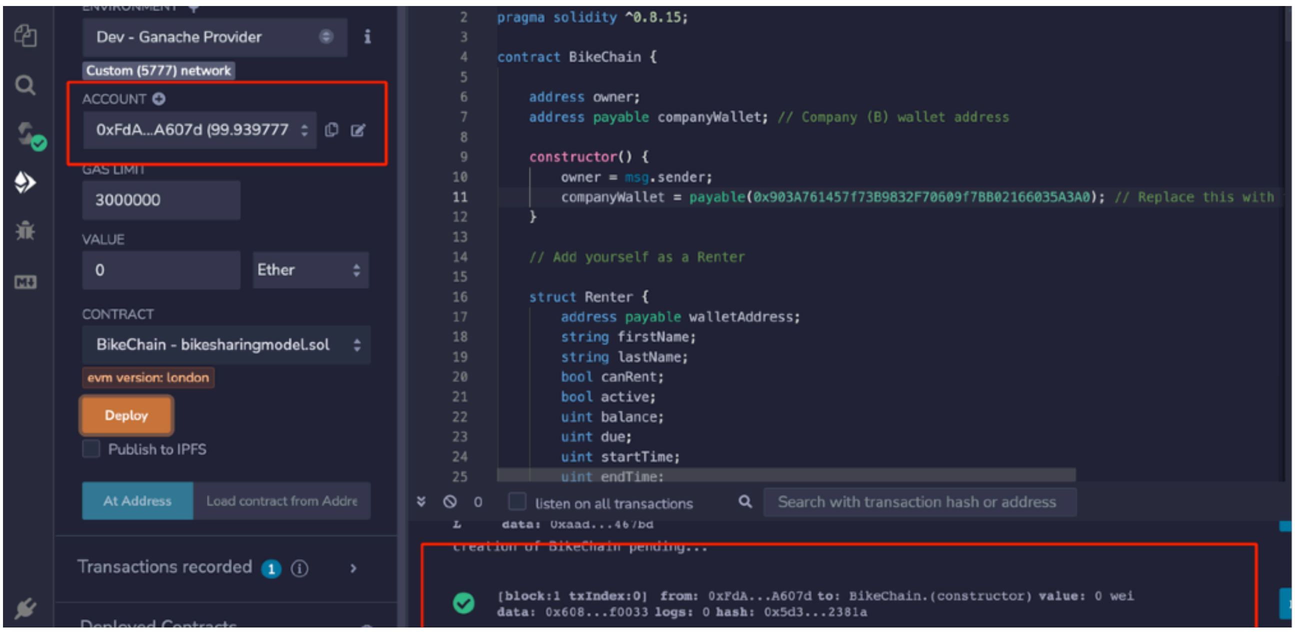

Figure 10: Successful deployed the smart contract

4.2. Implement of smart contracts

The six basic components of the smart contract are registration, deposit, the start of the rental period, the end of the rental period, the incentive model, and make payment. After add a new user, by providing the account address, the smart contract will send back information about the renter, including the user's last name, first name, the status of the current rental, starting and ending times, the account balance, the amount due, and the penalty.

4.2.1. User Registration

The first step in the bike sharing system is user registration, during which those who intend to utilise the service must set up an account. A web or mobile application that communicates with the smart contract can be used to do this. The smart contract calls the addRenter function, which accepts as inputs the renter's wallet address, first and last names, and other pertinent information (Figure 10). The given information is assigned to the struct fields by the smart contract, which also produces a new renter struct. With the wallet address serving as the key, the renter's information is now kept in the smart contract's renters mapping. The renter may now utilise bikes and receive incentives depending on their usage and conduct after registering on the platform. The renter can begin utilizing the bike sharing service by renting bikes and engaging with the smart contract for rental, reward, and penalty transactions after completing the registration procedure.

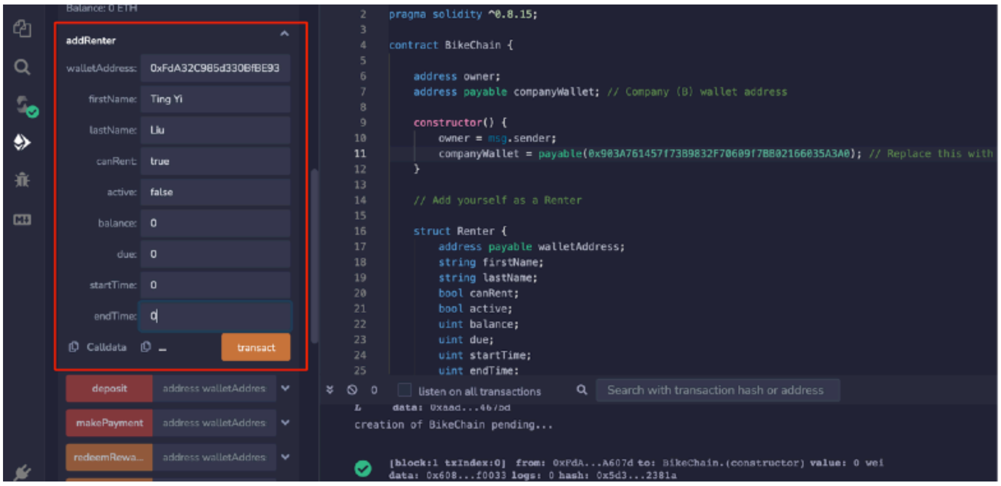

Figure 10: Smart contract addRenter function

You will get the renter's information stored in the renters mapping. This includes the firstName, lastName, canRent, active, balance, due, startTime, endTime, penalty, and the Rewards struct associated with that walletAddress. The renter's name is "Ting Yi Liu," and they have the ability to rent a bike (canRent: true). However, currently, they are not actively renting a bike (active: false) and have no pending balance (due: 0). There are no previous rental records, so the startTime, endTime, and penalty are all set to 0. Additionally, the renter has not completed any rides or earned any rewards yet (rewards: rideCount: 0, rideDistance: 0, leaderboardRewards: 0, leaderboardPositions: [false, false, false]) (Figure 11).

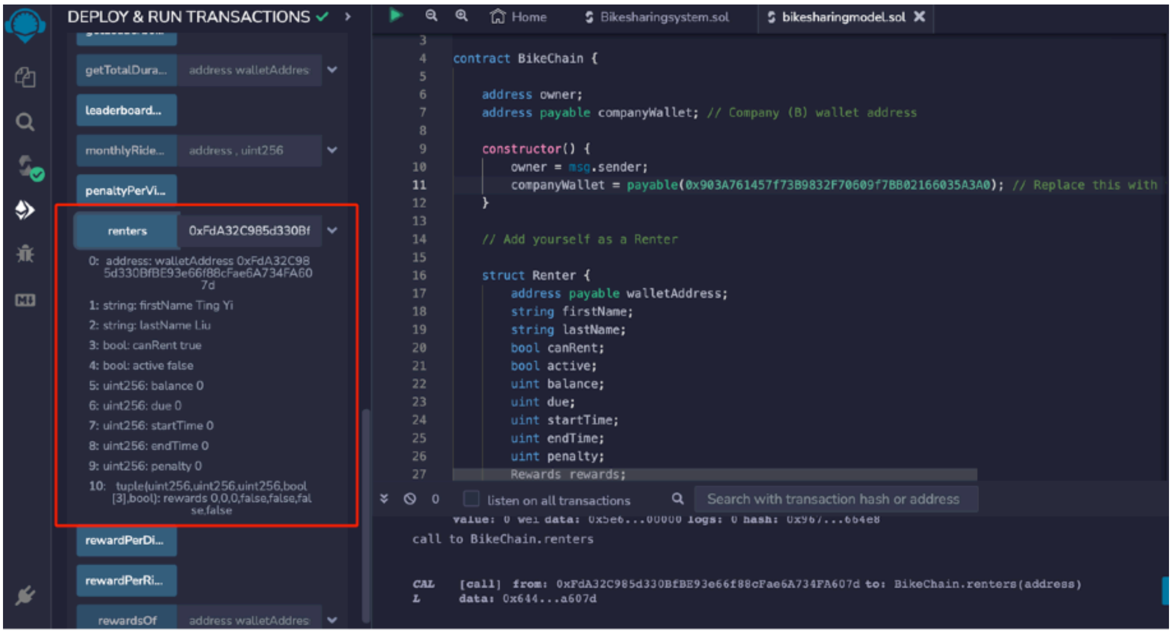

Figure 10: "renters" function shown all the information of user

4.2.2. Deposit

The deposit function allows users (renters) to add funds to their account balance in the smart contract by sending Ether with a transaction. The deposited amount is added to the user's existing balance, which can be used to cover pending dues or future bike rentals. As shown below (Figure 11), we added 5 ETH to deposit.

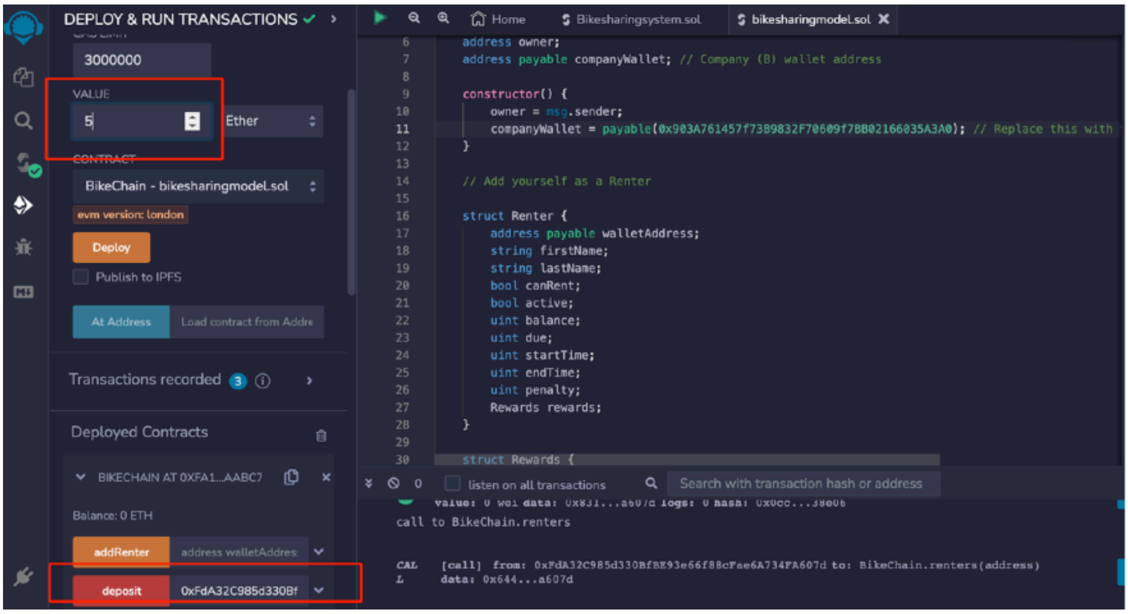

Figure 11: Deposit

4.2.3.Rent a bike

The “Start Rental” procedure specifies how long the renter will have to use the bike before deciding whether to return it. The renter will pay a price based on the amount of time used throughout the rental period (Figure 12).

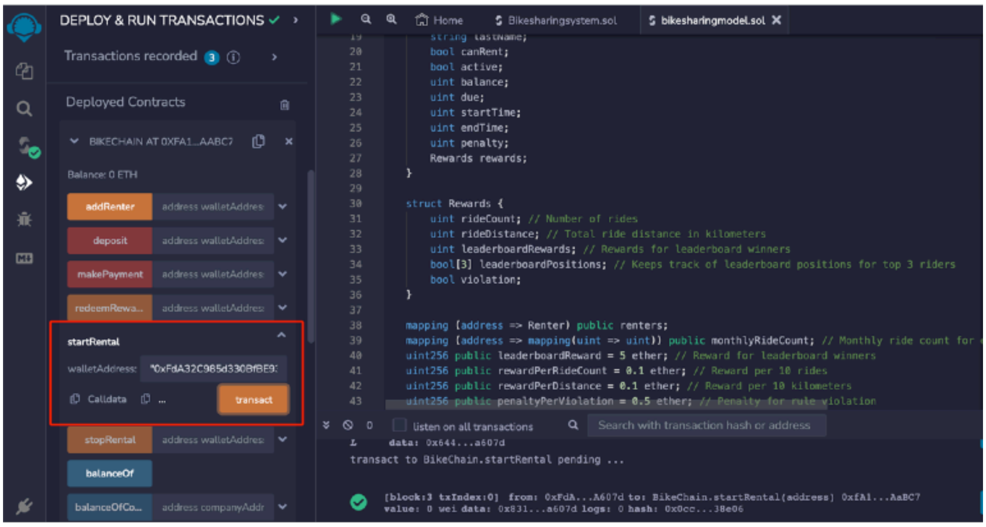

Figure 12: Start Renting a Bike

After using the "start rental" feature to initiate the bike rental process, the provided information reflects the current status: The individual's Ethereum wallet address is 0xFdA32C985d330BfBE93e66f88cFae6A734FA607d. The user is identified as "Ting Yi Liu." Although the ability to rent a bike (canRent) is marked as "false," the rental process is actively in progress (active: true). The user's account balance is 0, indicating no funds are currently available. No payment is immediately due (due: 0). The rental commenced at timestamp 1691057043, while the bike return time (endTime) remains unspecified (0). There are no penalties accrued (penalty: 0), and the rewards section indicates a ride count of 0, with no other rewards or violations documented.

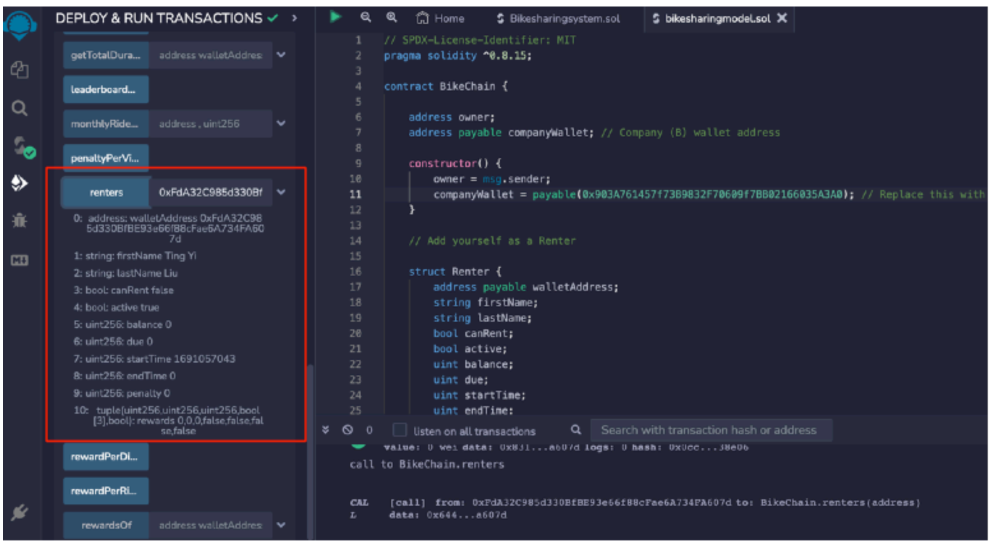

Figure 13: Check “renter” status after start rent a bike

4.2.4.Stop rental a bike

After the user has finished using the bike, the smart contract checks its state once again in the return stage. The smart contract locks the bike, determines the amount due, modifies the incentives and penalties, and logs the pertinent information on the blockchain once the user returns the bike. Users will be encouraged to return the bike abide by the regulations as a result. After the subsequent owner confirms that the bike is in excellent condition and completes the contract fulfilment and rental service. The riding distance on this side of the contract is currently entered manually (Figure 14). The actual application should be connected to the GPS to automatically update the riding distance.

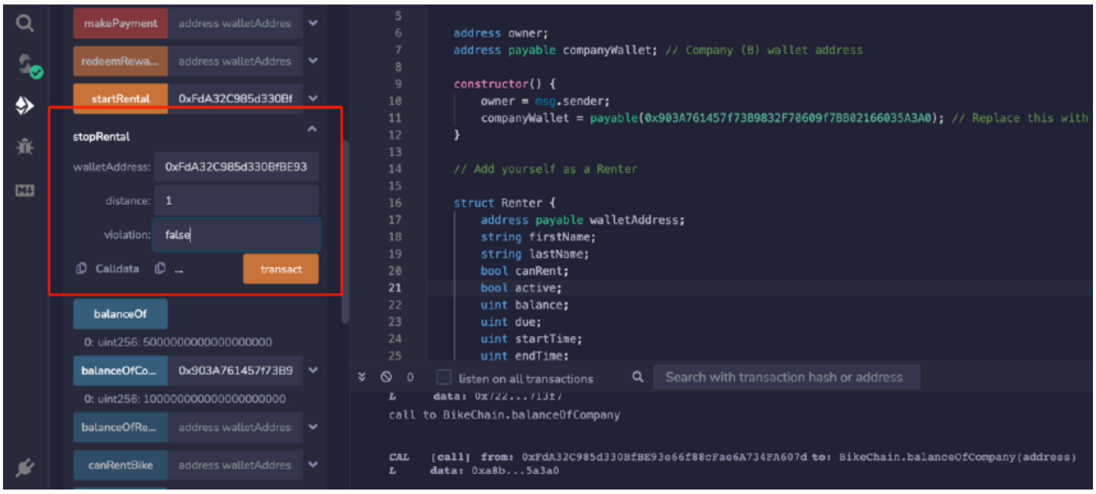

Figure 14: Stop rental bike

The renter's name is Ting Yi Liu. Currently, the renter cannot rent a bike (canRent is false) and is not actively using a bike (active is false). The renter's account balance is 5 Ether. The renter has a pending due amount of 0.01 Ether. The startTime indicates that the renter started a bike rental at a specific timestamp, while endTime shows the end time of the rental. The penalty value is currently 0, indicating no penalty has been applied. The rewards tuple shows that the renter has completed 1 ride (rideCount: 1) and covered a total ride distance of 1 kilometer (rideDistance: 1). The renter has earned 0 leaderboard rewards and holds the first position on the leaderboard (leaderboardPositions: [true, false, false]). Additionally, the renter has no violated the rules (violation: false).

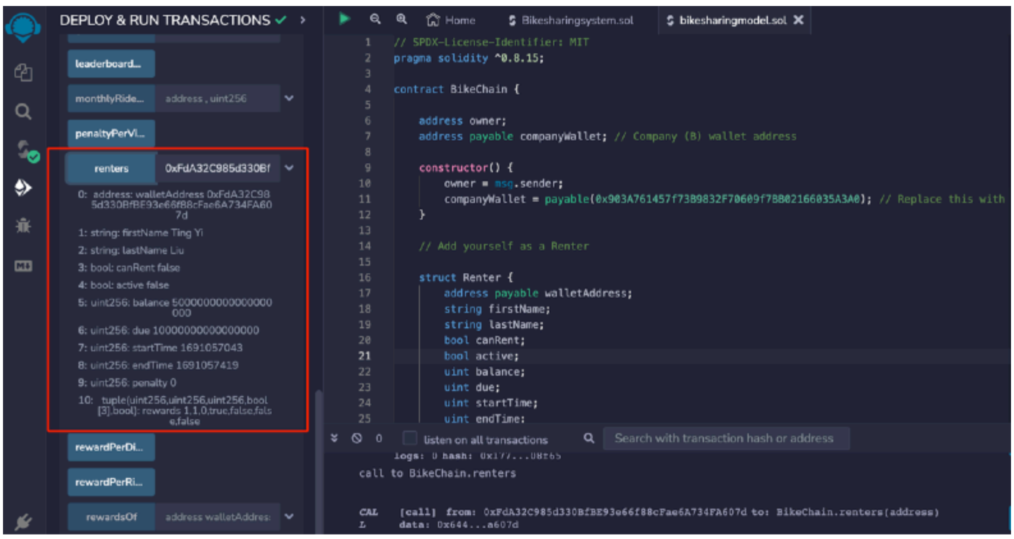

Figure 15: Check “renter” status after stop rental

4.2.5.Make payment

The makePayment function handles the payment process after the customer has completed their rental. It transfers the due amount from the customer's wallet to the company's wallet (companyWallet) as a payment for the rental. The customer is then rewarded with a reward amount based on the number of rides (rideCount) and distance traveled (rideDistance). The "makePayment" function in the bike-sharing smart contract is essential to completing a bike rental transaction and enabling the user to rent a bike again in the future. proceed to break down the "makePayment" function's steps:

Ending the Bike Rental: The user must start the “makePayment” function after their bike rental is over and they have returned the bike. The function is tagged as “payable” to allow users to transfer money during the transaction and requires the usr’s wallet address as an input.

Checking Outstanding Dues: The first action in the function is to check if the user has any unpaid balances from prior bike rentals, or outstanding dues. The command require(renters[walletAddress].due>0, “You do not have anything due at this time.”).

Validating Payment Amount: The function then determines if the sum supplied by the user (as determined by msg.value) is sufficient to pay for any outstanding dues. This check’s prerequisite is : require(renters[walletAddress].balance>=msg.value.. “You do not have enough funds to cover payment, Make a deposit, please.”)

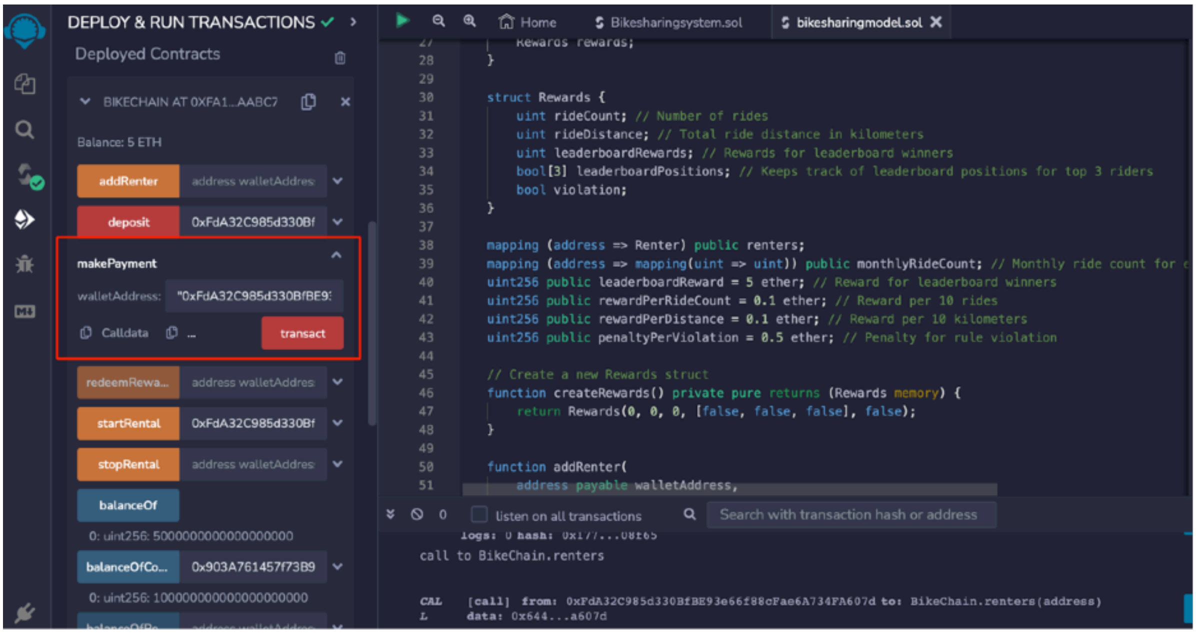

Figure 16: Make payment

In this state, the "Renter" has successfully made a payment, resulting in an updated balance. The "Can Rent" status is now set to "True," indicating that the user can rent a bike again. The "Ride Count" and "Ride Distance" rewards have been incremented, reflecting the completed rental activity. The "Leaderboard Positions" show that the user holds the top position in the first category. The "Violation" status remains false, indicating no rule violations. This status update signifies a successful rental payment and rewards accumulation for the "Renter."

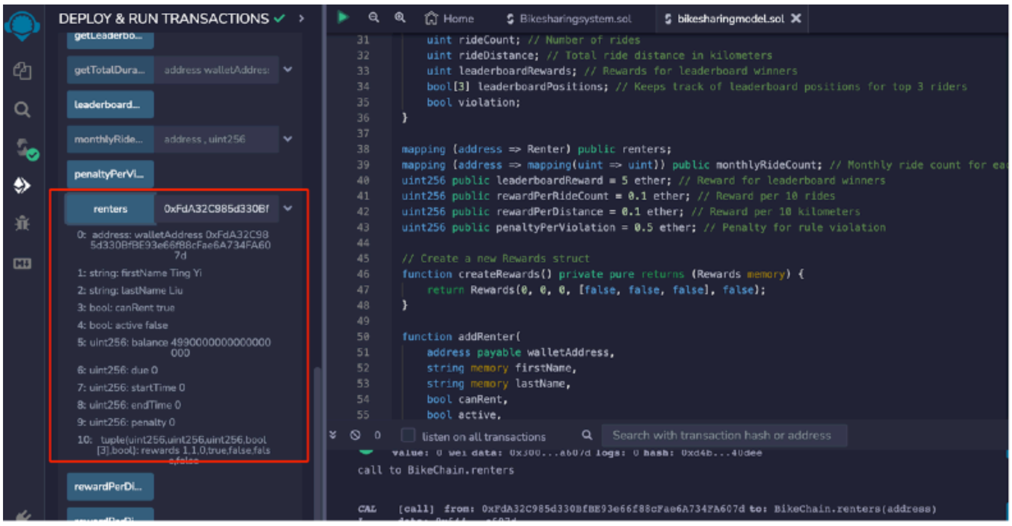

Figure 17: Check "renter" status after successfully making a payment

After a successful payment of the rental fee by the customer, the company account's balance will reflect the corresponding amount (Figure 18). The company account will receive the rental payment from the customer, and these payments will accumulate and be reflected in the balance of the company account. This means that the company account will show all the rental fees received, which are deducted from the payments made by the rental users. This approach ensures that the company can collect the necessary fees based on the rental transactions and manage funds and withdrawals as needed.

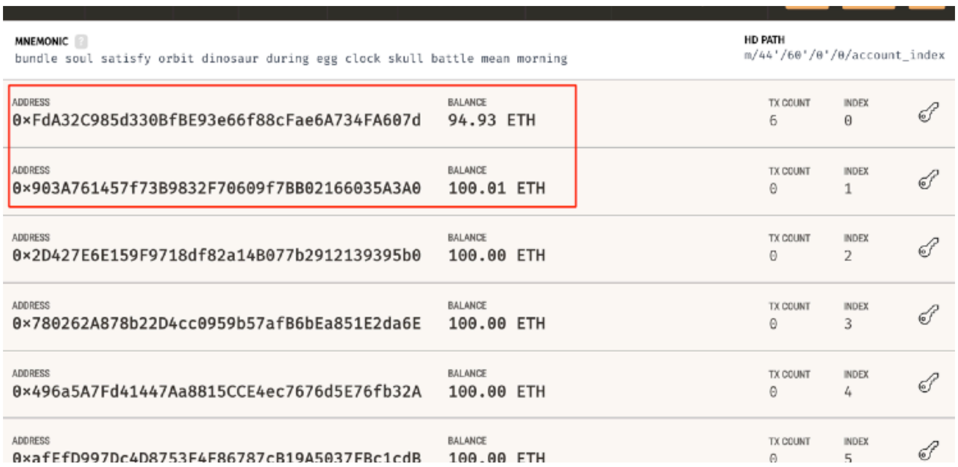

Figure 18: Business and Customer account status in Ganache

4.2.6.Incentive model

The incentive model used for bike sharing seeks to motivate users to behave properly and accomplish particular objectives. These incentives may include bonuses for riding duration, frequency, and leaderboard placements as well as fines for breaking the rules. The system of incentives created in this research is as follows:

Ride Frequency Rewards:
For every 10 completed rides, users will earn a specific reward, for example 0.1ETH.

Ride Distance Rewards:
For every 10 kilometres traveled, users will earn a specific reward, for example 0.1 ETH.

Leaderboard Rewards:
Users will be rated at the end of each month depending on how frequently and how far they rode throughout that month. The first-place user will receive 5 ETH, followed by the second-place user with 3 ETH, and the third-place user with 2 ETH. These awards will go to the top three users on the leaderboard.

Penalties for Violations:
Users who break the platform’s regulations, such as by parking in an inappropriate place or wrecking the bikes, may face consequences. A reduction in ride frequency and distance awards, as well as extra fines, such as 0.5 ETH, may be the outcome of violations.

Reward Type	Criteria	Reward Amount
Ride Count	Every 10 rides completed	0.1 ETH
Ride Distance	Every 10 kilometres ridden	0.1 ETH
Leaderboard Rewards	Top 3 monthly riders	5 ETH
Violation Penalty	Each violation	–0.5 ETH

Table 1: Incentive model

Users will earn 0.1 ETH as incentive for every 10 rides they complete and an additional 0.1 ETH for every 10 kilometers they bike under this incentive scheme. In addition, 5 ETH will be awarded to each of the top three riders on the monthly leaderboard. However, users will be charged -0.5 ETH for every time they break the bike-sharing restrictions.

```
mapping (address => Renter) public renters;
mapping (address => mapping(uint => uint)) public monthlyRideCount; // Monthly ride count for each user
uint256 public leaderboardReward = 5 ether; // Reward for leaderboard winners
uint256 public rewardPerRideCount = 0.1 ether; // Reward per 10 rides
uint256 public rewardPerDistance = 0.1 ether; // Reward per 10 kilometers
uint256 public penaltyPerViolation = 0.5 ether; // Penalty for rule violation
```

Figure 19: Incentive model smart contract

4.2.7. Ganache smart contract transaction

Ganache provides transaction details, such as transaction hash, status, and gas cost, for each executed transaction. We can view this information in the Ganache interface. The figure 20 shown this research all the transaction.

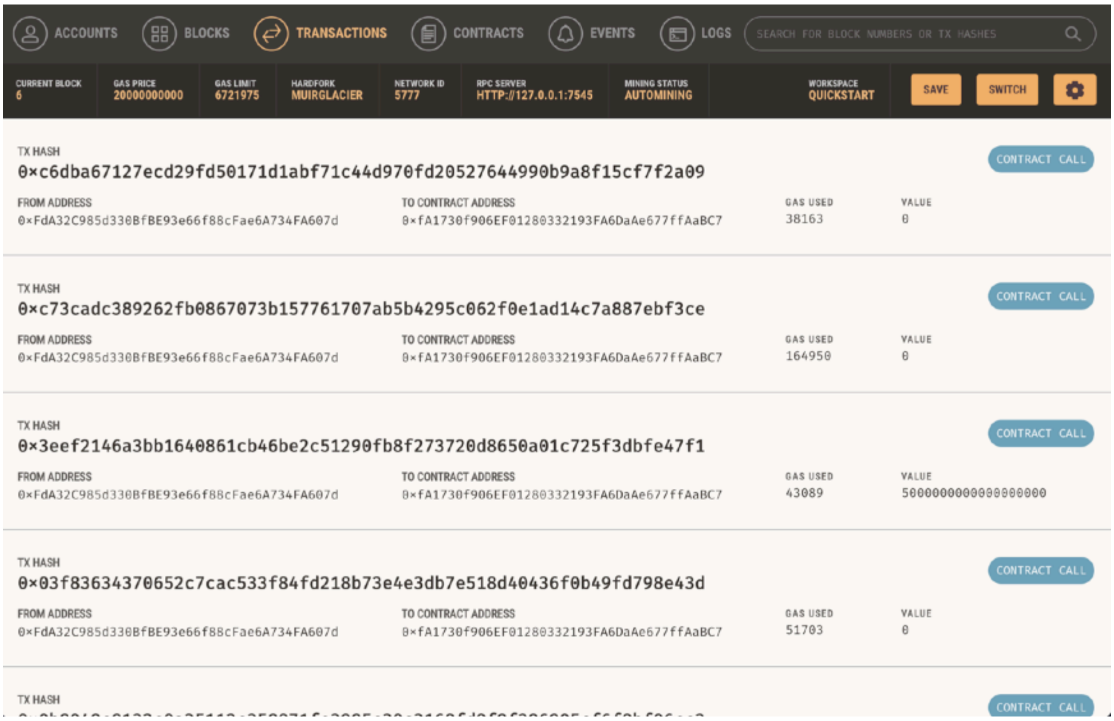

Figure 20: Ganache transaction page

5. Security and Privacy Considerations

Blockchain technology has created new opportunities for changing a number of industries, including mobility and transportation. Implementing blockchain-based bike sharing systems, which provide efficient, decentralized, and transparent platforms for users to rent and share bicycles, is one of the creative application cased. But resolving important security and privacy issues is crucial for the widespread use of such systems.

In order to maintain consumers' faith and confidence in blockchain-based bike sharing networks, security and privacy are of utmost significance. To do this, developers must carry out thorough smart contract audits to find and fix flaws. Strong access control techniques are used to secure sensitive data and prevent unwanted access. Additionally, data encryption should be used to safeguard user information, and reducing the amount of personally identifiable information stored promotes user privacy. Blockchain-based bike sharing systems may provide a safe, dependable, and user-centric experience by including these steps, as well as optimising gas use, making sure that secure oracles are in place, and encouraging user transaction verification. The effective acceptance and broad usage of blockchain technology in the field of bike sharing and urban mobility depends on addressing these security and privacy concern.

6. Discussion and Conclusion

6.1. Discussion

The discussion on blockchain-based bike sharing systems emphasizes both the major benefits and possible drawbacks of this ground-breaking technology. Bike sharing systems may provide consumers with decentralized, transparent, and frictionless rental experiences by employing blockchain. By automating payments and decreasing dependency on middlemen, the adoption of smart contracts streamlines the renting process and increases consumer convenience. A feeling of community participation is also promoted by the inclusion of user incentive mechanisms like awards for ride counts, ride distances, and leaderboard positions. With the help of these incentives, a more sustainable and ethical bike-sharing ecosystem may be created by encouraging careful driving, thoughtful parking, environment, and active participation.

6.2. Conclusion and further work

In conclusion, this project's bike sharing smart contract exemplifies the usage of a user-centric incentive system on the blockchain. This project have developed a decentralized system that encourages people to act responsibly and actively participate utilizing the Ethereum blockchain and Solidity smart contracts. Users are encouraged by the incentive system to ride their bikes more frequently, go farther, and contend for the top spots in the leaderboard. For good deeds like careful driving, considerate parking, and active participation, users are rewarded with ether. Users who break the regulations, however, are subject to punishment, which discourages misbehavior and encourages bike usage that is responsible.

The "makePayment" function is included into the smart contract, which guarantees a quick and safe transaction. The smart contract properly updates the user's balance and rental status, enabling them to effortlessly clear their debts and rent bikes once more for subsequent journeys. Looking ahead, a complete and user-friendly bike sharing platform may be created by combining the bike sharing smart contract with a suitable front-end User Interface (UI). Bike rentals and payments are simple and convenient with the integration of a front-end application, which allows users to engage with the smart contract in real time. Overall, the bike-sharing smart contract and a well-designed front-end user interface have the power to transform the bike-sharing sector by encouraging responsible bike use, honoring good deeds, and offering users a quick, secure, and transparent platform to enjoy bike rentals.

Reference

Al-Breiki, H., Rehman, M., Salah, K., Svetinovic, D. (2020). Trustworthy Blockchain Oracles: Review, Comparison, and Open Research Challenges. IEEE Access, (8), 85675-85685. https://doi.org/10.1109/access.2020.2992698

Bag, S., Viktorovich, D., Sahu, A., Sahu, A. (2020). Barriers To Adoption Of Blockchain Technology In Green Supply Chain Management. JGOSS, 1(14), 104-133. https://doi.org/10.1108/jgoss-06-2020-0027

Bennacer, S., Sabiri, K., Aaroud, A., Akodadi, K., Cherradi, B. (2023). A Comprehensive Survey On Blockchain-based Healthcare Industry: Applications and Challenges. IJEECS, 3(30), 1558. https://doi.org/10.11591/ijeecs.v30.i3.pp1558-1571

Chen, Z., Lierop, D. v., Ettema, D. (2020). Exploring Dockless Bikeshare Usage: a Case Study Of Beijing, China. Sustainability, 3(12), 1238. https://doi.org/10.3390/su12031238

Chen, L., Hsu, Y. (2020). Socio-ecological Predictors Of Frequent Bike Share Trips: Do Purposes Matter?. IJERPH, 20(17), 7640. https://doi.org/10.3390/ijerph17207640

Capponi, A., Fiandrino, C., Kantarci, B., Boukerche, A., Kliazovich, D., Bouvry, P. (2019). A Survey On Mobile Crowdsensing Systems: Challenges, Solutions, and Opportunities. IEEE Commun. Surv. Tutorials, 3(21), 2419-2465. https://doi.org/10.1109/comst.2019.2914030

Chen, Z., Lierop, D., Ettema, D. (2020). Dockless Bike-sharing Systems: What Are the Implications?. Transport Reviews, 3(40), 333-353. https://doi.org/10.1080/01441647.2019.1710306

Ethereum whitepaper ethereum.org. Available at: https://ethereum.org/en/whitepaper/ (Accessed: 13 July 2023).

Felson, M. and Spaeth, J. L. (1978) Community Structure and Collaborative Consumption: A Routine Activity Approach. American Behavioral Scientist, 21, 23. https://doi.org/10.1177/000276427802100411

Guo, Y., Yang, L., Chen, Y. (2022). Bike Share Usage and The Built Environment: A Review. Front. Public Health, (10). https://doi.org/10.3389/fpubh.2022.848169

Grishchenko, I., Maffei, M., Schneidewind, C. (2018). A Semantic Framework For the Security Analysis Of Ethereum Smart Contracts., 243-269. https://doi.org/10.1007/978-3-319-89722-6_10

Haque, A., Naqvi, B., Islam, A., Hyrynsalmi, S. (2021). Towards a Gdpr-compliant Blockchain-based Covid Vaccination Passport. Applied Sciences, 13(11), 6132. https://doi.org/10.3390/app11136132

Huurne, M., Ronteltap, A., Corten, R., Buskens, V. (2017). Antecedents Of Trust In the Sharing Economy: A Systematic Review. J Consumer Behav, 6(16), 485-498. https://doi.org/10.1002/cb.1667

Jia, L., Ren, Y., Feng, Q., Qian, C., Li, Z., Li, Z. (2022). An Electric Fence-based Intelligent Scheduling Method For Rebalancing Dockless Bike Sharing Systems. Applied Sciences, 10(12), 5031. https://doi.org/10.3390/app12105031

Kondor, D., Zhang, X., Meghjani, M., Santi, P., Zhao, J., Ratti, C. (2022). Estimating the Potential For Shared Autonomous Scooters. IEEE Trans. Intell. Transport. Syst., 5(23), 4651-4662. https://doi.org/10.1109/tits.2020.3047141

Kamal, R., Hemdan, E., El−Fishway, N. (2022). Forensics Chain For Evidence Preservation System: An Evidence Preservation Forensics Framework For Internet Of Things−based Smart City Security Using Blockchain. Concurrency and Computation, 21(34). https://doi.org/10.1002/cpe.7062

Kasireddy, P. (2019) *How does ethereum work, anyway?*, *Medium*. Available at: https://preethikasireddy.medium.com/how-does-ethereum-work-anyway-22d1df506369 (Accessed: 13 July 2023).

Li, Y. (2023). Exploring the Impact Of First Mile/last Mile Solutions On Traffic Congestion And Air Quality In Urban Areas. SSSH, 3(2), 66-74. https://doi.org/10.56397/sssh.2023.03.09

Liu, L., Li, F., Qi, E. (2019). Research On Risk Avoidance and Coordination Of Supply Chain Subject Based On Blockchain Technology. Sustainability, 7(11), 2182. https://doi.org/10.3390/su11072182

Ma, X., Cao, R., Wang, J. (2019). Effects Of Psychological Factors On Modal Shift From Car To Dockless Bike Sharing: a Case Study Of Nanjing, China. IJERPH, 18(16), 3420. https://doi.org/10.3390/ijerph16183420

Mi, Z., Coffman, D. (2019). The Sharing Economy Promotes Sustainable Societies. Nat Commun, 1(10). https://doi.org/10.1038/s41467-019-09260-4

Mackey, T., Kuo, T., Gummadi, B., Clauson, K., Church, G., Grishin, D., … & Palombini, M. (2019). 'Fit-for-purpose?' – Challenges and Opportunities For Applications Of Blockchain Technology In The Future Of Healthcare. BMC Med, 1(17). https://doi.org/10.1186/s12916-019-1296-7

Pinna, A., Ibba, S., Baralla, G., Tonelli, R., Marchesi, M. (2019). A Massive Analysis Of Ethereum Smart Contracts Empirical Study and Code Metrics. IEEE Access, (7), 78194-78213. https://doi.org/10.1109/access.2019.2921936

Ramadhan, D., Wibowo, L., Nugroho, A. (2022). State Of the Art Blockchain Enabled Smart Contract Applications In The University. B-FronT, 2(2), 70-80. https://doi.org/10.34306/bfront.v2i2.229

Susanto, B., Masrek, M., Khairuddin, I. (2022). Implementation Of Smart Contract Technology In Financial Services Institutions. E-BPJ, SI10(7), 249-254. https://doi.org/10.21834/ebpj.v7isi10.4129

Shen, Y., Zhang, X., Zhao, J. (2018). Understanding the Usage Of Dockless Bike Sharing In Singapore. International Journal of Sustainable Transportation, 9(12), 686-700. https://doi.org/10.1080/15568318.2018.1429696

Shang, W., Chen, J., Bi, H., Sui, Y., Chen, Y., Yu, H. (2021). Impacts Of Covid-19 Pandemic On User Behaviors and Environmental Benefits Of Bike Sharing: A Big-data Analysis. Applied Energy, (285), 116429. https://doi.org/10.1016/j.apenergy.2020.116429

Schnieder, M., Hinde, C., West, A. (2021). Land Consumption Of Delivery Robots and Bicycle Couriers For On-demand Meal Delivery Using Gps Data And Simulations Based On The Time-area Concept. Sustainability, 20(13), 11375. https://doi.org/10.3390/su132011375

Shen, Y., Zhang, X., Zhao, J. (2018). Understanding the Usage Of Dockless Bike Sharing In Singapore. International Journal of Sustainable Transportation, 9(12), 686-700. https://doi.org/10.1080/15568318.2018.1429696

Wang, W., Song, J., Xu, G., Wang, H., Su, C. (2021). Contractward: Automated Vulnerability Detection Models For Ethereum Smart Contracts. IEEE Trans. Netw. Sci. Eng., 2(8), 1133-1144. https://doi.org/10.1109/tnse.2020.2968505

Wang, Y.S., & Kogan, A. (2018). Designing confidentiality-preserving Blockchain-based transaction processing systems. International Journal of Accounting Information Systems, 30, 1-18. doi:10.1016/j.accinf.2018.06.001

Wang, J., Li, Y. (2022). Soft Economic Incentives and Soft Behavioral Interventions On The Public's Green Purchasing Behaviour - The Evidence From China. PRBM, (Volume 15), 2477-2499. https://doi.org/10.2147/prbm.s373123

Welcome to remix's documentation!¶ *Remix*. Available at: https://remix-ide.readthedocs.io/en/latest/ (Accessed: 13 July 2023).

Xu, M., Chen, X., Kou, G. (2019). A Systematic Review Of Blockchain. Financ Innov, 1(5). https://doi.org/10.1186/s40854-019-0147-z

Zhu, H., Zhou, Z. (2016). Analysis and Outlook Of Applications Of Blockchain Technology To Equity Crowdfunding In China. Financ Innov, 1(2). https://doi.org/10.1186/s40854-016-0044-7

Zhu, Y. (2022). Design and Application Of Legally Valid Payment Templates Based On Linking Contracts. Computational and Mathematical Methods in Medicine, (2022), 1-9. https://doi.org/10.1155/2022/1331237