Blockchain-Based Governance in Fractional Ownership: Mitigating Zero-Sum Games Through Decentralized Autonomous Agents

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Abstract. The sharing economy is a mega-trend in the world and fractional homeownership is on the rise. When each transaction is a high-stake bargaining game involving multiple stakeholders, maintaining a harmonious and frictionless fractional ownership in real estate is challenging. While academics and practitioners have been focusing on nascent technology like blockchain application in this domain, their potential in supporting the governance of fractional ownership is not fully understood. Using a design science research approach, this paper studies the conflicts of interests in fractional ownership real estate transactions through the lens of zero-sum game and three dimensions of full, equal, and trustful participations. It then proposes a novel, blockchain-based governance ecosystem built on a decentralized autonomous organization.

Keywords: Blockchain · Governance · Risk, and compliance · Decentralized autonomous organization · Fractional ownership

1 Introduction

More and more, we need to share our place in a very open way. Some symbolic examples of the sharing economy mega-trend are the Airbnb model or the property unit ownerships and fractional house ownerships. The current situation of the real estate market in developed countries, including the US, is that people who can afford to buy a house individually are getting older. Owning only a shared building unit or one fraction of a house becomes a preferable choice for individuals to get onto the housing ladder [1]. In the context of this study, the fractional ownership real estate transaction (FORET) is referred to as the housing transactions of people who could not afford or own a house individually but desire to buy a fraction of a place to live. This definition of fractional ownership is purposefully distinguished from other investment ownership such as real estate investment trusts (REITs), shares, or tokenized assets. Agents play an essential role in this type of real estate transaction. Without an agent, the consumer becomes a less protected and more vulnerable party [2]. As FORET is one of the most complex types of real estate transaction [3], the time required to finish a FORET might be counted by years if it involves a mortgage or loan. Prior research revealed that the dilemma of a real estate transaction is often rooted from the incomplete information

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condition of joint-ownership agreement [1, 4]. FORET involves multiple owners and intermediaries such as lawyers, banks, insurance companies, sales agents, and so on. This means the conflicts of interests in a FORET are multiple and multilayers. Solving the conflicts of interest in a FORET to achieve harmonious and successful ownership is challenging. Transaction participants need to rely on an optimal search strategy based on the information they have. Once the demand and supply match, buyer and seller will start engaging in a series of bargaining games that are usually chaotic with interwoven strategies [4]. Thus, it often results in not achieving a FORET match. For example, to maximize the benefits, both agent and principle would hide some part of information regarding the property. Or more seriously, an agent might work for two sellers on the same real estate with different fractions without their knowing. On the other hand, if the bargaining is successful, buyer and seller will need to deal with several arrangements with agents, which often become a puzzle. The full ownership real estate transaction has been proven as a highly complex process, especially in the high value low frequency transactions [5]. In FORET, the complex of communication and interaction between participants is shifted to a higher level due to the assemble of multiple agents and multiple owners (Fig. 1). Motivated by these issues, this paper desires to shed light on the principal-agent problems in a FORET from zero-sum game perspectives aiming to provide a solution to mitigate the relevant conflict of interests. The paper first seeks answers to the research questions "what are the zero-sum games of principal-agent problems in a FORET? And how to use information tools to mitigate these conflicts of interests?". Prior studies have looked at principal-agent problems in real estate transactions under game perspectives such as the transactional game by Berne [6], Patron and Roskelley's bargaining game [7], Lulu and Zhi multi-agents' game [8]. Nevertheless, these studies mostly focus on the bargaining game. Moreover, none of the previous works has converted the real estate game into three subcategories to analyze its principal-agent problems. By answering the research questions, this paper shows a need for solutions that move beyond business-as-usual using evidence from science to reassess the relationships between agent and principal. Such solutions can help governing transaction execution and mitigating conflict of interests between involved parties. One of the potential solution is the emerging technology of blockchain, which is growing attention in supporting fractional ownership transactions. Several studies have proposed blockchain solutions to resolve transactional verification, transparency, and governance [9, 10]. It is notable that even though blockchain remains in its nascent years, it is predicted to be a potential decentralized governance framework for real estate property [11, 12].

Design science research (DSR) is a methodology that is motivated by the desire to improve the environment by the introduction of innovative artifacts and the processes for building these artifacts [13]. Using DSR as the methodology, this paper aims to (i) identify problems of FORET using the agency theory approach with the support of online experiment platform, (ii) Develop a novel governance, risk, and compliance (GRC) framework typically for fractional ownership real estate transactions that benefits involved parties, (iii) improve transaction transparency to mitigate conflict of interest in the multi-owned property, and (iv) fulfill the knowledge gaps of fractional ownership research domain. The following discussion reviews the relevant extent literature. Next, the adopted design science research methodology is explained. Then the conceptual artefacts, proof of concept, and the system artefact will be described in the discussion and evaluation plan.

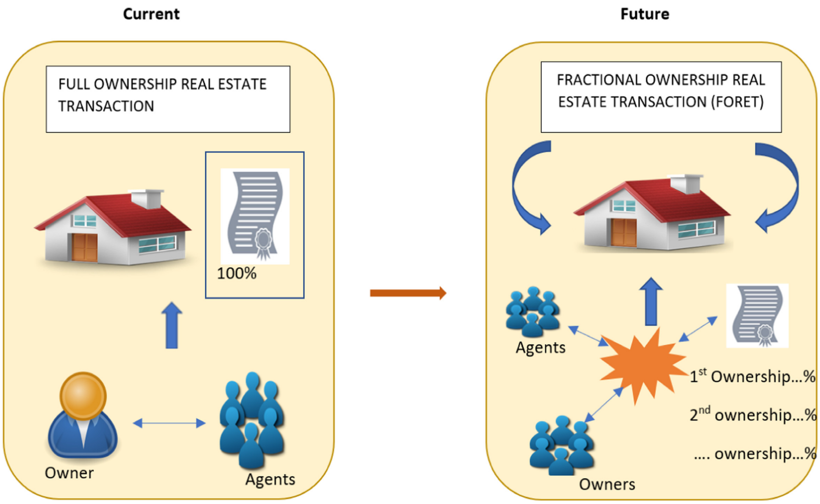

Fig. 1. Full and fractional ownership real estate transactions.

2 Literature Review

2.1 Real Estate Transactional Games

The transactional game emphasizes using transactions to discover information [6]. In the context of Berne's [6] study, a game is an ongoing series of complementary ulterior transactions progressing to a predictable outcome. A game is generally established by a set of repetitious and plausible transactions with a concealed motivation. One of the typical transactional games is the "insurance game", in which no matter what type of interaction, the agents will perform as a hard player as they aim for the highest outcome of the game – the clients sign the insurance contracts. This principle also applies to other games and occupations such as "the real estate game", "the panama game", and the "balance Sheet" game. In the transactional game, how individuals interact with one another, and how the ego states affect each set of transactions would be fully focused. By which, the transactional game believes that the change of these interactions would be the path to solve the problems by providing solutions rather than just the understanding. The unproductive or counterproductive transactions would be considered as the signs of problems at the ego state. Berne [6] believes that virtually everyone has something problematic about their ego states. Hence, the negative behaviors cannot be solved by giving the treatment to the problematic behaviors only but by analyzing individual's developmental history to adjust their behaviors from the root. Berne [6] purports that the most important aspects of transactional game is the contract, which is an agreement made by both players to pursue specific goals that each of the player desires.

In terms of principal-agent problem in a transactional game, Grohman [2] identified the elements that are necessary for an agency relationship to exist between the selling broker and the purchaser. As a result, the purchaser usually reveals to the broker material information which the broker is obligated to disclose to the seller. Following this perspective, Clauretie and Daneshvary [14] conducted a quantitative study in exploring the volatility of property price impact on principal-agent problem during the transaction timelines. The study suggested that bargaining power is a factor that impacts the successful outcome of real estate transactions. By estimating the effects of the changes that agent made on selling timeline and transaction price, the findings showed that except for the high amount of agency costs, the agent-consumer tactics changed when it was closer to the expired date of listing contract. The discrepancy between agent and consumer's expectations regarding listed transaction fees would create principal-agent conflict. This conflict usually resulted in a change of agent before the transaction finishes, which is equivalent to the weakening bargaining power of the consumer. Specifically, prices are lower if the property is sold near the expiration of the listing contract, indicating that the price-reduction effect dominates the broker-efforts. By using multi methodological approach, Yavas [4] identified that broker played a more prominent role during a real estate transaction than any other third party, and the principal-agent problem engaged in the seller-broker relationship. Patron and Roskelley [7] analyzed the two-period bargaining game between buyers, sellers, and real estate agents which were selected to determine the sales price of a house. The results showed that agents seemed to pay less effort on bargaining when receiving commissions or working for buyer. Agents perform similarly with little effort on bargaining advice in the less market competition condition. While when the potential returns were large or the second agent appear, agents likely bargained aggressively. The same scenario appeared when the house's sales price is closely related to the agent's reputation and future business opportunities.

Lulu and Zhi [8] figured out that investment process of decision-making in the real estate market is a multi-agent-stage dynamic process. In this process, the ultimate equilibrium is an outcome of most of the games that the participants adjusted themselves under certain conditions. Based on Berne's [6] perspective, Ricks and Egbert [15] discovered that applications mostly relied on simulated crowds to populate games and system architecture resulting in the issue that agents did not socialize naturally with each other. The study thus proposed an expressive algorithm for adding a new dimension of realism into simulations. This architecture allowed agents to have multiple social interactions with other agents evolving multiple stages extracted from the psychological area of transactional analysis. Remarkably, the presented algorithm had a flexible architecture that will run with almost any obstacle avoidance algorithm. It included bi-modal crowds and social environments that can be changed in real-time. The results showed that the social crowd algorithm tested in real-time with up to 4,000 agents were far more realistic behaviors than previously simulated. Kim, Bang, and Ko [16] emphasized that inter-agent interactions played an important role in digital space for social interactions between agents and people. The study developed a simulation that replaced human communication by a card game. This card game was corresponded to the ego state model of transactional game. The agent communication module represented the agent-agent transactions based on the ego state model. The agents, the attacker, and defender, then participated in a game simulation with the cards that have messages and personalities. To win the game, the agents firstly needed to identify the intentions of their opponent – other agents. Then showing a card that matched their opponent's sample word or personality. Transactional games are believed that they could be applied to investigate economic decision-making process of principal and agent [6]. As individual economic actors in markets interaction might be influenced by subconscious cognitive processes and transactional games, there may exist an historical component that could adjust these principal-agent' behaviors. The study tried to seek evidence that showed the impact of subconscious social transaction games played between individuals on outcomes of the decision strategy in the context of a marketplace.

Using agency theory as an approach to research conflicts of interests between transaction participants has long been conducted ubiquitously. Nevertheless, there is only a limited amount of research has framed the principal-agent problem into games. Notably, among these studies, the principal-agent problem hasn't been studied in a specific domain of fractional ownership and included three dimensions of full, equal, and trustful participations in order to propose a solution via improvement of governance, risk, and compliance (GRC).

2.2 Blockchain-Based Governance

Blockchain Governance, Risk, and Compliance (GRC) in Real Estate. The effectiveness of GRC in adjusting strategic decisions of transactions' participants has been proven in prior research. It is believed that IT GRC provides a framework of decision rights and accountabilities that provoke the desirable behavior of participants [17]. From this perspective, Butler and McGovern [18] build a conceptual model and information system (IS) framework for the design and adoption of an environmental compliance management system. With the focus on environmental compliance and risk, this study explores the problems of GRC in dealing with regulations and to identify how these problems are being solved using the compliance management system. Furthermore, the study proposes a process-based conceptual model and related IS framework on the design and adoption of this compliance management system. Surujnath [19] proves that blockchain could radically reinvent the existing market infrastructure, hence the current body of derivatives laws and regulations would need to be amended to adapt to these changes. By analyzing scholarly articles and the opinions of actively engaged entrepreneurs, Sulklowski [20] identifies that distributed electronic ledgers will only be realized in the context of effective GRC. The current capacity of real estate management provided by a tech tycoon in Blockchain-as-a-service (BaaS) such as SAP or IBM includes object management, contract management, credit management, space optimization, and business process management. Nevertheless, it remains a lack of comprehensive transaction governance framework built on blockchain for fractional real estate transaction. Several academic studies have been carried on the applications of blockchain for real estate management: Wang and Kogan [21] employed DSR to build up a confidentiality-preserving Blockchain-based transaction processing system; Study by Chong et al. [22] presented a comparative case study of five blockchain-based business models to prove that blockchain is effective in improving business processes governance; Ziolkowski, Miscione, and Schwabe [23] used the qualitative method to study decision problems in blockchain governance. The findings of these studies provided a better understanding of how blockchain governance links to existing concepts and how it is enacted in practice. In terms of using DSR methodology, Wouda and Opdenakker [24] proposed a framework to improve the quality of the data by using the decentralized mechanism though which enhance the transaction process of an office building. The study also presented an application that was built up alongside the design. Hoksbergen et al. [5] employed DSR to propose a hash table database with a blockchain backbone for knowledge management of high value low frequency real estate transactions. Aiming to resolve the conflicts of interest between agent and consumer in real estate transaction, Huh and Kim [25] used blockchain to validate algorithms that could secure real estate transactions through encryption. Notably, Huh and Kim [25] built up a research model to compare and verify the practical Byzantine fault tolerance (PBFT) algorithm of hyperledger through the blockchain agreement process. The authors then implemented a virtual machine (VM) research methodology to propose a verification process for real estate contracts. This finding represented that the main functions of the smart contract could be included in the elastic models. However, this study mainly focused on rental aspects of real estate transactions that have been popularly provided by BaaS companies recently. The current research and BaaS services showed that there is a gap in bridging blockchain and governance for real estate transactions, specifically for FORET. Nevertheless, the flourishing services of blockchain-based GRC in building management, as well as the current research framework proved that there is a possibility of constructing a comprehensive blockchain-based GRC for a typical type of real estate transaction including FORET. A qualitative study by Kim [12] in analyzing fractional ownership in blockchain-enabled asset tokenization figured out that blockchain is expected to resolve problems of centralization, inefficiency, and information asymmetry in the innovative market. Whitaker and Kräussl proposed a conceptual framework for retained fractional equity that might potentially have broad implications for compensation of early-stage creative work in any field [26]. Graglia and Mellon [27] examined that blockchain is a novel technology in its characteristics as a social technology. It thus can be designed to govern the behaviour of groups of people through social and financial incentives. Konashevych [28] presented a concept of real estate tokenization, which includes legal, technological, and organizational aspects. The study proposed a theory of a title token which can be a basis for developing a new type of property registries. Current research on tokenization assets built on blockchain shows the possibility of employing such technology to develop a GRC framework for fractional ownership transactions, of which FORET would be a sample that has a reasonable scale to build up a pilot study.

The Decentralized Autonomous Organization as Autonomous Agent. The concept of Decentralized Autonomous Organization (DAO) was originally derived from Bitcoin, which also can be concerned as the initial prototype of DAO. The appearance of DAO has shifted GRC to a new level [11]. The DAO, which acts as the manager of smart contracts, is operated autonomously in a decentralized network architecture [10, 29]. By which, it significantly transforms the traditional ways of payment, transaction structure, ledger, protocol, ownership, and information verification into a brand-new type of governance recognition [9]. Based on DAO functions, Merkle described DAO as an entity that owns internal property that can update its internal state, is responsive to the members, and run the smart contracts [10]. These are some of the most basic functions which DAOs can perform through its organs provided by the Ethereum blockchain. Nevertheless, there are no compliance standards (like the ERC20 for tokens) for DAO. Motivated by this issue, Buterin [30] published a series of codes to program DAO that contains the assets and encodes the bylaws of smart contracts. This white paper suggested that Ethereum provides blockchain with a built-in fully-fledged Turing-complete programming language by which smart-contracts can be utilized to encode arbitrary state transition functions. However, DAO remains constraints in its technical design, typically in the security issues. Forward and Dhillon explained a DAO is a blockchain entity built on a consensus of decisions by its members which is presented in the form of DAO tokens usually [31]. There are only two entities participating in a DAO, including an executive (company) and members (smart contracts). Forward and Dhillon thus denoted DAO's significant steps in running a crowdfunding project such as setting up DAO, creating a wallet, creating stocks, assigning shares, issuing new stocks, and assigning shares to the other entity under the bylaws. Following this research stream, Norta [32] built up the electronic community of business collaborating DAOs to the point of consensually agreed upon smart contracts. The study resolved the problem of currently existing smart-contract solutions that equip the protocol layer on top of blockchains with Turing-complete programming languages by introducing the agent-based negotiation into DAO. This negotiation is a semi to fully automated negotiation. The agent-based coordinated-negotiation architecture allows conducting complex cross-organizational collaborations. Due to DAO is programmed to be an optimal system, without inefficient human negotiations where all policies were defined by program code [29], it allows investors to finance and manage new companies on the Ethereum blockchain directly.

3 Design Science Research Methodology

As DSR examines the problems through an inherent awareness of existing problems rather than by primarily an observation method for example. It generally guides the study design for the development of a new system [13, 33]. Owing to this paper seeks for the problems between participants of a FORET in order to develop a GRC system as a solution, it thus is suitable to follow DSR framework. The multi methodological approach is included to give a deeper understanding of research problems and propose solutions by the full or partial integration of more than one methodology [34]. In a real estate game, both agent and consumer are rational, thus they always try to maximize the payoffs. Hence, their strategy might change during the bargaining process depending on the actual situation. Due to the adjustable nature of strategic decisions of agent and consumer in the real estate games, it's insufficient to observe the negotiation process by only one experiment. This paper thus included the design of the experiment (DOE) approach to the DSR methodology framework. The integration of the DOE approach is to execute the experiments of three levels of games. The DOE approach propounds experimenters doing a sequence of small experiments instead of relying on one big experiment to give the answers [35, 36]. DOE emphasizes that while one big experiment might provide a valid result, it is more general to perform multiple experiments before attaining the final answer. In other words, repeatedly conduct small experiments might give more insights into the research subjects. The sequential or iterative approach of DOE thus works best as the logical move through stages of experiments. Each stage of the experiment provides insight as to how should the next experiment get done. Based on the cyclic multi-methodological approach by Nunamaker et al. [33], this paper implemented the DOE approach to construct an experimental design science research (EDSR) framework (Fig. 2).

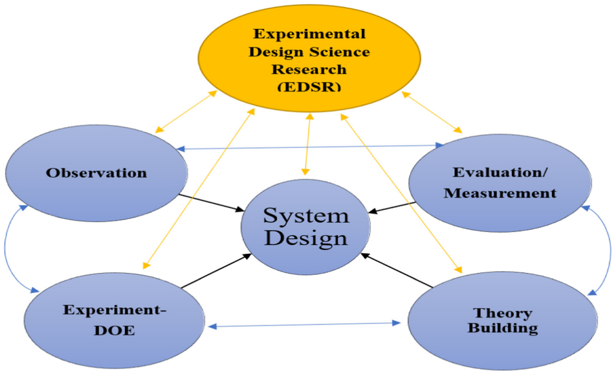

Fig. 2. The EDSR framework.

The significance of the EDSR is, by including the DOE approach, it builds up the artefacts and systems based on the results obtained through a series of small experiments. It thus can be considered as a unique approach to the DSR methodology. In the context of this research, following the EDSR framework, the strategic decisions of agent and consumer were tested repeatedly throughout game sessions. It thus can reflect comprehensively the conflicts of interests between agent and consumer with a higher reliability of test results. Hence, the choice of integrating DOE into the DSR cycle is appropriate. Anderson and Whitcomb [39] argue that the DOE is a crucial element in the success of process development and improvement. In contrast to traditional experimental methods, DOE delivers a more effective and scientific approach to achieve meaningful results. DOE thus has been widely acknowledged as a foundational work in experimental design. Up to now, DOE has been applied across research domains including information systems (IS) areas [39].

4 Conceptual Artifact

This paper focuses on conflict of interests in FORET. By proposing a blockchain-based GRC system framework, it expects to mitigate the zero-sum games between agents and consumers by implementing decentralized autonomous agents. The theoretical framework underlying the establishment of Fig. 3 revolves around agent and consumer's conflicts of interests and is a linkage of relevant studies on real estate zero-sum games from agency theory perspective. This theoretical framework established a foundation for constructing conceptual and system artefacts. The conceptual artefacts, which were constructed by using the EDSR framework, include the concept of participation dimensions in a FORET reflected in the zero-sum games between agent and consumer. These dimensions include:

- The search game – the "full" dimension. This game refers to the efforts of obtaining the entire body of information. This game reflects the principal-agent problem in the early stage of FORET.
- The bargaining game – The "equal" dimension. This game reflects the efforts to negotiate the agency costs meanwhile guarantee equal rights and responsibilities of both agent and consumer.
- The trust game – The trustful dimension. This game refers to finding the optimal "Nash equilibrium" in trust of both sides to avoid risks accompanied by violable contracts (see Fig. 3).

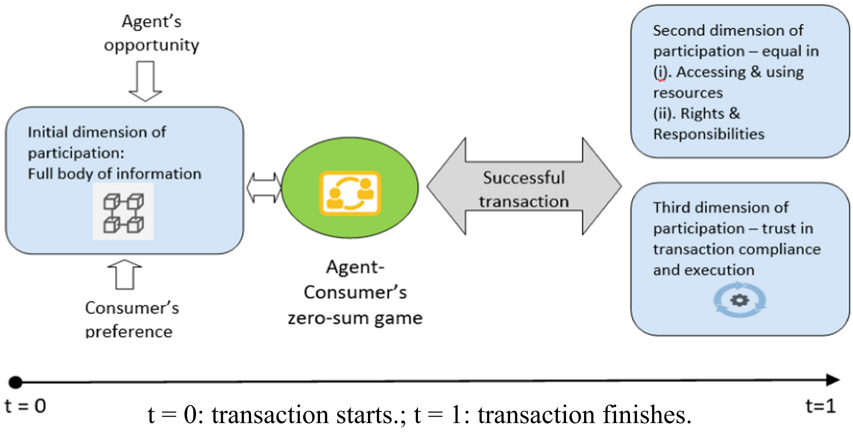

Fig. 3. Dimensions of agent-consumer's participations.

While the problems in FORET, which are zero-sum games between participants, lay on GRC framework, the blockchain technology would serve as a potential solution. The implication of agency theory approach performs as a bridge to deliver the solutions to resolve these problems. This interconnection created multidisciplinary research in the context of information systems.

5 Proof of Concept

This paper provides the proof of concept for the proposed conceptual artefacts by using the DOE approach integrated into DSR methodology to executing experiments on the oTreehub. oTree is an open-source and online platform for implementing interactive experiments in the visual laboratory. By using oTree, this paper simulates three levels of conflict of interest between agent and consumer in a FORET. The experimental factors include agent and consumer. Three levels of experiments include search game, bargaining game, and trust game.

5.1 Search Game Experimental Design

A search game is a zero-sum game with two players that occurs in a search place [37]. It can also be expanded to the business domain that contains representative dilemmas such as the principal-agent problem. In the context of this experiment, the search game is converted to become an online experimental game on the oTreehub website, for instance the Matching Pennies game. The Matching Pennies game is a zero-sum game as one's gain is the other's loss (Fig. 4). The probability of choosing "Heads" or "Tails" is distributed between players, and there is no Nash equilibrium. The asymmetric payoffs of the Matching Pennies game can represent the full dimension of participations – the whole body of information. For example, to get higher interest, the agent might have to decide whether to disclose or not the full information to the consumer and vice versa.

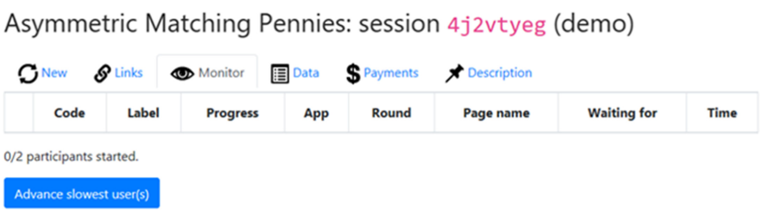

Fig. 4. Matching pennies game configuration.

The experiment has three stages each session. Each stage has four rounds. The player will be matched with another one in the room and play four rounds with the same player. After each stage, the player will be matched with a new player. In each stage, the agent will be the Row player, and the consumer will be the Column player. Both agents and consumers simultaneously choose between "Heads" and "Tails". If their choices match, the Row player (consumer) earns 0, while the Column player (agent) earns 1. If the choices mismatch, the Row player (consumer) earns 1, while the Column player (agent) earns 0. Adopting this simulation to be the principal-agent problem in the context of FORET can be denoted as below: (i) "Heads" and "Tails" can represent the strategy of agent and consumer separately for provide full information or hide part of the information, (ii) when the choices match, whether both provide complete information or conceal information, the agent earns the point for getting the transaction done. The consumer earns 0 for paying fees for a fair service, no gain no loss, (iii) when the choices mismatch, it means there is asymmetric information between agent and consumer. The agent then earns zero for failing to acquire the consumer. The consumer earns 1 for not paying fees but gains a certain amount of knowledge or experience, (iv) in the case both agent and consumer earning 0, the transaction can still be considered as complete as the consumer pays fees to gain a fair service, agents get the number of costs which is equivalent to expense without earning.

5.2 Bargaining Game Experimental Design

The bargaining game is the most popular type of principal-agent problem in a real estate transaction [14]. This experiment is designed typically for the bargaining game in the context of FORET. In this game, two players will perform the role of agent and consumer separately. They will be matched with each other to conduct bargaining over the distribution of lottery tickets. There are 100 lottery tickets that can be divided between agent and consumer. Each player's payoffs are based on the outcome of a lottery conducted at the end of the game. It will define who the winner is. Each player will be in a different lottery, and the value of cash prizes might be varied. This design is to match with the fact that even though a FORET can be established, the consumer and agent will face uncertainties after signing the agreements. This type of issue is similar to drawing a lottery at the end of the game. Nevertheless, it might not always be the result that one is the winner, and one is the loser. It might instead be that both agents and consumers win the respective lotteries, or both lose the lotteries. The likelihood of winning relied on the numbers of lottery tickets that the player has. In other words, the bigger number, the higher possibility to win. For instance, if the player has 10 tickets, the probability of winning is 0.10; if the player has 50 tickets, the probability of winning the cash prize is 0.50, and so on. Once the game begins, two players have up to five minutes to bargain with each other regarding how to divide the 100 lottery tickets. The agent and the consumer can each make an unlimited number of proposals. These proposals are in the form of: I receive [BLANK] tickets, and you receive [BLANK] tickets. The total number of proposed tickets cannot be larger than 100. Each time each player makes a proposal, the amount is showed on the other person's screen. If the player accepts the proposal at any time within five minutes, the game is successfully completed, and each player received the number of tickets as proposed. If two players cannot reach an agreement, the game is failed, and both receive zero tickets. The cash prize is distributed separately between two players with different amounts. Both players do not know the cash prize that the other person would receive if he/she wins and vice versa (Fig. 5).

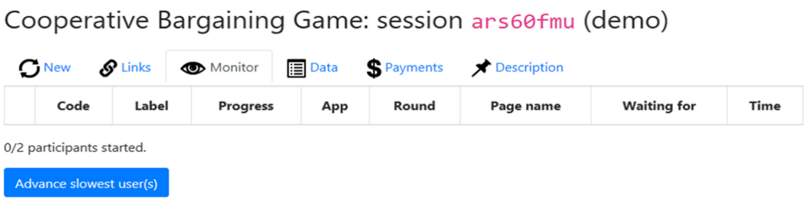

Fig. 5. Bargaining game configuration.

5.3 Trust Game Experimental Design

The Trust Game or the investment game, which was initially designed by Berg et al. is an experiment of choice to measure trust in economic decisions [36]. The concept of trust in the study by Berg et al. referred to the confidence in an economic primitive. In other words, trust is the principle of the player's interest per se in an economic transaction [38]. The conflicts of interest between agent and consumer in a trust game lay on the fact that both consumers and agents cannot completely trust each other. For example, the consumer would not entirely trust the intermediaries in sending money. On the contrary, the agent might suspect the consumer in payment compliance. In the context of real estate transactions, it might be less stressful because of the appearance of intermediaries such as the licensed lawyers, property advisers, and city councils. Nevertheless, due to the high level of human involvements, consumer and agent might still concern about the moral risks in executing a violable contract. In FORET, the problems that aggravate trust is more complicated. The factors that need to be considered include agent reputation issue, financial leverage issue, sharing space issue, legislation, and so on. For example, the consumer might use financial leverage to gain the mortgage while their actual assets and income are much lower than the criteria, or the satisfaction in sharing common space, and so on. As the players are rational, it might result in each player are not willing to take risks. Hence, the Nash equilibrium in the trust game is zero. In this experiment, the two players act separately as an agent and a consumer to play a game in perfect information condition. Each player has a project timeline and relative payoffs. The player also knows the other player's project timeline and payoffs. Based on the information each player has, they need to decide which period they want to launch their project (Fig. 6).

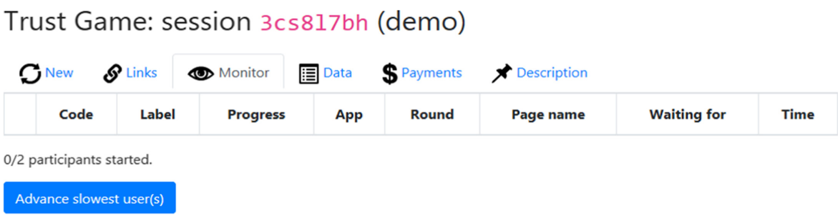

Fig. 6. Trust game configuration.

The period is distributed from 0 to 20, with the relative payoff counts from 0% to 100%. Each player's decision will reflect their trust in the information they have, that is, trust or not the data of project timeline and payoffs that was provided by another player. This experiment is set up with the purpose to represent the trust issues of both players.

5.4 Execution

The experiments were conducted by the participations of two players at two separate locations. The players cannot interact with each other during the experiments. The experiment executor was responsible for results recording and coding. Total time of experiments: three to four hours for running five sessions of each game. Device: PC/laptop, internet protocols. Platform: cloud, oTreehub. Instruction: oTreehub.-com → public project → game theory_sim; trustgame1.

5.5 Findings

Data collected from the experiments showed that the results are consistent with proposed conceptual artefacts. The game scores after five sessions of the experiment suggested that: (i) it was difficult to have a match in the search game. For instance, in the matching pennies game the change of payoffs led to changes in the optimal strategy of the two players. When both players chose "Heads", the consumer receives maximum payoffs of only 0.5. The agent then has a more significant advantage when choosing more "Heads" while the consumer tended to choose "Tails" (see Fig. 7 and Table 1).

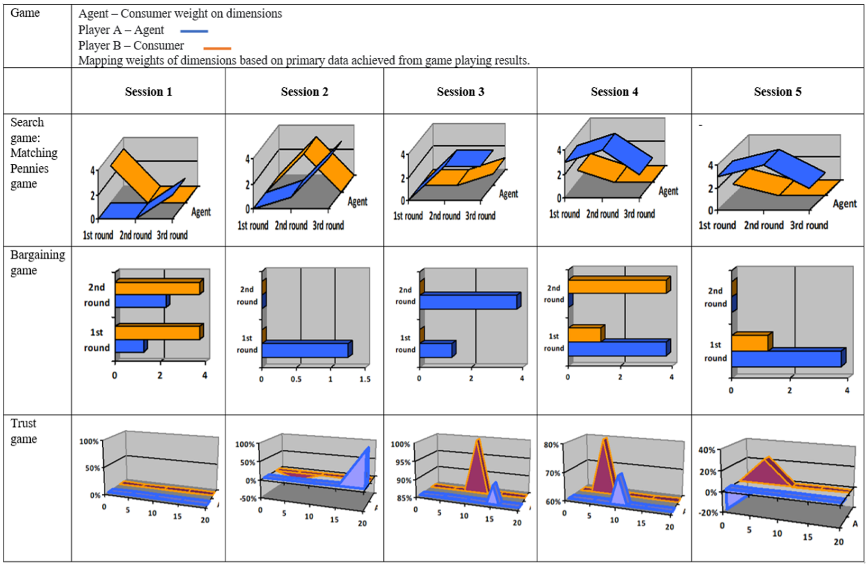

Fig. 7. Game scoring throughout five sessions

(ii). The bargaining game and trust game were hard to achieve a Nash equilibrium, which was the optimal situation for both agent and consumer. In the bargaining game, the number of proposals the players offered to each other throughout five sessions sequentially as 5, 18, 9, 8, 9, to gain the proportions of tickets. However, even with more tickets, the game might still have 0 payoffs for both players (see results of sessions 2 and 3 of bargaining game), (iii) in the trust game, both players showed a divergence in trust in each other. Both the agent and the consumer tried to be the winner, seeking maximum benefits throughout the sessions, resulted in failing in getting payoffs (see results of session 1).

The total number of choices in search games for each player throughout five sessions was calculated as 4 stages $\times 3$ rounds $\times 5$ sessions = 60 times. The results of three games, which represent the tendency of three dimensions of full, equal, and trust, are presented in Fig. 8. The results of each dimension in each session were calculated as population mean (expected value) of its stages' scores using formula 1.

$$\mu = \frac{\sum_{i=1}^{N} x_i}{N} \tag{1}$$

In the formula 1, x_i is the session of the game, with i value from 1 to 5. N is the number of stages in the game session that the players played. This calculation represents the central tendency of the dimensions.

Table 1. "Heads" and "Tails" in matching pennies game

	Heads	Tails	Total
Row	22	38	60
Column	45	15	60

The final scoring is a measurement of central tendency of each dimension. Agent-consumer's game scoring was different in three dimensions of full, equal, and trust throughout five sessions (S1 to S5). It shows a divergence and fluctuated tendency of the full, equal, and trustful participations between agent and consumer even in the same game. These results are reasonable to lead to further tests using DOE in a larger sample scale (minimum 30 samples) for the quantitative analysis that was mentioned in the methodology section.

6 System Artifact

To mitigate the conflicts of interest between agent and consumer, which was reflected on the above experiments, a novel blockchain-based GRC framework for FORET is proposed herein. The system framework includes three layers, i.e., user/service, database, and governance. The system employs both private blockchain and consortium blockchain from a BaaS provider to construct the decentralized apps (dApps) and the DAO. In the BaaS blockchain, users can access the virtual table to verify data and

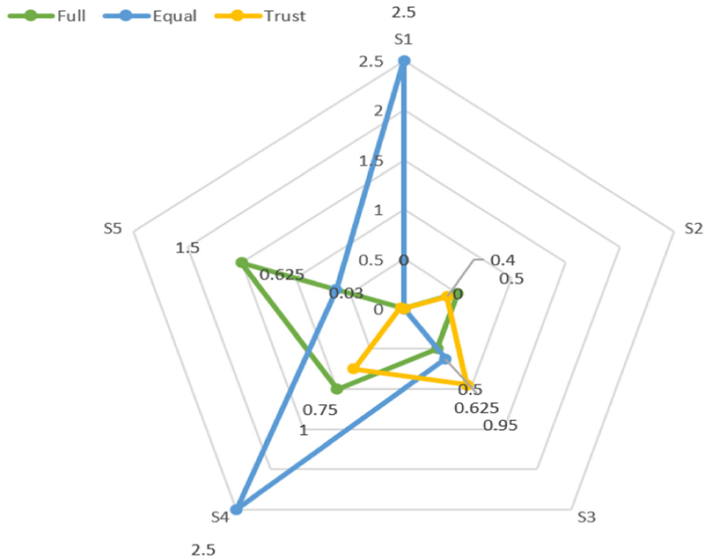

Fig. 8. Final scoring.

integrate it to multichain. In this system, token performs as a tool for verification rather than for trading purposes. The system will then transfer transaction records to a BaaS cloud platform and integrate them into BaaS blockchain via a service adapter.

Moreover, the decentralized verification mechanism of this system could be integrated into executive processes of FORET. The distributed governance framework allows participants to validate the transaction, manage the contract processes, and conduct the real-time audit. This design enables the DAO to govern smart contracts and execute FORET within peer-reviewed, transparent, and secured settings. By which, we expect this blockchain-based GRC system to empower the controlled user group and reduce the conflicts of interest between participants.

7 Discussion and Evaluation Plan

As blockchain is an emerging technology that has sparked arguments over its effectiveness, security, and legislation [11, 19, 26], the blockchain-based system artifact proposed in this paper is in the initial design phase. In future research, a qualitative analysis will be carried out using a case study to examine the systematic concepts at the early stage of the experiments. Additionally, for a more effective evaluation, a quantitative measurement with a sample size of 40 to 50 players will be carried on. This would support more sequential interactive experiments between games, thus might provide deeper insights. Furthermore, an accomplished dApps will be built up alongside this design using blockchain services offered by BaaS firms such as SAP or Microsoft Azure. In terms of the validation plan, the system artefacts will be validated using DSR guidelines of evaluation [13, 33]. In particular, field study, testing, and description methods will be implemented. The field study will provide a full range of experiments and simulations to discover facts, test hypotheses, and demonstrate findings. The prototype can be deployed and obtain feedbacks within six months. Meanwhile, testing methods such as Black box, White box, and Grey box would be practical tools to validate the solution. The description method will allow the artefacts to be evaluated based on existing knowledge obtained through reviews of experts such as Property experts/managers, Lawyers, IS experts, Banking experts. Solutions to improve DAO security will also be taken into consideration when constructing the prototype in the future. The proposed system will also be developed and generalized to apply to other types of fractional ownership transactions rather than FORET (Fig. 9).

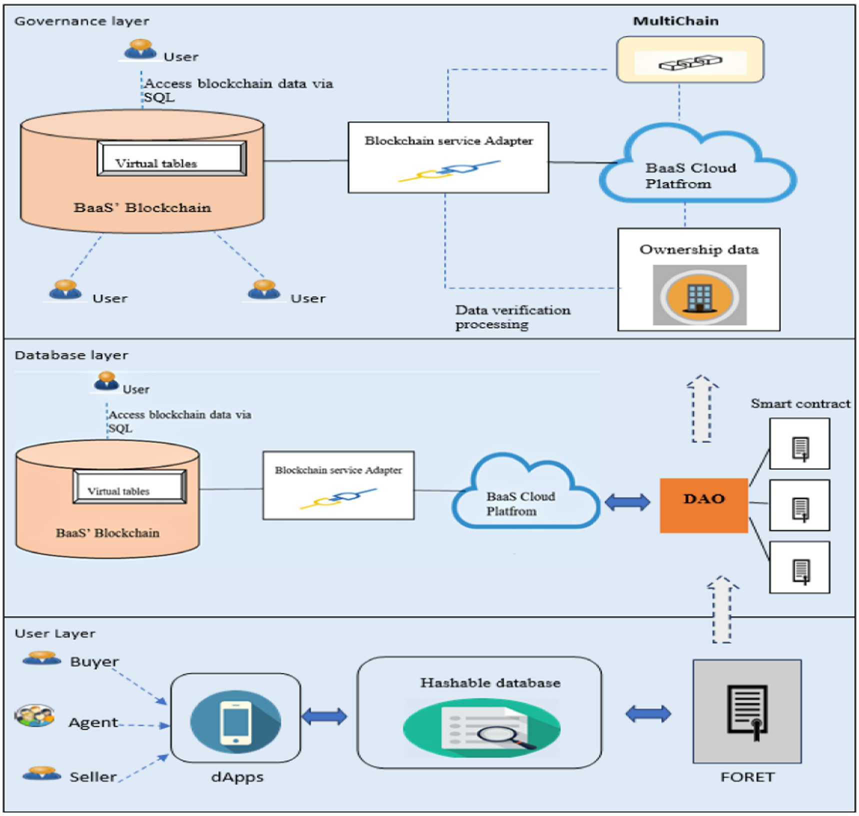

Fig. 9. Blockchain-based GRC System framework.

8 Conclusion

This study is a discovery of the principal-agent problem in FORET under the lens of zero-sum games. The principal-agent problem in FORET has raised concerns of compliance management as well as transparency of transaction execution. From the agency theory perspective, these conflicts of interest in FORET involve the agency costs, principal-agent problem, and risks accompanied by violable contracts. The experiment results showed that it is difficult to have a match in providing a full body of information between agent and consumer, the trust between agent and consumer is divergence, and the Nash equilibrium, which stands for the optimal situation for both two players, is hard to achieve. To mitigate these conflict of interests, this study uses DSR methodology along with the agency theory to propose a systematic design of a framework built on blockchain technology. The purpose is to mitigate the agent-consumer problems in FORET. In future research, a prototype of the framework will be built up alongside this design using blockchain technology. This blockchain-based architecture can be integrated into the executive processes of FORET. It works as a decentralized governance center allowing participants to conduct the transaction, contract executions, and real-time audit. This system can be employed but not restricted to FORET. It is expected to mitigate the conflicts of interest and assist the transaction participants in avoiding various operational risks. The research artefacts of this study would potentially be generalized in terms of offering a decentralized governance mechanism to other types of fractional ownership transactions.

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