A blockchain-based solution to improve real estate transactions

***Abstract*—The process of buying and selling properties is widely recognised to be complex, difficult to navigate and opaque. In this paper, we analyse the real estate transaction process, focusing on the due diligence phase. We propose a blockchain-based solution to expedite the real estate transaction process and make it more transparent. Although the solution is thought for EU countries and the UK, it can be applied to multiple jurisdictions as the focus is bringing transparency in the process. The solution creates a system where buyers and sellers can access reliable information upfront before embarking on the transaction process. Experts can also assess the accuracy and completeness of documentation. By performing cosmetic changes, the solution can be adapted to multiple jurisdictions.**

I. Introduction

Real estate is a unique, complex and one of the largest industries in the world, and it has always played a vital role in economies globally. Institutional investors such as pension funds, insurance companies and endowments allocate a significant part of their capital to alternative assets, including real estate [1]. However, the real estate industry is known to resist change and is seemingly allergic to adopting new technology [2]. The real estate transaction process is inherently outdated, complex, and fragmented. It is highly time-consuming and represents a considerable financial burden for both buyers and sellers, given the annual incidence of more than a quarter of house sales falling through. Real estate transactions face the challenge of information inefficiencies and, consequentially, high transaction costs.

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A. Transaction process

Real estate transactions face the challenge of information inefficiencies and, consequentially, high transaction costs. The time taken to complete the purchase of a real estate asset is crucial for investors as they see liquidity as a key factor when choosing where to invest. Liquidity can be defined as "the ability of an investor to trade assets into a cash form or vice versa. It is used more loosely to describe the speed and/or volume of transacting in a given market." [3]. The ability to enter and exit real estate markets is constrained by the time transaction taken and the challenge of matching buyers and sellers with appropriate assets at appropriate prices. For buyers and sellers, this generates significant opportunity costs if investment or disinvestment is delayed. Nearly all market participants would cite low liquidity as a (problematic) characteristic of commercial property as an asset class [4]. The time taken by a transaction, together with uncertain prices and changes to prices over the transaction period, constrains the ability to enter and exit property markets at specific times. Time to transact has important implications for risk and return. A delay to realise the capital value will result in a reduction in the total return. Uncertainty about the timing of receipt of capital value adds to the volatility of expected returns, with long delays being associated with increased uncertainty. Low liquidity has two associated implications: firstly, the time required to actualize the market value of an asset increases, and secondly, there exists a potential risk for the market price to fluctuate during the interval between the decision to sell and the execution of the sale [5]. Thus, the actual return may differ from the expected. A prospective vendor in the real estate market encounters ambiguity regarding the accurate valuation of the asset, uncertainty regarding potential purchasers, and uncertainty regarding the probable date of sale. These supplementary facets of uncertainty may not be entirely captured in retrospective evaluations of property market performance. [4].

The lengthier the sale period, the more likely that market conditions will change, and the investor is less certain about the cash flow[5]. There are a number of dimensions of liquidity, including:

1) the rate of turnover/transactions and the time taken to transact
2) the costs associated with transacting (both formal costs – buy or sell fees – and information costs)
3) the impact of the decision to transact on the price of the asset and the prices of similar assets
4) uncertainty as to the achieved price or return at the time of the decision to transact

B. Causes of delay

Studies [6] have undertaken a structured investigation of the most important causes for delay in commercial real estate transactions. Through interviews conducted among commercial real estate experts, it emerges that the process map for a transaction is constituted of 150 individual steps and several actors were involved. Steps were grouped into five major stages such as (1) the preparation, (2) marketing (required to establish an asking price of a property), (3) the due diligence period, (4) the post-exchange period and (5)

post-completion period when the land registry collects taxes and records the legal ownership. Results show that in the current paper-based system, transactions are often delayed, and the time taken runs beyond expectations. In the UK, delays are found to occur in close to 40% of all transactions [7]. The study found that, in summary, a lack of an up-to-date single pool of standardised property information seems to be the most critical cause for delay. Going into more detail, seven major causes for delay were identified with reference to the stages of the transaction process.

II. Blockchain-based solution to reduce the time taken

During the past few years, blockchain has raised interest because of the significant potential innovation could bring into the real estate industry by improving efficiency, transparency and trust.[2]. A blockchain system is attractive because it could reduce the total transaction time to complete a sale [8]) by automating the entire transaction process, as it can assist with the organisation and data management of access control, distribution and validation of information. The combination of blockchain technology and smart contracts has the potential to significantly reduce the time and costs of real estate transactions by eliminating intermediaries, as the mutual trust in third parties can be replaced with an automated process, where a computerised trading protocol is designed to enforce the contract. Thanks to these new technologies, contracts can be embedded in digital code and stored in transparent, shared databases, where they are protected from deletion, tampering, and revision. Multiple intermediaries that in the current process contribute to increasing the transaction costs might no longer be necessary [9].

Among the multiple ways in which blockchain can help improve the real estate transaction process, we focus on how this technology can help reduce the time taken in the due diligence phase. Significant evidence shows that lack of information upfront, lack of transparency and lengthiness of the overall process are key issues in real estate transactions. The analysis undertaken shows that the time taken for searches is paramount, and it is often a primary cause of delays. The use of blockchain technology applied to real estate transactions can enhance transparency, reduce lengthiness and improve the overall transaction process.

A. Choosing the software language

Real estate transactions are heavily regulated, and there are strict laws and regulations regarding data security and privacy. The project is developed in Daml (Digital Asset Modelling Language) an open-source language which has the appropriate characteristics to develop legal smart contracts. Daml is developed by Digital Asset, providing a development framework for creating complex and multi-purpose business applications that require sophisticated workflows and smart contracts. It has an abstract ledger on which an application can be developed and then integrated with various blockchain platforms, like Hyperledger Sawtooth, Hyperledger Fabric, Corda, etc. The language is developed using Scala, and its compiler is written in Haskell programming language. [10]. The language allows the assigning of fine-grained permissions and different roles to users, distinguishing between parties who can only access the ledger data and parties actively performing actions (e.g., submit or sign transactions)[11]. By default, in Daml, it is possible to create three pre-defined types of parties with different privileges: (i) signatory, (ii) controller, or (iii) observer parties. A signatory can propose an action and sign and submit contracts to the ledger. The controller is the counterparty, who can perform actions (e.g., accept or deny) on a proposal made by the signatory. Finally, the observer is a witness (e.g., regulator, auditor) with no controlling abilities, possessing only visibility and access to transactions and data. [11]. The language has a built-in feature for testing the functionalities of prototypes by creating so-called scenarios specifying different actions performed by the parties, creating contracts and simulating real-world business applications. The platform maintains a comprehensive record of transactions and modification history by creating a new contract for all changes and updates to existing contracts. The previous version is archived and remains visible on the ledger as an archived contract. This process ensures that the entire history of modifications and transactions is permanently stored and readily available on the platform. There are multiple Daml use cases in the industry. In 2021, the BIS Innovation Hub launched a project in collaboration with the Hong Kong Monetary Authority (HKMA), to improve efficiencies in the distribution of green bonds and to facilitate more insightful reporting on the environmental impact of green bond proceeds [12]. In 2021, Deutsche Börse, a financial market infrastructure provider, chose Daml to develop its new fully digital post-trade platform, D7. The recently launched cloud-based platform, designed to integrate with Distributed Ledger Technology, facilitates effortless automation of same-day issuance while eliminating the requirement for paper-based procedures. It streamlines and automates the entire lifecycle of digital securities, including issuance, custody, settlement, and asset servicing.[13]. In 2023, Goldman Sachs announced the bank has a new digital asset platform, GS DAP. The platform is built on top of Digital Asset's smart contract language, Daml, and Canton, a blockchain with privacy features. Tokenization platforms built using Daml have the ability to capture the complete intricacies of asset lifecycles, encompassing rights, obligations, and cash flows. Digital Asset's privacy protocols ensure that data is only shared with authorized stakeholders while also supporting the scalability required to enable global asset connectivity.[14]

B. A blockchain-based solution to improve real estate transactions. How it works

The proposed solution aims to improve real estate transactions by reducing the time taken by the due diligence process. In most countries, real estate transactions rely on

qualified professionals such as notaries or solicitors to ensure the asset documentation is accurate and truthful. However, searches need to be repeated for every sale, even if there are no factual changes or if the same asset is resold in a short time. The reason for this is that once documents are downloaded from official websites or collected from the offices, it is not possible to ensure that they have not been altered in any way or they are truthful and complete. The impossibility of relying on the existing documents causes duplication of searches and additional work with significant cost and time increase.

The proposed solution relies on blockchain technology to ensure documents are stored correctly and on the legal role of professionals guaranteed by law. While blockchains are well-suited for transferring assets or data that is intrinsic to the blockchain, their ability to assess the accuracy of externally-entered data is limited. In essence, the veracity of the ledger's contents is a distinct matter, as a blockchain does not inherently confer trustworthiness upon the data entered, nor the parties entering it [15]. This observation aligns with the principle of "garbage in, garbage out" (GIGO), meaning that input ambiguity should be assumed as a given. Inaccurate input is treated by a blockchain in the same manner as any other input, whereby it is hashed and recorded as a mere hash value within the blocks. The blockchain solely ensures that the data remains unchanged. For this reason, in the proposed solution, actions such as uploading and updating documents are only performed by qualified professionals who are binded by law to be truthful and act with integrity. Because the reliability of data is paramount, the solution implements an additional check performed by other professionals to assess the accuracy and completeness of the documents. Through a scoring system, professionals can be invited to review the documents and assign a score.

Key characteristics of the project:

- it focuses on the transaction time, aiming to reduce the time taken for searches and improve transparency.
- to ensure privacy and compliance with the regulations regarding property transactions. The system is based on a private blockchain whose nodes are trusted solicitors and/or public institutions.
- it proposes a solution to provide buyers and sellers with more information upfront by collecting assets' documentation, thus reducing transaction failure.
- to ensure the truthfulness of information, all documents are uploaded to the blockchain by qualified professionals.
- it creates a scoring system performed by qualified professionals to assess the accuracy and completeness of assets' documentation.

The figure1 provides an overview of the structure of the solution proposed. With the asset owner's permission, qualified professionals collect asset information and documents and upload the asset's package into the blockchain through a user interface. Professionals can also update, consult and download

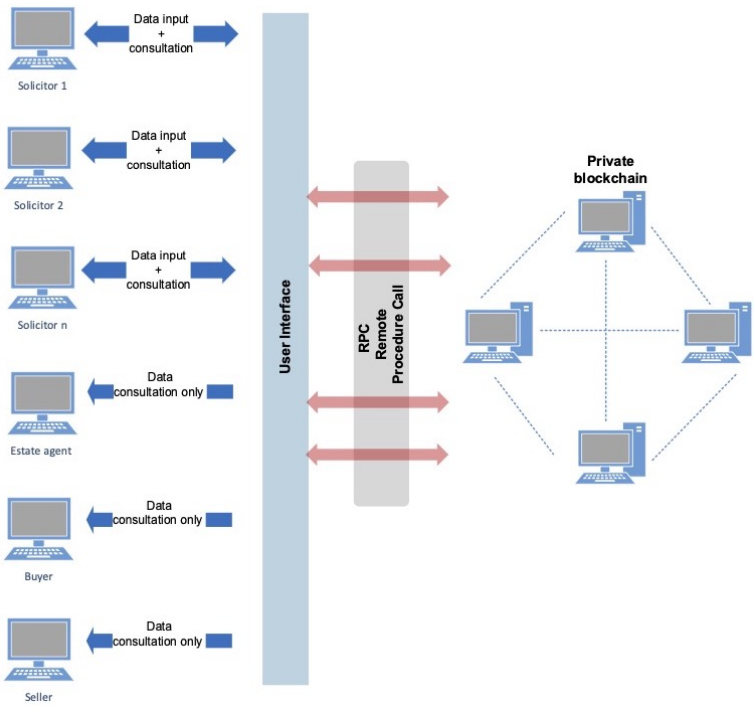

Fig. 1. Structure of the system.

documentation. The asset owner can also give permission to estate agents and potential buyers to view and download documentation. To ensure the truthfulness of information, only qualified professionals are allowed to upload and modify documents in the ledger. Thanks to the private blockchain, documents are uploaded and stored securely. Upon request, documents are retrieved from the ledger through a Remote Process Call (RPC). RPC is a communication protocol that facilitates the invocation of a procedure or subroutine located on a remote system over a network. This allows a program to execute a service provided by another program, even when they are geographically distributed and operate on different networks. In this protocol, the caller is not required to have any knowledge of the underlying network details or physical location of the callee. Therefore, RPC enables transparent communication between distributed programs, which can collaborate and work together as if they were running on the same system.

Figure2 and 3 represent the diagram to create a smart contract to upload the property documentation to the ledger.

1) Smart contract - Asset. The asset is created by the solicitor. The asset schedule contains all relevant information, such as the address of the property, description, and list of documents, a link to the list of documents. If required, it can also contain a list of valuables contained in the property, which may be an interesting option in case of sales through auctions. The schedule includes the

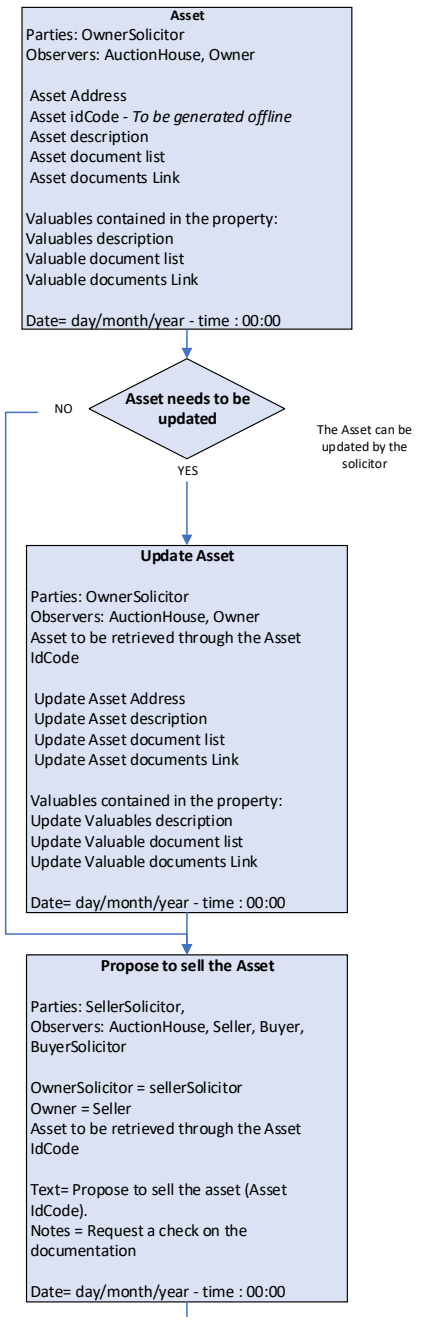

Fig. 2. Create Asset and Propose to sell.

relevant parties involved (solicitors, auction houses or estate agents, buyer and seller) and the time when the asset was created. Each asset can be retrieved through a unique ID Code, which identifies the asset and allows parties to refer univocally to a specific property, even when changes occur and are archived through multiple smart contracts.

2) Smart contract - Update Asset. The Update Asset smart contract allows the solicitor to update and make changes to the documentation.
3) Smart contract - Propose to sell the asset. This smart contract allows the current owner to propose the asset to a potential buyer. Even though authorised solicitors are the only ones who are allowed to operate and interact with the ledger, other parties can be invited as observers, such as the auction house, the estate agent (depending on the type of sale), the buyer, seller, and buyer's solicitor. The smart contract also allows notes and text for the parties to formalise the proposal and interact with each other.
4) Smart contract - Review proposal. This smart contract allows the buyer's solicitor to assess the offer and give feedback on the documentation.
5) Smart contract - Accept/Reject proposal. These smart contracts allow to accept or reject the proposal. If the documentation is incomplete or considered not satisfactory by the buyer, the seller's solicitor has the option to update the asset documentation and provide the clarification required through the smart contract "update Asset".
6) Smart contract - Sell asset. If the proposal is accepted, the seller's solicitor formalises the proposal to sell. The sale can happen offline (as per the usual process) or through an online auction. However, the sale of the asset is outside the scope of this project.

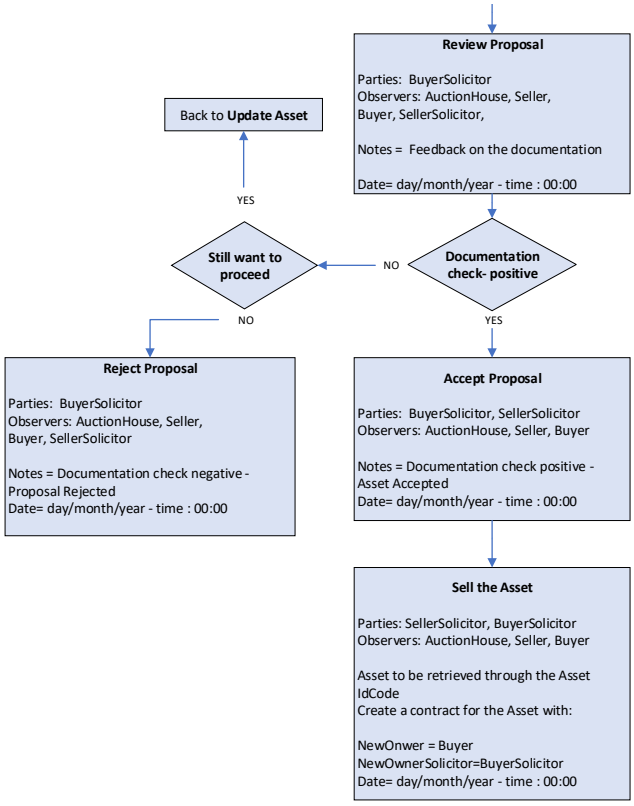

Fig. 3. Review Proposal and sell Asset.

The diagram in figure 4 represents the diagram to create a smart contract to score the accuracy and completeness of the

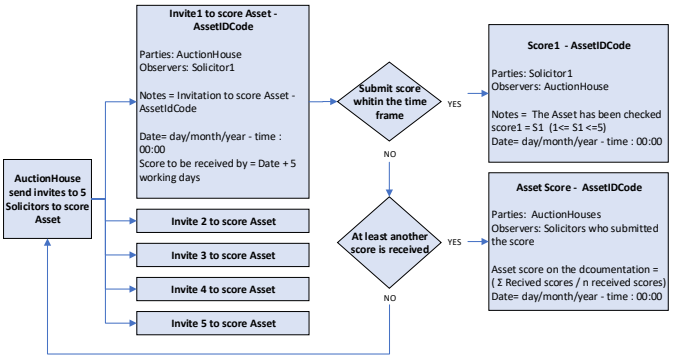

Fig. 4. Asset scoring system.

documentation.

1) Smart contract - Invite to score Asset. A smart contract is created to send an invite to selected solicitors to assess the completeness and accuracy of the property.
2) Smart contract - Score. Solicitors assess the documentation and input the score in the system. The asset is univocally identified through the ID Code. The score is between 0 and 5, with 0 being the lowest score. The smart contract allows solicitors to input a comment. The time and date of the score are recorded. If the solicitor doesn't reply in a given time frame, the invite to score the asset is assumed as rejected and sent to another solicitor amongst the selected ones.
3) Smart contract - Asset Score. If at least one score is received, a smart contract is created with the score of the asset. The overall score is calculated as an average of the score received. The time and date of the overall score are recorded.

C. Technological solution. Extract of the code

The code in figure 5,6,7 shows how to create an asset and make changes and updates using the Daml language. The asset is identified through the IdCode, and the function `FetchbyKey` ensures that the asset can be retrieved from the ledger even if changes and modifications occur. The solicitor is the Party who actually operates on the ledger, while the Auction House (or the estate agent) are invited as an observer.

The code in figure 8, 9,10, 11 shows how to make the proposal to sell the asset using Daml language. The owner solicitor creates a proposal to sell the asset, and the seller solicitor, the auction house or the estate agent and the seller are invited as observers. If the proposal is accepted, a contract is created to formalise the proposal.

The code in figure 12 shows how the scoring system is created using Daml language. Daml language allows inviting selected solicitors to score and create a contract with the asset score in a single template. To avoid double voting, solicitors who have already voted are removed automatically from the voting list.

```
module Asset where

type AssetId = ContractId Asset

template Asset
  with

    ownerSolicitor : Party
    owner : Party
    auctionHouse :Party --also makes sure that all parties are legit
    address :Text
    idCode: Text --To check how to create an asset ID. To be generated offline
    a_description : Text
    a_documents : [Text]
    a_docLink : Text --to be reviwed to create a link to the documents
    v_description : Text
    v_documents : [Text]
    v_docLink : Text --to be reviwed to create a link to the documents
    date: Time

  where
    signatory ownerSolicitor
    observer owner,auctionHouse

    key (ownerSolicitor, idCode) : (Party, Text)
    maintainer key._1
```

Fig. 5. The code creates an Asset and defines the Parties involved.

```
choice UpdateAsset
  : ContractId Asset
  with

        updated_address :Text
        updated_a_description : Text
        updated_a_documents : [Text]
        updated_a_docLink : Text
        updated_v_description : Text
        updated_v_documents : [Text]
        updated_v_docLink : Text
        updated_date:Time

  controller ownerSolicitor
    do
        create this with

          address = updated_address
          a_description = updated_a_description
          a_documents = a_documents ++ updated_a_documents
          a_docLink = updated_a_docLink
          v_description = updated_v_description
          v_documents = v_documents ++ updated_v_documents
          v_docLink = updated_v_docLink
          date = updated_date
```

Fig. 6. The Choice allows parties (Controllers) to update the Asset if needed.

Figure 13 shows the test scenario. Daml language allows testing the code by creating a hypothetical scenario. Parties are defined at the beginning of the test, and different cases are tested, such as "create asset", "update asset", "create and submit Proposal", "reject proposal', "score the documentation". The code compiles correctly, and The scenario above produces the following script result. As we can see, the simulated ledger

```
template AssetHelper
    with
      caller : Party
  where
    signatory caller

    choice GetAssetByIdCode : (AssetId, Asset)
        with
          idCode : Text
        controller caller
        do
          fetchByKey @Asset (caller, idCode)
```

Fig. 7. FetchByKey function allows parties to retrieve the Asset from the ledger.

```
module SellAsset where

import Asset

import DA.Time (time)

type AssetProposalId = ContractId AssetProposal
type AssetContractId = ContractId AssetContract

template AssetProposal
    with
        idCode : Text
        proposerOwnerSolicitor:Party
        proposerOwner:Party
        notes: Text
        date: Time
        ownerSolicitor: Party
        owner :Party
        auctionHouse: Party

    where
        signatory ownerSolicitor
        observer owner, proposerOwner, auctionHouse, proposerOwnerSolicitor

        key (ownerSolicitor, idCode) : (Party, Text)
        maintainer key._1

-- What the seller can do (through the Owner Solicitor)
```

Fig. 8. The code shows how to make a proposal to sell the Asset.

```
-- What the seller can do (through the Owner Solicitor)

-- Propose to sell the asset
        choice MakeAssetContractOffer
            : AssetProposalId
            with
                assetproposal : Text
            controller ownerSolicitor --buyer sends feedback to owner solicitor
            do create this

--revise the offer
        choice ReviseAssetContractOffer
            : AssetProposalId
            with
                offerRevison :Text
            controller proposerOwnerSolicitor
            do create this with
                notes = offerRevison
```

Fig. 9. Option for the Seller.

retrieves the asset through the Asset ID code and performs the prescribed operations. The system also shows who is allowed to see actions and operate on the ledger.

The project shows how blockchain technology can help improve real estate transactions by tackling the time taken by

```
-- What the buyer can do (through the New Owner Solicitor)

--reject the offer
        choice RejectAssetContractOffer
            :  AssetProposalId
            with
                feedback : Text
            controller proposerOwnerSolicitor
            do create this with
                notes = feedback

---accept the offer
        choice AcceptAssetProposal
            : AssetContractId
            controller proposerOwnerSolicitor
            do
                create AssetContract with
                    idCodeAsset = idCode
                    buyer =  proposerOwner
                    seller = owner
                    buyerSolicitor = proposerOwnerSolicitor
                    sellerSolicitor = ownerSolicitor
                    contractNotes = notes
                    contractDate = date
                    auctionHouseInContract = auctionHouse
```

Fig. 10. Options for the Buyer.

```
template AssetContract
    with
        idCodeAsset: Text
        buyer : Party
        seller: Party
        buyerSolicitor : Party
        sellerSolicitor : Party
        contractNotes : Text
        contractDate : Time
        auctionHouseInContract :Party

    where
        signatory buyerSolicitor, sellerSolicitor
        observer buyer, seller, auctionHouseInContract

        key (sellerSolicitor, idCodeAsset) : (Party, Text)
        maintainer key._1
```

Fig. 11. Reject or Accept the Asset Proposal.

searches and the lack of transparency and upfront information. The accuracy of information uploaded to the ledger is ensured by the solicitors or other qualified professionals who drive the real estate transaction process and are responsible and accountable for the accuracy and truthfulness. All relevant documents of a property are safely stored in the ledger and can be retrieved upon request to provide the seller with upfront information, even before they embark on the process. Providing information upfront enhances transparency and can speed up the property buying and selling process as it helps buyers to make informed decisions and saves time for the sellers to avoid

```
module Scoring where

import Daml.Script
import DA.Set as Set
import DA.Action
import DA.List

template Score
  with
    assetidCode: Text
    scoreCalculator: Party
    calculatedScore: Decimal
    scoreVoters: Set Party
    alreadyVoted: Set Party

  where
    signatory  scoreCalculator
    observer scoreVoters

    ensure (intersection scoreVoters alreadyVoted == Set.empty) &&
      (alreadyVoted /= Set.empty || calculatedScore == 0.0)

    choice Score_Vote: ContractId Score
      with
        scoreVoter: Party
        score: Int

      controller scoreVoter
      do
        assertMsg "The score must be an integer between 1 & 5" $
          (score>=1 && score<=5)
        assertMsg "The voter is not on the list of allowed voters" $
          (Set.member scoreVoter scoreVoters)
        create this with
          calculatedScore = (intToDecimal score + calculatedScore * intToDecimal (size a
            / (intToDecimal (size alreadyVoted) + 1.0)
          scoreVoters = Set.delete scoreVoter scoreVoters
          alreadyVoted = Set.insert scoreVoter alreadyVoted
```

Fig. 12. The code shows how to create a scoring system to assess the completeness and accuracy of the asset documentation.

Asset:Asset

id	status	ownerSolicitor	owner	auctionHouse	address	idCode	a_description	a_documents	a_docLink	v_description	v_documents	v_docLink	date	CCS	Caristy	Claudia
#7:1	active	'CCS'	'Claudia'	'Caristy'	"Mulholland Drive 135"	"XX2325XXX"	"Villa by the sea with a wonderful view"	["VillaDoc1", "VillaDoc2", "VillaDoc3", "VillaDoc4", "VillaDoc5", "Villa6", "VillaDoc4", "VillaDoc5", "Villa6", "Plan 1st Floor"]	"http://villaDocumetsLocation_Updated"	"Klimt Portrait of Adele Bloch-Bauer and Le Moulin de la Galette -Renoir"	["KlimtDoc1", "KlimtDoc2", "KlimtDoc3", "Renoir1", "Renoir2", "Renoir3", "Renoir1", "Renoir2", "Renoir3"]	"http://valuableDocumentsLocation_updated"	1970-01-01T00:00:00Z	X	X	X

Scoring:Score

id	status	assetidCode	scoreCalculator	calculatedScore	scoreVoters.map	alreadyVoted.map	Score Calculator
#15:1	active	"XXX"	'Score Calculator'	3.0000000000	GenMap[]	GenMap['Party1'->(), 'Party2'->(), 'Party3'->(), 'Party4'->(), 'Party5'->()]	
						'Party1'	-
						'Party2'	-
						'Party3'	-
						'Party4'	-
						'Party5'	X

SellAsset:AssetContract

id	status	idCodeAsset	buyer	seller	buyerSolicitor	sellerSolicitor	contractNotes	contractDate	auctionHouseInContract	CCS	Caristy	Claudia	Misskin	Silvia
#9:1	active	"XX2325XXX"	'Silvia'	'Claudia'	'Misskin'	'CCS'	"The plan of the first floor is missing. Please update the documentation"	1970-01-01T00:00:00Z	'Caristy'	X	X	X	X	X

Fig. 13. Daml Scrip resulting from the test scenario.

time waste due to transaction failure. Providing information at an early stage can also encourage good practices, such as the stipulation between parties of a formal commitment to buy/sell (preliminary agreement) as recommended by professional bodies and institutions such as RICS (Royal Institute of Chartered Surveyors). This would avoid a phenomenon called ”gazumping”, which occurs when a seller initially agrees to sell a property to a particular buyer but subsequently accepts a higher offer from a different buyer prior to formal contract execution. Gazumping may be driven by factors such as the seller’s pursuit of greater financial gain, a preference for a swifter transaction, or unforeseen obstacles encountered by the original buyer, such as financing difficulties. Gazumping has generally negative consequences for the original buyer such as frustration, as well as financial loss associated with sunk costs. Additionally, this practice can contribute to decreased trust and instability in the housing market. It is worth highlighting that a formal commitment at an early stage is only possible if the buyer is provided with all relevant information about the property. Another advantage of the proposed system is the scoring mechanism, where qualified solicitors are invited to assess the completeness and accuracy of the documentation provided. Solicitors can be selected manually or through a random selection amongst a pool of qualified solicitors. A random selection would improve the reliability of the system even further, as there would not be any connection between the actors of a particular sale and the pool of solicitors who provide the documentation score. To encourage participation,

solicitors could be rewarded for providing the score with perks or tokens from the platform. However, the random selection of solicitors and rewarding mechanisms are outside this project's scope.

III. Challenges and limitations

Although blockchain technology shows potential to enhance the effectiveness and safeguard the authenticity of real estate transactions, there remain technical obstacles that need to be overcome to ensure the widespread adoption of the technology in the real estate industry. Real estate assets have unique characteristics that distinguish them from equities and bonds due to factors such as high transaction costs, prolonged holding periods, rigorous regulatory oversight, and entry barriers. [2]. The transaction process is dominated by professional consultants who have a vested interest in preserving their income streams, resulting in chartered surveyors, brokers, and lawyers potentially resisting technological innovations that aim to disrupt their work.[16].

The real estate industry generates a significant amount of data, including property listings, transactions, and legal documents. There are different types of blockchain networks based on their features regarding the level of decentralization, scalability and security. In this study, we assumed work on a consortium blockchain in a permission-based blockchain network format, developed using Daml language to show the feasibility of blockchain technology as an infrastructure for improving real estate transactions. In this type of blockchain network, a selected set of nodes make the consensus determination, and the efficiency and scalability of the network are higher than the public ones. However, the tradeoff is a lower level of security compared to a completely public blockchain such as Bitcoin [17]. A significant degree of storage and processing power is essential in a public blockchain network, given that the verification of a new block necessitates all previous transactions to be presented. However, permission-based and consortium blockchains such as Hyperledger Fabric do not impose such a burden on the network as they are more efficient and have better scalability [17].

Blockchain technology is still in its early stages of development, and there is currently a lack of standardization and interoperability between different blockchain platforms. This can create challenges when attempting to integrate blockchain into existing real estate systems and platforms. Additionally, despite the inherent security features designed into blockchain technology, apprehensions persist regarding possible security breaches and hacking. Given the sensitive nature of real estate transactions, which entail the exchange of confidential financial and personal information, ensuring security becomes a pivotal concern in the adoption of blockchain within the industry. Furthermore, the adoption of blockchain technology in the real estate industry may entail a considerable degree of technical know-how and resources, encompassing the creation of tailor-made smart contracts and applications. As such, this may pose obstacles for small-scale firms or entities with constrained resources. There is significant evidence that the knowledge deficiency has resulted in the inadequate realization of the relevance of the technology. At the organizational level, there is a lack of awareness, and executives have displayed hesitancy in embracing innovative blockchain technology. This is attributable to their inability to perceive a significant return on investment, as well as the absence of coherent employment of the technology.

IV. Conclusions

Despite the limitations discussed above, we believe that the proposed solution has the potential to significantly improve the real estate transaction process. The solution relies on blockchain technology and on the regulatory framework, which, in most countries, controls property transactions. Blockchain technology ensures the data stored is tamper-proof and forgery-resistant, while qualified professionals are responsible for the truthfulness and accuracy of data, overcoming the GIGO problem. The solution proposed has attracted the attention of investors in the real estate sector and public institutions. An MVP (minimum viable product) based on the concept and code published in this paper has been funded by a well-renowned university.

References

[1] Dror Poleg. *Rethinking real estate: A roadmap to technology's impact on the world's largest asset class*. Springer, 2020.

[2] Hugo Pieter Wouda and Raymond Opdenakker. Blockchain technology in commercial real estate transactions. *Journal of Property Investment and Finance*, 37(6):570–579, 2019.

[3] P McNamara. Exploring Liquidity. 1998.

[4] Neil Crosby and Patrick McAllister. Liquidity In Commercial Property Markets: Deconstructing The Transaction Process. (rep-wp2004-07), 2004.

[5] Shaun Bond, Neil Crosby, Soosung Hwang, Tony Key, Colin Lizieri, George Matysiak, Patrick McAllister, and Charles Ward. Liquidity in Commercial Property Markets. 1(5):117, 2004.

[6] Saull Andrew and Baum Andrew. The Future of Real Estate Transactions Report Summary The future of real estate transactions: Technology, innovation and the real estate conveyancing process. 2020.

[7] Andrew Saull, Andrew Baum, and Fabian Braesemann. Can digital technologies speed up real estate transactions? *Journal of Property Investment and Finance*, 38(4):349–361, 2020.

[8] Atefeh Mashatan and Zachary Roberts. An enhanced real estate transaction process based on blockchain technology. *AMCIS 2017 - America's Conference on Information Systems: A Tradition of Innovation*, 2017-Augus(Swan 2015):1–5, 2017.

[9] Marco Iansiti and Karim R. Lakhani. The truth about blockchain. *Harvard Business Review*, 2017(January-February), 2017.

[10] Md Tauseef Alam, Sujit Chowdhury, Raju Halder, and Abyayananda Maiti. Blockchain Domain-Specific Languages: Survey, Classification, and Comparison. *Proceedings - 2021 IEEE International Conference on Blockchain, Blockchain 2021*, pages 499–504, 2021.

[11] Candidate Number. On Blockchain and Non-Fungible Tokens (NFTs): opportunities , challenges and the emergence of a new asset Supervised by Dr Silvia Bartolucci. 2022.

[12] Emanuel Kohlscheen, Marco Lombardi, and Egon Zakrajsek. BIS Working Papers. *Globalization*, 19(943):20, 2021.

[13] Digital Asset. Deutsche Börse Names Digital Asset Strategic Technology Partner for its New Digital Post-trade Platform. ttps://www.digitalasset.com/use-cases/custody-safekeeping, 2021. [Accessed on 15 March 2023].

[14] Digital Asset. Goldman Sachs' Tokenization Platform GS DAP™, Leveraging Daml, Goes Live. https://www.digitalasset.com/use-cases/tokenization, 2023. [Accessed on 15 March 2023].
[15] Floor Seuren. Introducing Blockchain to Commercial Real Estate: Exploring the applicability of blockchain technology in lowering transaction costs of the commercial real estate due diligence process. page 144, 2018.
[16] Veuger, Jan. PropTech 3.0: the future of real estate. *University of Oxford Research*, 2021.
[17] Alireza Shojaei, Jun Wang, and M E Rinker. Exploring the feasibility of blockchain technology as an infrastructure for improving built asset sustainability Andriel Fenner.