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Blockchain Technology in Commercial Real Estate: Developing a Conceptual Design for Smart Contracts

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Abstract:

Commercial real estate transaction processes are inherently complex, multi-faceted, and multifarious due to multiple intermediaries, a high volume of signed documentation, high costs, and the illiquid nature of these transactions. An emerging area in blockchain technology is smart contracts which hold much potential to transform the commercial real estate industry through the digitalization of decentralized business models that ensure transaction transparency and validity. Despite the potential benefits of smart contracts, their use in the commercial real estate industry is at a nascent stage. In response to this gap, this study proposes a novel approach using Ethereum blockchain technology to enable intermediaries to transact in an informationally symmetrical way within an open real estate in Switzerland. The proposed conceptual model employs tokenisation on the blockchain and is developed using the action design science research methodology. The model undergoes several stages of evolution from pre-design, which is validated through expert interviews, to arrive at the final conceptual design. The study identifies key factors that influence the application of blockchain in real estate transactions, namely adoption, governance and compliance, transaction costs, transparency and immutability, security, and scalability. The results indicate that smart contracts have the potential to significantly reduce transaction costs and improve efficiency in the commercial real estate industry.

Keywords: Design Science Research, Action Design Science Research, Blockchain, Smart Contracts, Commercial Real Estate.

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1 Introduction

The commercial real estate market ranks among the largest asset classes on the global trading markets (Wouda & Opdenakker, 2019). Commercial real estate is distinctly different from other assets (e.g., equities, bonds) as they have high transaction costs, and long-term commitments, are subject to legal jurisdictions, and are bound to the local markets and other barriers to entry (Dijkstra, 2017; Yeoh et al., 2023). This complexity is further accentuated by the heterogeneity and immobility of the commercial real estate industry, high reliance on manual processes with high-cost structures, and a variety of contracts required to outline the relationship among all intermediaries, including their responsibilities, liabilities, and duties (Breuer & Steininger, 2020; Karamitsos et al., 2018).

The commercial real estate market asymmetry underpins the lack of transparency due to asymmetric information and places the transactional process subject to administrative burdens which are bound by each local jurisdiction and require a reshaping of the real estate industry (Krupa & Akhil, 2019).This asymmetric information problem is especially prevalent in high–value, low-frequency assets such as the commercial real estate market (Hoksbergen et al., 2019). The context of this study is the Swiss commercial real estate market. This market has experienced a significant rise in the demand for real estate due to several factors including an increase in foreign investment and its desirability as a corporate headquarters location and country of residence (Bürgi & Nägeli, 2019). Swiss real-estate investment is restricted by a Swiss federal law known as 'Lex Koller' (also known as the 'Federal Law on the Acquisition of Real Estate by Persons Abroad').

To operate in this highly regulated environment, the stakeholders involved in the Swiss real-estate market are seeking technological innovations to remain compliant. As a result, the traditional real-estate market is increasingly being defined as 'property-tech', like other sectors such as financial services that are referred to as fin-tech. One such technology that is increasingly gaining the attention of stakeholders in the Swiss real-estate market is blockchain technologies, specifically, Ethereum, a decentralized blockchain platform that establishes a peer-to-peer network that securely executes and verifies application code, called smart contracts.

Blockchain technology, a decentralized digital database of transactions, also known as a distributed ledger, enables transacting parties to the exchange ownership of digitally represented assets in a real-time and immutable peer-to-peer system without the use of intermediaries (Morkunas et al., 2019). As the database is maintained by a network of computers that verify a transaction in real-time before it is approved and added to the ledger (Morkunas et al., 2019), blockchain provides a high level of transparency (Akram et al., 2020) and trust (Schweizer et al., 2017).

Empowered by the Ethereum platform, developers can tokenise a wide range of high-value, scarce assets (e.g., currencies, securities, properties, real estate) that can be transferred between parties without involving a central entity (Chen, 2018). In the context of this study, the issuance of blockchain tokens acting as the digital representation of an asset can revolutionize many aspects (i.e., buying, selling, managing) of commercial real estate assets (Altynpara, 2023; Latifi et al., 2019; Yeoh et al., 2023). As blockchain tokens are highly liquid and easily tradable (Sehra et al., 2017), they can transform the commercial real estate industry by reducing the number of intermediaries (Altynpara, 2023), securing digital property records (Wouda & Opdenakker, 2019), and improving due diligence (Altynpara, 2023).

Tokenization design concepts have already been developed to the proof of concept stage (e.g., blockchain-enabled multiple listing service (Krupa & Akhil, 2019)). Benefits include increased process efficiency and operational excellence by sharing processes and information (Morkunas et al., 2019; Thota, 2019) and the auto-execution of smart contracts (Rahmadika & Rhee, 2018) by enabling peer-to-peer (P2P) digital payments (Garcia-Teruel, 2020). Despite their name, smart contracts are not considered legal contracts (Fridgen et al., 2021).

Against this background, the aim of this study *"is to design and evaluate a novel blockchain-based smart contract prototype for commercial real estate transactions".*

To achieve this aim, we followed a design science research method (Hevner et al., 2004) as it is suited to addressing 'wicked problems' (Holmström et al., 2009) by building and evaluating design artifacts (March & Smith, 1995). An artifact is defined as constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems) (March & Smith, 1995; Hevner et al., 2004). Artifacts enable the representation, analysis, understanding, and development of information systems (March & Storey, 2008).

The remainder of the paper is structured as follows. First, the fundamentals of blockchain and ADSR are presented. Then the research methodology is outlined. Next, the application of ADSR and the emergent artifacts are presented. Followed by a discussion and implications for the real estate market. The paper ends with a conclusion.

2 Background Literature

This section explains the fundamentals of blockchain technology and its relevance in the context of commercial real estate, as well as provides an overview of action design science research.

2.1 Fundamentals of Blockchain

Blockchain is broadly defined as a distributed database comprising records of transactions that are shared among participating parties (Zhao et al. 2016). Blockchain technologies can be divided into four types (see Figure 1). *Public* (i.e., everyone can check the transaction and verify it, and can also participate in the process of getting consensus), *private* (i.e., node will be restricted, not every node can participate in this blockchain, has strict authority management on data access), *consortium* (i.e., the data can be open or private, can be seen as partly decentralized), and *hybrid* (combines elements of both private and public blockchain) (Niranjanamurthy et al., 2019; Jha, 2023).

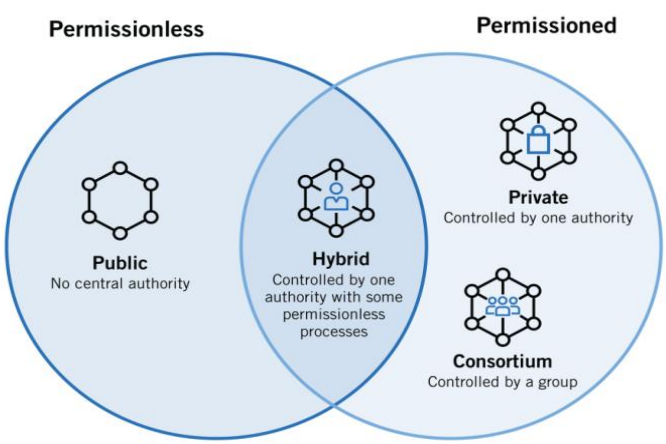

Figure 1. Types of Blockchain (Source: Jha (2023))

Blockchain consists of five technological layers (see Figure 2) with each of these layers having different properties and characteristics. The application layer encompasses applications and smart contracts. A smart contract is a code program identified by a unique address in the network and it consists of components that are a set of executable functions and input parameters which are a required function in the contract (Karamitsos et al., 2018).

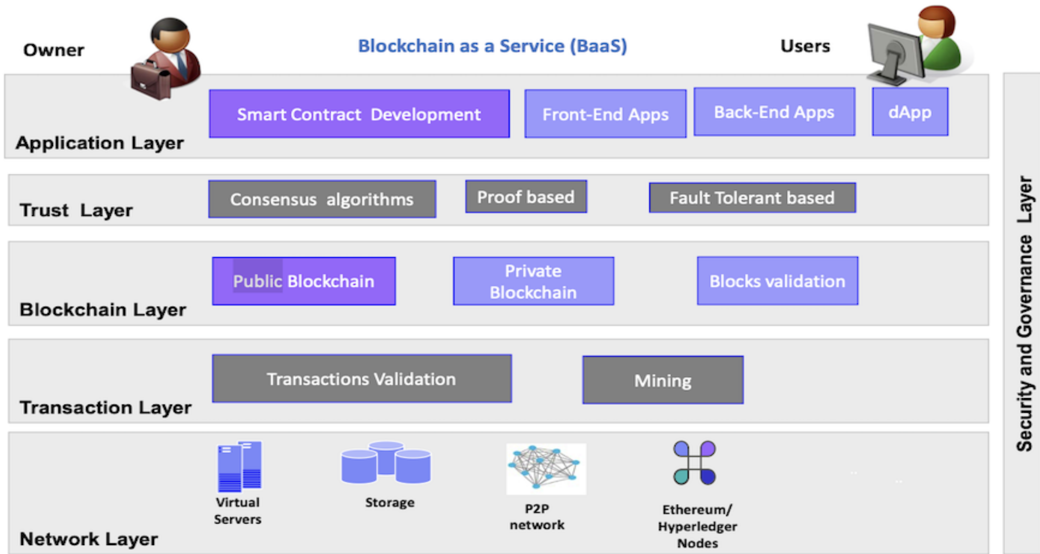

Figure 2. Blockchain Layers (Source: Karamitsos et al. (2018, p. 181))

Blockchain allows transacting parties to exchange ownership of digitally represented assets through peer-to-peer (disintermediated) transactions to be verified with an algorithmic hash (see Figure 3) on a shared ledger (Thomas & Negash, 2023; Morkunos et al., 2019).

Other benefits of blockchain include enhanced security through end-to-end encryption (Atlam et al., 2018), speed and traceability (Hughes et al., 2019), transparency and auditability (Wang et al., 2019), and data quality and integrity (Casino et al., 2019).

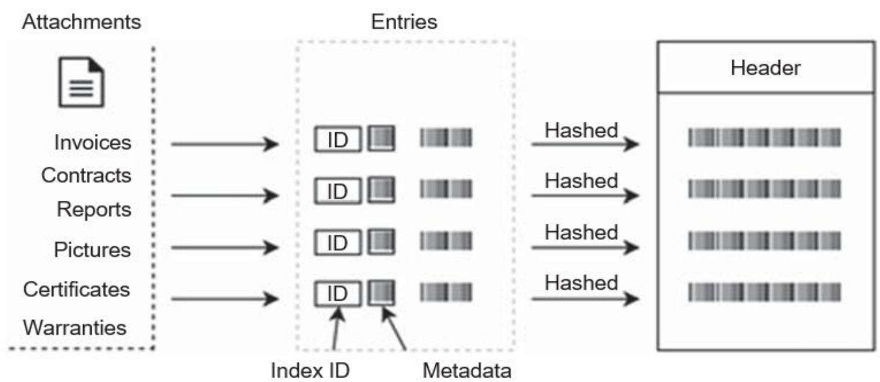

Figure 3. Blockchain Technology (Source: Wouda and Opdenakker (2019))

As a smart contract has a unique address, it can be traced and verified which builds trust in the system (see Figure 4).

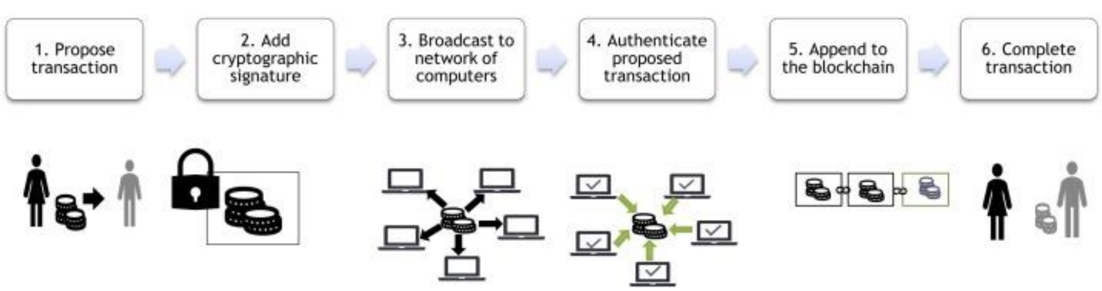

Figure 4. Steps of Asset Exchange Between Two Transacting Parties (Source: Morkunos et al. (2019))

2.2 Blockchain in The Context of Commercial Real Estate

The commercial real estate business model is transactional by nature and process-oriented. Any improvements therefore need to focus on the transactional components (i.e. parties in the transaction like seller and buyer) and on the process (i.e. the process is designed in a step-by-step transaction way that therefore includes buyers, sellers, and intermediaries).

Emerging technologies are increasingly being used to connect different parties in the sector and to reduce barriers to productivity (Ullah et al., 2018). Smart real estate technologies are considered a 'game-changer' for the previous human-centric interaction process, specifically in the context of commercial real estate (Jylhä et al., 2019). Increasingly, it is being realized by using machine learning (Annervaz et al., 2016), decentralization of nodes, and P2P network process (Thilini & Wickramaarachchi, 2019), thus creating the basis for the use of blockchain technology. The key advantage of blockchain technology is the automated contract in the form of decentralized information (Karamitsos et al., 2018) and how it leverages the effect of crowdfunding (Montgomery et al., 2018). Furthermore, blockchain technology enables the storage of digital land rights on the decentralized ledger (Badea et al., 2019) and an automated transaction workflow to achieve faster cash settlements through digital smart contracts (Rahmadika & Rhee, 2018). In doing so, it significantly reduces the time of execution and efficiency of transactions (Dijkstra, 2017), transparency (Ameyaw & de Vries, 2021), and trust (Veuger, 2018; 2020). However, there are certain risks such as the market risk of platform failure and the credit risk of default or liquidity which the new financial ecosystem called 'Decentralized Finance' (DeFi) and which needs to be considered by transforming traditional real estate assets into blockchain protocols that run without intermediaries (Zhang & Li, 2021). Real estate contracts involving property owners, financiers, users, builders, brokers, notaries, and the land registry could be designed on a decentralized blockchain smart contract (Wouda & Opdenakker, 2019).

2.3 Overview of Action Design Science Research

To build and assess a new artifact, there is a need to establish the reciprocal shaping of a desired artifact within the context of the real estate industry rooted in the practical implementations of the Action Design Science Research (ADSR) method (Mullarkey & Hevner, 2018). The ADSR method (see Figure 5) proposed by Mullarkey and Hevner (2019) consists of four phases: (Phase 1) Diagnosis, (Phase 2) Design, (Phase 3) Implementation, and (Phase 4) Evolution. Each phase consists of four steps: (Step 1) Problem Formulation, (Step 2) Artifact Development, (Step 3) Reflection and Evaluation, and (Step 4) Formalization of Learning.

The initial diagnosis stage deals with the problem formulation and the research gaps (e.g. asymmetric information and the separate record keeping (ledger) problem of mistakes from paper-based recording practice resulting into the higher burden of legal requirement and transaction costs). The second stage Building, Intervention, and Evaluation (BIE) forms an iterative cycle with the research implication and fosters the elaborated artifact creation (Mullarkey et al., 2013; Mullarkey & Hevner, 2015; 2018).

Iivari (2015) proposes two strategies for ADSR design science research: (1) designing an IT meta-artifact in response to a set of problems (class), which can then be tested in a specific context and (2) solving a specific problem for a client through a concrete artifact, which then provides the basis to distill a generalised solution for a class of problems from the experience of its implementation (Strategy 2).

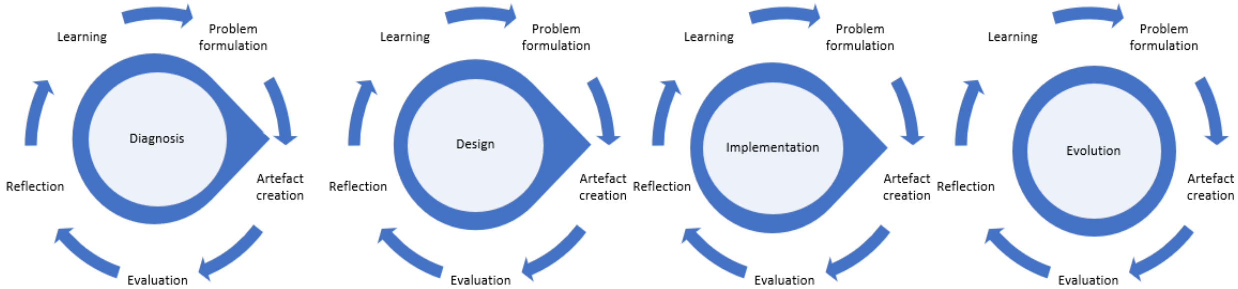

Figure 5. Action Design Research (ADR) Phases and Steps (Source: Adapted from Mullarkey and Hevner (2018, p. 4))

3 Methodology

3.1 Application of the ADSR Methodology – Research Artifacts - Conceptual Model & Prototype

The ADSR method proposed by Mullarkey and Hevner (2019) is adopted in this study (see Table 1). By applying ADSR to address a class of problems of the real estate market, this study provides a state-of-the-art “as is” design model, considering the key theories, models, and previous research on the research subject – the commercial real estate contract. The diagnosis has thus been underpinned by the ADSR literature to depict the “as is” model (artifact 1 “as is” model).

Following from the “as-is” modeling as part of the diagnosis, the design phase is based on the problem formulation that includes findings from the diagnosis-related literature review. The commercial real estate transaction (artifact 2a: pre-design of a full conceptual model) is therefore built by addressing its current weaknesses (i.e. information asymmetries, process inefficiencies). This yielded an unvalidated pre-design that set the foundation of the new conceptual model, which was then externally validated through the content analysis of expert interviews (artifact 2b: validated conceptual design). The conceptual model was then transformed into the technical implementation model by the mapping of all factor categories to a proof-of-concept model in line with the practice-based concept evaluation of usefulness as recommended by Prat et al. (2015). The technical implementation model entails the prototype design (model 3a prototype design) and solution architecture (model 3b prototype architecture) as well as a demonstration of the functional feasibility of the research pilot solution (model 3c prototype development).

As shown in the logic of the ADSR model (Mullarkey & Hevner, 2019), the evaluation itself entails prototype testing (4a) and prototype statistics (4b). In this sense, the prototype smart contract is developed on the Ethereum Blockchain (Github) and tested on various operational scenarios (sender-receiver relations) to determine the proof-of-use and demonstrate the prototype utility and process efficiencies (4a prototype testing). In parallel, the prototype proof of value is determined by the analytical statistics which is carried out by empirical market survey (N=700) participants to investigate whether a prototype solution can create value (4b prototype statistics - proof of value).

Table 1. ADSR Methodology – Phases and Stages as Applicable to the Scope of this Research

Phase	Steps	Application in this study
Diagnosis Phase	Step 1: Problem formulation	Problem is formulated based on the traditional design of the contract
	Step 2: Artifact development (artifact 1 “as is” model)	Diagnosis of the weaknesses of the traditional contract based on the comprehensive (thematic) and systematic literature review
	Step 3: Reflection and evaluation	During the ongoing diagnosis, important issues were discovered, reflected and evaluated
	Step: Formalization of learning	A set of design principles was articulated, positioning the case problem as an instance of a class of traditional contracts within the real estate industry
Design Phase	Step 1: Problem formulation	Problem was formulated based on the design of the AS-IS-Concept for pre-concept before actual implementation deployment.
	Step 2: Artifact development (Artifact 2a Pre-design and 2b Conceptual model design based on expert interviews)	Pre-design of the new conceptual model final design (our second artifact)
	Step 3: Reflection and evaluation	By means of qualitative content analysis, the TARGET design model is added to the study interview categories during the reflection and evaluation phase
	Step 4: Formalization of learning	Final design of the new conceptual model TARGET (i.e., second artifact)
Implementation	Step 1: Problem formulation	Problem is formulated based on the new conceptual model TARGET for the actual deployment
	Step 2: Artifact development (Artifact 3a solution architecture and prototype development 3b)	Development of the new prototype solution based on the diagnosis, qualitative content analysis, and practice sensemaking activities

	Step 3: Reflection and evaluation	The reflection stage is characterized by multiple rounds of elaboration and iteration.
	Step 4: Formalization of learning	Learning lessons from implementation are taken for future research discussion.
Evolution	Stage 1: Problem formulation	The problem is formulated based on a systematic review of the literature, an explorative survey investigating the customers' acceptance of previous empirical studies of digital real estate to assess the suitability of the prototype solution
	Step 2: Artifact development (Artifact 4a prototype validation supported by an empirical market survey and final evaluation 4b)	Market survey - empirical survey for evaluation of the utility effectiveness comparison between the existing and new design.
	Step 3: Reflection and evaluation	The final evaluation confirmed the utility and effectiveness of the blockchain system and captured several benefits for different types of stakeholders.
	Step 4: Formalization of learning	The final evaluation confirmed the utility and effectiveness of the blockchain system and captured several benefits to different types: speed, transparency, security, quality, validity, utility, trust, cost, efficiency

3.2 Evaluating the Artifacts

Through role-based sampling, twenty domain experts were selected as they had extensive experience and knowledge of the real estate market (see Table 2). Participants varied in terms of their role, country of work, and use of digital innovations in real estate.

Table 2. Interviewee Profile

Job Title	Location
VP Commercial Finance	United Arab Emirates
Director Emerging Technologies	
Co-Founder & Chief Operations Officer	United States of America
Principal	
Founder, Principal Broker	
Managing Director	
Vice President Real Estate/Brokerage	Canada
Vice President Real Estate/Brokerage	
Manager	Netherlands
Consultant Digital Transformation	
Product Manager	Brazil
Manager	Denmark
Blockchain Strategist	England
Managing Partner	Switzerland
Chief Operations Officer	Spain
Lead Partner	Nigeria
Property Developer	Hong Kong
Co-Founder & CEO	India
Founder, Blockchain & Smart Contract Developer	Italy
Chief Marketing Officer & Partner	Isreal

4 Designing and Evaluating the Artifacts From Conceptual Model to Prototype

4.1 Application of the ADSR Methodology – Artifact 1 diagnosis of the "As IS" model

The ADSR process (see Figure 6) with the diagnosis phase – a comprehensive state-of-the-art literature research to understand the structure of the traditional old design commercial real estate transaction, specifically the components such as real estate models, business and transaction cost models as well as legal aspects. As with other ADSR projects, this research process consists of an iterative cycle - problem formulation (1), artifact development (2), reflection and evaluation (3), and formalization of learnings.

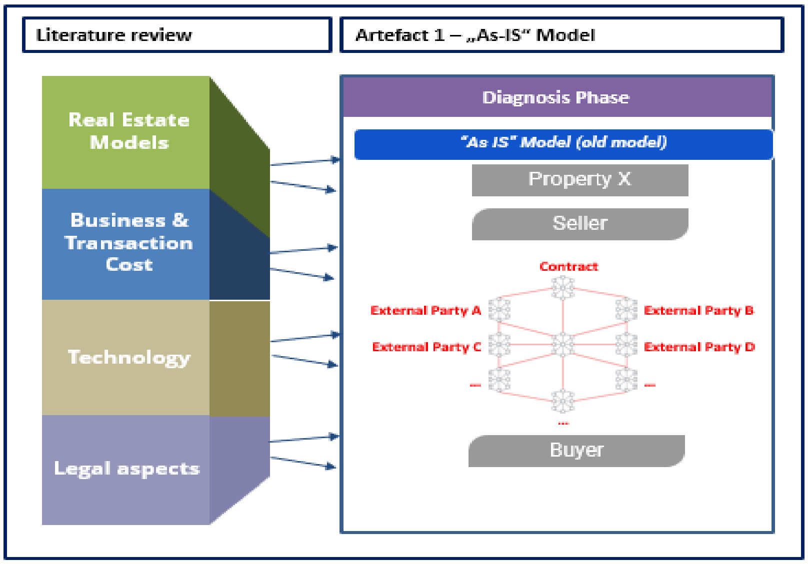

Figure 6. Artifact Development – Artifact 1 "As is» Model (Old Design)

Evaluation & Reflection: The evaluation of the traditional real estate model is based on a literature based thematic analysis which includes a systematic literature review used to identify key issues, specifically problems related to intermediary involvement and trust deficits, as well as asymmetry of information in real estate contracts. In this sense, the real estate models conclude on the problems between intermediaries (Krupa & Akhil, 2019; Morena et al., 2020) and associated issues with trust (Secinaro et al., 2021; Zavadskas et al., 2021). In this sense, real estate contracts show a high degree of asymmetric information (i.e., one party in the current design always knows more about the contract than the other party (Krupa & Akhil, 2019; Shahab & Allam, 2020; Hoksbergen et al., 2021) (Artifact "AS IS" – Model (Buyer and Seller - Actors and Roles)). Second, the recurring breaks between intermediaries implicitly heighten the weaknesses associated with centralized trust whereby intermediaries as a centralized trust mechanism are prone to errors (Veuger, 2018) that are time-consuming and create additional difficulties for cross-border operations (Garcia-Teruel, 2020), low efficiency and transparency resulting in the slow speed of processing transactions (Hoxha, 2019; Sladić et al., 2021) (→ Artifact "AS IS" – Model (Technology and database layer)). Third, changing requirements on the legal aspects create problems of asset liquidity and barriers to scalable project finance (Morena et al., 2020; Konashevych, 2020b), market entry problems (Saull et al., 2020), non-scalable finance, risk diversification and complex legal set-up procedures for micro-investments (Kumar et al., 2021, Gupta et al., 2020) (Artifact "AS IS" – Model (Market regulations, later KYC/AML under Blockchain)).

Learning: The learning of the diagnosis phase generates insights to identify flaws in the current design of the transaction process leading to six major learning effects for the design (see Table 3).

Table 3. Design Flaws in the Transaction Process

Learning Effect	Citation Source
Intermediaries and associated trust weaknesses	Krupa & Akhil, 2019; Morena et al., 2020; Secinaro et al., 2021; Zavadskas et al., 2021
Asymmetric information	Dutta, 2020; Shahab & Allam, 2020; Zavadskas et al., 2021
Speed of transaction	Hoxha, 2019; Sladić et al., 2021
Transaction costs	Dakhli et al., 2019; Kalyuzhnova, 2018; Frolov, 2020; Mashatan & Roberts, 2017
Market entry	Saull et al., 2020
Investment management, non-scalable finance, risk diversification, and complex legal set-up for micro-investments	Kumar et al., 2021; Gupta et al., 2020

4.2 Application of the ADSR Methodology – Artifact 2 Concept (2a Pre-Design and 2b New Design)

The aim of the design phase is to explore design options based on a literature review (pre-design) and to verify the design principles to determine what is feasible for the optimised solution. In this sense, the problem statement of the commercial real estate transaction weaknesses is verified by the qualitative content analysis of interview data to critically evaluate previous literature findings which undergoes an iterative cycle of problem formulation (1), artifact development (2), reflection and evaluation (3), and formalization of learnings.

4.2.1 Application of the ADSR Methodology – Artifact 2 Concept (2a Pre-Design)

Problem Formulation: The problem formulation of the pre-analysis connects with the diagnosis phase where the comprehensive literature and systematic literature reviews derived in this study form the relevant business context supported by the empirical statistical analysis. The pre-design helps to develop technology-based solutions addressing existing drawbacks within commercial real estate contracting. The pre-design is a baseline for the future target conceptual model where this study's factors are set and tested by the control variable. Pre-exploratory expert interviews were conducted by means of qualitative content analysis techniques (Saunders, 2012). Depending on the course of the Interview, the order of the questions may have varied and questions arising from the context of the interview may have been added (Saunders, 2012). In this specific case, the “To-Be” model – pre-analysis (Artifact 2a) was developed by 20 industry experts based on the qualitative content analysis in NVIVO.

Artifact Creation: This study outlines the factors as a baseline for the new target model which is derived from the literature review (diagnosis). The *Artifact 2a* of the design phase is the pre-design of the conceptual model identified from the literature and theory and requires empirical validation (see Figure 7). In this sense, the qualitative content analysis is conducted where structured interviews are applied to the business owners within the real estate, business, technology, and legal industries.

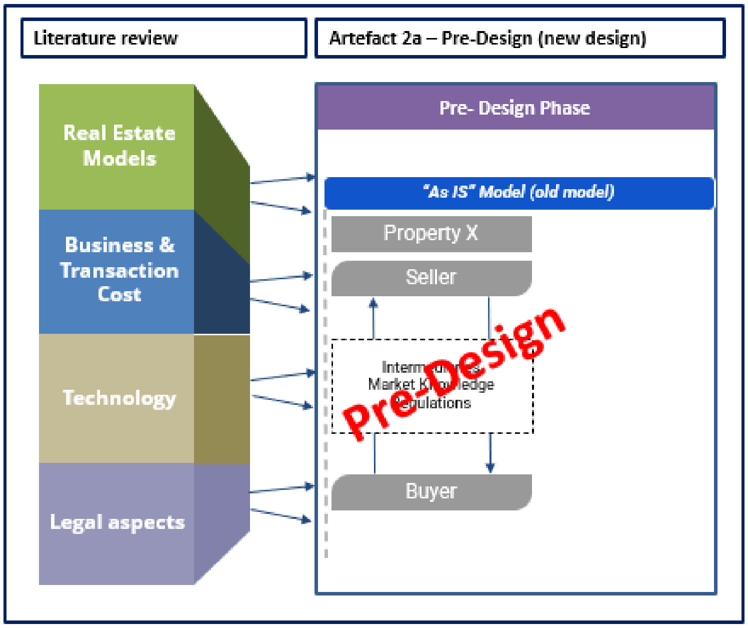

Figure 7. Artifact 2- "To-Be" Model (New Design) – Artifact Pre-Design (2a)

4.2.2 Application of the ADSR Methodology – Artifact 2 Concept (2b New Design)

Problem Formulation: The problem of the new design showed that the real estate market has a problem when it comes to establishing secured and compliant commercial real estate transactions in an economical and timely way. There is a large optimization opportunity both on the process side and cost side. In the following sub-sections, we address the implementation and design of such a system that could, ultimately, increase the overall industry efficiency.

An emergent theme from the qualitative data was a consensus by the interviewees that the adoption of smart contracts in the commercial real estate industry was a sustainable technological solution to transform the industry worldwide. The transition from the status quo (old design) to a new design for the acquisition process in commercial real estate is illustrated as a conceptual model (see Figure 8).

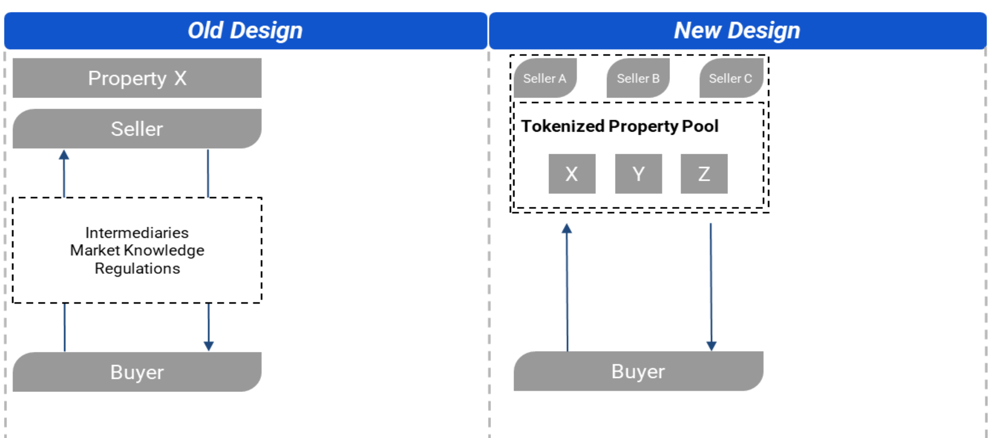

Figure 8. Design of the Conceptual Model (verified factors) – Old Design vs. New Design

Artifact Creation: In this context, the diagnosis phase (unvalidated pre-design) provides the foundation of the new conceptual model, which is then externally validated through the qualitative content analysis of expert interviews (artifact 2b: validated conceptual design) as illustrated in Figure 9.

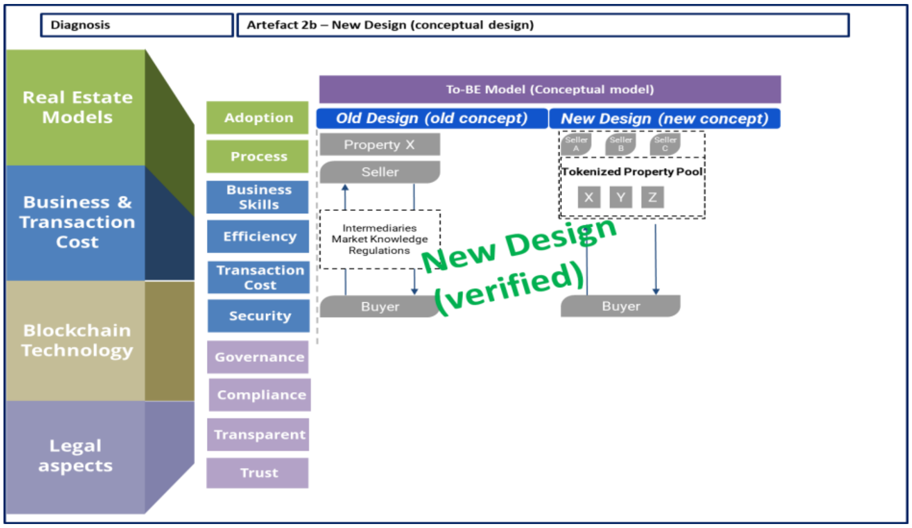

Figure 9. Design of the Conceptual Model (verified factors) – Old Design vs. New Design

Evaluation & Reflection: *Artifact 2b* in the design phase is the design of the conceptual model, identified from the literature and qualitative content analysis which was conducted through semi-structured interviews.

4.2.3 Insights from the Expert Interviewees (2b New Design)

As part of the study, interviewees were asked about current trends, strengths, weaknesses, risks, and opportunities of blockchain in the real estate sector. This data contributed to the design principles for the prototype development of smart contracts by identifying the gaps and additional parameters for the conceptual model to develop the Proof of Concept/Prototype.

Adoption: The factor adoption factors were mentioned as one of the most crucial parameters during the expert interviews since it will ultimately define our ability to distribute efficiently an asset to multiple parties. Furthermore, adoption is an important parameter that really affects how such blockchain-based systems will be implemented within the blockchain technology revolution. The redesign of the old real estate process demonstrates that traditional commercial real estate processes can be encoded as an ERC777 smart contract.

Governance & Compliance: The issue of asset illiquidity and high barriers where people/organizations are interested in storing the investment funds securely where the value will be kept more stabilized (Baum, 2017). Blockchain technology has the potential to transform the real estate industry through tokenization and property rights (Konashevych, 2020a; 2020b). With the help of smart contracts, a computerized transaction protocol that executes the terms of a contract, the smart contract can enforce the conditions of a contract digitally with no intermediary required (Vidhyalakshmi & Geetha, 2019).

Transaction Costs: Blockchain technology presents an opportunity for the real estate sector as it provides the basis for redesigning the traditional approach. the decentralised smart real estate contract gives the potential to reduce the transaction costs by transparently automating the so-called ‘middleman’, including land registry, housing authority, appraiser, and notary office, and brings direct interaction between buyer/borrower and seller. The blockchain technology through the smart contract self-executes the transaction with the terms of the agreement between buyer and seller who are directly P2P connected to all the P2P nodes on the decentralized blockchain network without any intermediaries. This decentralised mechanism connects the buyer and seller directly without any intermediary by eliminating the problem of intermediaries (i.e., third parties) which would eliminate the redundancies and require lower transaction costs. The existing system consists of employing a broker or a middleman to perform transactions of assets. The proposed conceptual model is designed in a way where the buyer and seller are directly written into lines of algorithmic code which is distributed to all the P2P nodes on the decentralized blockchain network and logically from this argument by design itself abolishes the intermediate layer between the buyer and seller.

***Transparency & Immutability*:** The proposed application provides a higher skill for the purpose of auditability, immutability, and transparency where specific asset errors will be encoded on the smart contract. Smart contracts address the issue of asymmetric information through automation, transparency, and security that underpin the symmetry in the consensus between parties in the process. The traditional real estate purchasing process has been described as inefficient due to extensive manual review and verification of financial and legal documents as well as manually updating multiple systems with redundant information or heavy reliance on multiple third parties which results in high manual effort of third parties and systems accompanied by multiple sources of truth each controlled by a different intermediary.

***Skills*:** The main barrier to the adoption of this technology is that stakeholders are not willing to change and embrace the blockchain and smart contracts. There is a heightened concern that people do not understand technology and the scarcity of a highly skilled technical workforce in the industry. Yet, the application of blockchain technology brings new possibilities for eliminating mutual delusion and concealment during the sale, rental, and lease processes, thus achieving digitization of real estate ownership (Krupa & Maganalli, 2019).

***Security*:** Ethereum is considered a highly secure system because of the high amount of cryptography and the cost associated with trying to perform various attacks that could change the state of a transaction and show that decentralization through algorithm-based consensus provides a reliable ecosystem in which real estate transactions can be safely preserved on the blockchain protocol for all real estate lifecycles. The redesign of the real estate contract is subject to economic, financial, and technological favourable conditions, however, the legal aspects such as governance and compliance need to be assured by the algorithm-based security of the smart contract ERC777. The real estate asset tokenisation is backed up by the consensus mechanism by the fractional ownership of the token holder and achieves investment liquidity in a real estate market and removes significant market barriers to enter the real estate market even for the small income investors. The security of asset illiquidity and high market barriers hindered people/organisations from making real estate investments. Tokens on the blockchain as a technological concept are the closest solution to the legal concept of titles because they provide for evidence of ownership and can be transferred from one address to another while giving exclusive access to such an address to the owner (Konashevych, 2019).

4.2.4 Application of the ADSR Methodology – Artifact 3 Implementation (3a Design, 3b Implementation, 3b Architecture, 3c Development)

In the context of the qualitative content analysis, the interviewees stated that the implementation requires a concerted effort and willingness by all stakeholders. Such efforts show that the industry is willing to move forward, although the rate of adoption is low. The apparent inefficiency and costly structures that must be implemented to perform a smart transaction are a concern for the industry. Consequently, the study identified that the industry has a problem when it comes to establishing secured and compliant commercial real estate transactions in an economical and timely way. As a result, the decentralised blockchain technology can foster investment and entrepreneurship, while reducing investor risk appetite by storing the investment funds more secured in asset-backed regulated “Security Tokens”. Application of the ADSR Methodology – Artifact 3 Design (3a Prototype Design).

***Problem Formulation*:** The research project was selected to be developed under the ERC protocol and showcase the prototype development. In the Ethereum community, ERC stands for Ethereum Requests for Comments, and are crowd-developed standards that, when applied, guarantee compatibility and interactivity between certain types of smart contracts. For example, ERC20 was one of the first standards adopted by the community and provided a simple, easy-to-use interface for developing fungible tokens that could then be traded on exchanges. Those trades were made possible by the implementation of standardized functions and variables that allowed for easy integration on token exchanges.

***Artifact Development*:** The *Artifact* of the *Prototype Implementation* phase is the transformation to a techno prototype model (Artifact 3a), architecture options (Artifact 3b), and building the prototype solution (Artifact 3c).

In this context, the prototype consists of a three-tier architecture (i.e., Actors and Roles, Business Services, and Databases (see Figure 10)).

***Evaluation & Reflection*:** The research evaluates the architecture options and reflects on the basic architecture of the prototype, it is important to first define the functionalities, external factors, and legal pressures that the project needs to factor to be a feasible implementation. From the interviews and literature reviews, a precise idea of some of the common principles the prototype will need to respect has been derived.

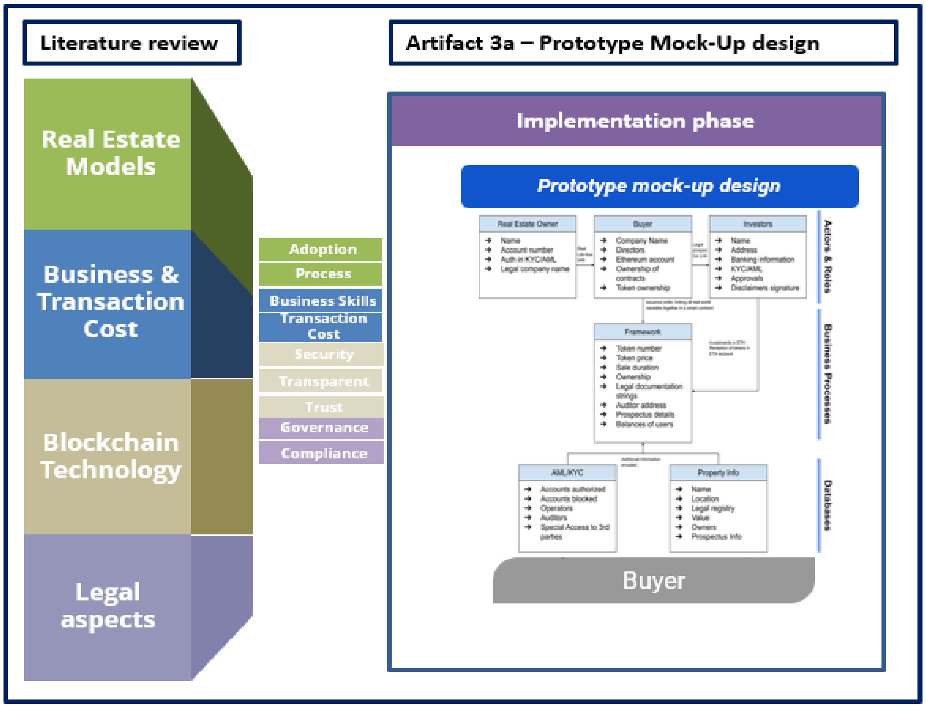

Figure 10. Artifact 3a- Prototype Mock-up Design (Implementation Phase)

4.2.5 Application of the ADSR Methodology – Artifact 3 Implementation (3b Prototype Solution Architecture)

The next iterative cycle is to find a solution for the prototype. The aim of the implementation phase is to develop an ensemble instantiated artifact. In this sense, the implementation is to transform the conceptual model into the technical prototype, select an appropriate architecture (Artifact 3a), and build a prototype development (Artifact 3b) system to address the research problem of the commercial real estate transaction weaknesses. As the study follows the structured ADSR method, the next iterative cycle continues with the design phase.

Problem Formulation: The solution architecture for this study was tested using a single asset building to demonstrate the utility of the prototype utility. To support the local prototype testing with a global blockchain network, a fully functioning version of the smart contract was deployed on the Ethereum Rinkeby test chain. The prototype is ERC-20 compliant, and its code is open-sourced and extensively peer-reviewed on Github, thereby making it accessible for transactions and testing all around the world. The protocol is stored in the Ethereum Rinkeby network database. For convenience and to avoid convergence with real-world projects, fictional real estate was used. The scenarios were designed for prototype testing and are subject to the relation between buildings and tokens (a scenario with one asset building and multiple buildings as a portfolio).

Artifact Creation: Our research 3-tier architecture model is comprised of (i) actors and roles, (ii) business processes, and (iii) databases (see Figure 11).

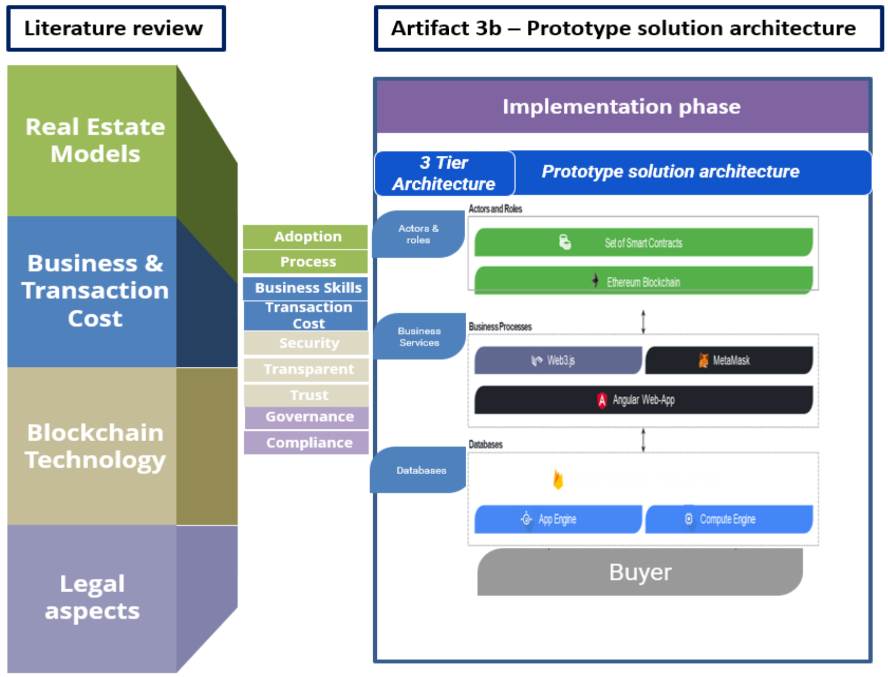

Figure 11. Artifact 3b- Prototype Solution Architecture (Implementation Phase) (Source: Adapted from Karamitsos (2019))

Evaluation & Reflection: During this step, important issues were discovered and acted upon which involved important decisions about the actors and their roles, business processes, and use case scenarios to understand the underlying database solutions. The development of the prototype application layer was realised based on the Real Estate Investment Platform (Swiss Realty) on the 3-Tier Architecture as recommended by (Karamitsos et al., 2018) allowing investors to invest in commercial Real Estate both in the form of cryptocurrencies and FIAT currencies. Figure 12 illustrates the three-Layers/Implementation Model for the commercial real estate smart contract.

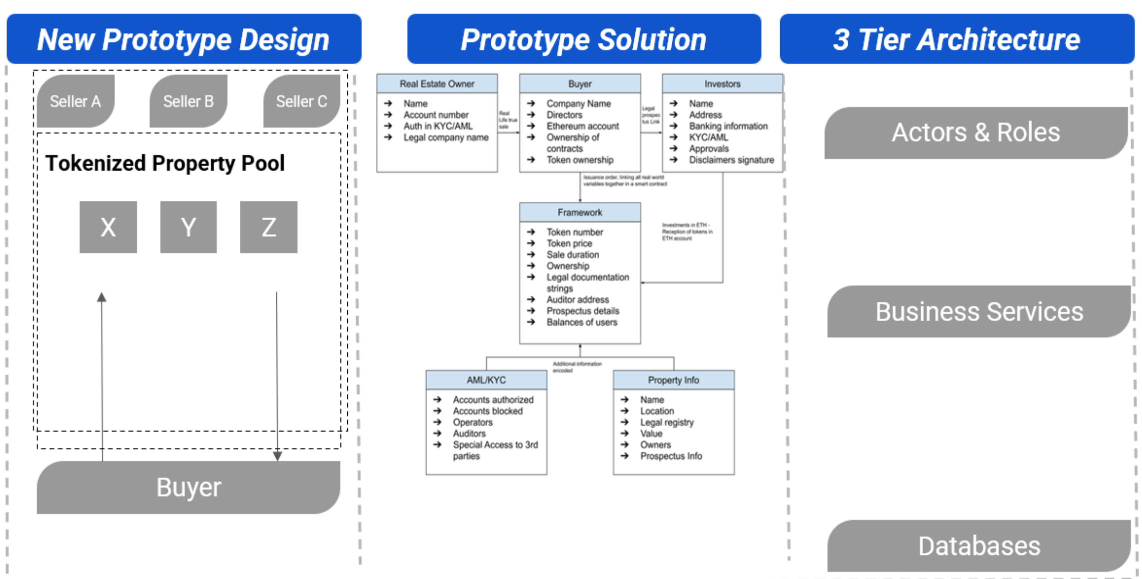

Figure 12. Three-Layers/Implementation Model for the Commercial Real Estate Smart Contract

Actors & Roles: Property owners are the entities or physical people owning a particular real estate being sold partially or entirely on the blockchain. A property owner only interacts with the property buyer and will receive the entirety of the funds raised through the model. The property buyer is an entity or a physical person who would like to purchase the property on sale by the property owner. The property buyer is the person raising the funds through the blockchain system. This entity or person is the actor that "tokenizes" the property which means it must handle the smart contracts development as well as the marketing of its fund-raising actions. Investors are entities or physical persons that have been granted the right to invest through the blockchain system in the various pieces of real estate proposed.

***Business Services*:** The business and KYC processes included in the smart contract-based prototype design are listed in Table 4.

Table 4. Business and KYC Processes

Business Processes	KYC Processes
Investors buy the token ("ACCAS") with fiat or other cryptocurrencies. The synthetic derivative swap will separate ownership of the real estate from the token holders.	This study ensures that KYC and AML-procedures and operations remain feasible and controllable where KYC/AML registration needs to be performed.
The investor sends money and receives the token as proportional rights to most of the real estate ownership certificates.	It only takes on regulatory responsibilities for the limited number of initial investors. Once traded on the secondary market the regulatory burden in terms of financial and KYC/AML obligations, the token is traded in the automatic KYC/AML decision matrix, which is customised in the way that either an approval or rejection is issued to the investor.
The fund property Swiss Realty S.A. receives money raised to fund a real estate portfolio.	For verification reasons, the KYC/AML operators are essential elements of the prototype solution on Ethereum Smart Contract since investors registered through the platform to interact with existing properties being sold on it. In the case of approval, the data entry can continue until the investor confirms the process.
Real estate is split up into tokens Le Accacia shopping mall which is split into ACCAS tokens. The terms of the agreement that Swiss Realty S.A. will uphold will be embedded in the investment note.	The transaction is successfully executed, and the property gets a true sale.
The Investors are rewarded with ownership tokens of the real estate token ownership and will be registered in real-time on the Ethereum blockchain.	The transaction in the secondary market is characterised by the derivative sale where the cross-legal entity sales of tokens are pre-requisite of a legal entity set up at the individual jurisdictions.

***Database Processes*:** Application and presentation server smart contract on Ethereum blockchain that ensures the use of common tools for further development of blockchain-based applications.

1. Presentation Server: Blockchain Layer
2. Application Server: Live Web Application Layer
3. Database Server: Google Cloud Environment

***Learnings for the Solution Architecture*:** The first layer is about the data storage part (1), where the Github community advises storing valuable information. The first layer of data storage is covered with the efficient usage of the database, where the use of tokens to automate database management, ownership, and tradability of investors' participation. The storage part will tackle the task of storing its databases, variables, and any other value that will be used in the future and that should not be strictly local. The second layer is the application logic layer (2), the logic contains all the flow parts of the contract (buying a token, validating an address, etc.). The logic part will handle all the process and business logic, meaning that it will hold functions, a succession of actions, and the ability to write on the storage part. The logic part will see a similar division between smart contracts related specifically to assets being sold and a smart contract handling the central variable storage. It is also important to mention that on top of each logic contract sits an asset sale smart contract, that allows for seamless purchase of given assets. Finally, the artifact will also consist of one overarching smart contract holding variables shared by all asset sales. Such variables could be permissions given to Ethereum accounts to invest, operate, or even modify specific variables on specific assets.

4.2.6 Application of the ADSR Methodology – Artifact 3 Development (3c Prototype Development)

Problem Formulation: The prototype development for this research focused on the single asset buildings shopping name "Les Accacias" for simplicity reasons to demonstrate the artifact Proof of Concept/Prototype utility.

Artifact Creation: In this sense, the research artifact prototype development (Artifact 3c) shows how to use the codification potential of blockchain technology to turn it into a technical information system architecture, particularly the ability to translate the paper-based real estate contract into the algorithmic blockchain protocol to establish a decentralised infrastructure to ensure consistency of the separate ledgers of Buyer, Seller, Notary, Land Registry, Housing Authority and provide a key-value database as an end-to-end database. For instance, such a database could be established on the common agreed database (e.g. Google Cloud, Amazon Web, or Microsoft Azure, application server). For example, Live Web as outlined in Figure 13 below.

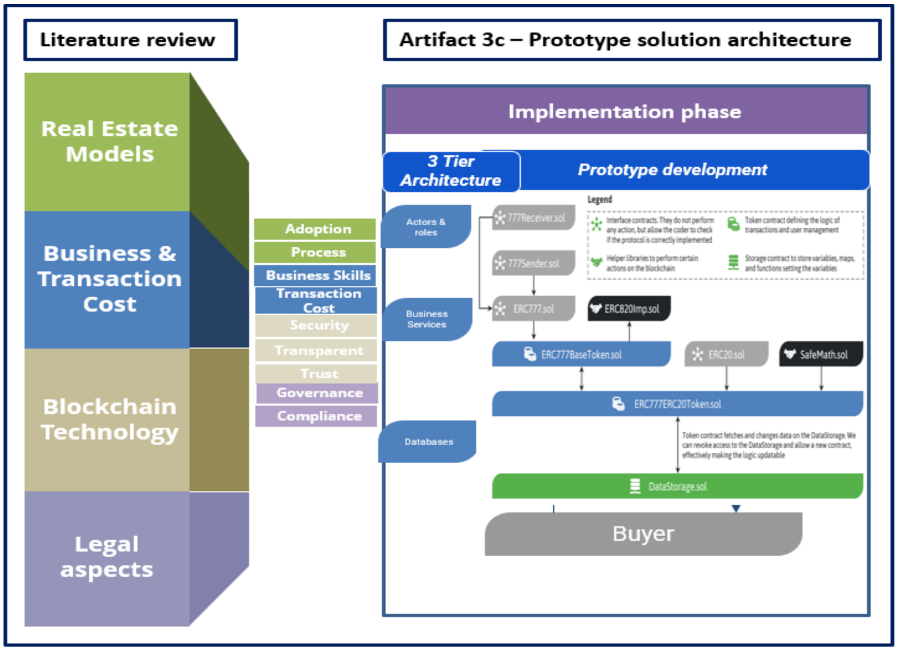

Figure 13. Artifact 3c- Prototype Solution Architecture (Implementation Phase) (Source: Steiner AG/Swiss Realty Model based on Jacques Dafflon's Github (2020) and Tokenhook (2021))

The research demonstrates the inherent optimal properties of an Artifact or provides optimality bounds on Artifact behaviour. The optimisation process is analysed precisely under the section implementation of the smart contract in the results.

1. Token contracts define the logic of transactions and user management.
2. Storage contracts are used to store variables, maps, and functions settings the variables.
3. Helper libraries are used to perform certain actions on the blockchain.
4. A token contract fetches and changes data on the data storage.
5. Interfaces allow the coder to check if the protocol is correctly implemented.

The prototype development aims to set up a legally viable and regulatory-approved blockchain-based real estate tokenization platform:

1. Issue tokens publicly to Swiss nationals.
2. Issue tokens privately to family, friends, and founders who are EU citizens.
3. Establish entities that protect software and other IPs and manage asset cash flows.
4. Protect services legally with low-cost crypto licenses.
5. Validate and apply lessons learned to the core legal structure of the first STO.
6. Involve regulators early on to guarantee approval.

4.2.7 Application of the ADSR Methodology – Artifact 4 Prototype Evolution

The aim of the evolution phase entails prototype testing (4a) and prototype statistics (4b). In this sense, the prototype smart contract is developed on the Ethereum blockchain (Github) and tested on various operational scenarios (sender-receiver relations) to determine the proof-of-use and demonstrate the prototype utility and process efficiencies (4a prototype testing). In parallel, the prototype proof of value is determined by the analytical statistics which are carried out by empirical market survey (N=700) participants to investigate whether a prototype solution can create value (4b Prototype Statistics - Proof of Value).

The next iterative cycle continues with the design phase. In this sense, the implementation phase undergoes an iterative cycle of problem formulation (1), artifact development (2), reflection and evaluation (3), and formalization of learning.

4.2.8 Application of the ADSR Methodology – Artifact 4a Prototype Testing

Problem Formulation: The evaluation of the prototype development is conducted by means of prototype testing with computer-simulated tests and end-to-end user testing. The evaluation of the prototype should rely on prototype testing to demonstrate its worth with evidence addressing criteria such as validity, utility, quality, and efficacy of the prototype development (Gregor & Hevner, 2004). In this study, the evaluation of the prototype relies on development tests that have been performed using solidity and the truffle framework as it provides an accurate Ethereum blockchain replica to test smart contract deployment, the gas cost of doing so, and provides an interface on which specific transactions can be accurately tested and measured (see Figure 14).

Artifact Testing: The tests have been performed using solidity and the truffle framework as it provides an accurate Ethereum blockchain replica to test smart contract deployment, the gas cost of doing so, and provides an interface on which specific transactions can be accurately tested and measured.

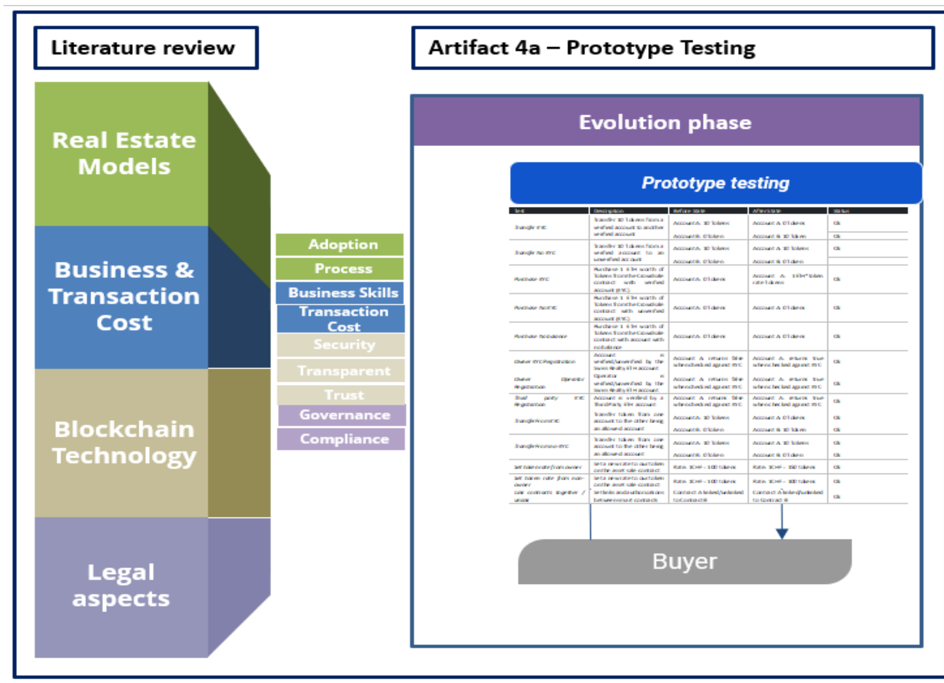

Figure 14. Artifact 4a - Prototype Testing (Evolution Phase) (Source: Steiner AG/Swiss Realty Model based on Dafflon, (Github, 2020))

Evaluation & Reflection: The conceptual model and prototype development presented were based on the expert panel interviews noted earlier. To build a reflection around the prototype, it is useful to provide the reader with a mapping of which points derived from the expert panel were considered in the prototype.

Testing Parameters

Adoption & Skills**:** Those principles governed the choice of the blockchain itself. A blockchain with an already high number of users and a valid cryptocurrency was required as well as one that has many developers and people working with it daily. As such the prototype was developed on Ethereum.

Governance**:** The focus on governance here lies in the organization needed to manage accounts authorized to perform transactions. The prototyped KYX/AML smart contract holds at its core mechanisms to efficiently manage authorizations. Those mechanisms permit several behaviours such as third-party authorizations of accounts, the ability for accounts to check whether they are authorized, the ability for external accounts to audit the accounts authorized.

Compliance**:** As outlined by the experts, the compliance principle is probably the toughest and hardest point to include in the prototype. The compliance aspect of the project mostly passed through the implementation of offline corporate structures, the production of legal and financial documents, and the notification to regulatory bodies of the activities performed on such a platform.

Cost**:** The cost attribute of the prototype is rooted in the use of the Ethereum blockchain. As described earlier, the Ethereum blockchain runs on an essential crypto currency which is ETH. In the Ethereum blockchain, ETH serves to provide incentives to the participants to mine transactions.

This study has tested an ETH transaction of 0.16 ETH which at the time of the transaction represents approximately a transaction of 21.5 EUR and took less than 30 seconds for completion with a cost of 0.000105431 ETH, which represents approximately 0.01 EUR to be processed.

Security**:** Security has been included in the prototype by implementing the recommendations from the community and following the ERC777 standard but also by implementing the logic/storage structure that allows the developers to update and patch existing threats in their smart contract implementations.

One can easily check the blockchain transactions that occurred within the smart contracts and check the relative benefit of the solution from a transaction cost and time management perspective.

4.2.9 Application of the ADSR Methodology – Artifact 4b Prototype Statistics

Problem Formulation**:** Quantitative data was collected to further elaborate on the utility of the developed and prototypically tested concepts. Peffers et al. (2012) propose various artifact evaluation and validation techniques which include demonstration, simulation, experimentation (lab or case study), using metrics, benchmarking, logic reasoning, mathematical proofs, field studies, dynamic analysis, expert evaluation, functional testing, action research among others. During the empirical study of the data-intensive survey (N= 700),) the output and input of the respondents are measured and the data is used to understand the relations, causalities, and determine the utility and relation function by the regression analysis and test the validity, utility, quality, and efficacy of the prototype development.

Artifact Creation**:** An important aspect is the use of the term kernel theory which refers to the behavioural theory that forms the core of a design theory. There is a broad consensus that kernel theories are theories from natural or social sciences and serve as a foundation for artifact construction (Walls et al., 1992). In this study, kernel theory is applied to derive market behaviour from statistical analysis. Subsequently, the statistical analysis provides a solution for the meta-design a class of artifact conceptual models (Design) and prototype development (Implementation) and validates the artifact construction, and provides evidence of whether the prototype development fulfils the criteria to address the problem space.

5 Discussion

This study contributes to the advancement of understanding of how blockchain technology can support the digital transformation of the commercial real estate market by identifying eight potentials and four factors. The emergent prototype from this study shows that traditional commercial real estate processes can be encoded as an ERC777 smart contract, which leads to the reduction of transaction costs and a tokenization-driven increase in revenues and profitability. Thereby, a variety of contributions both to the academic debate and to business practice can be derived.

In the academic context, the study contributes by advancing the theoretical understanding of the use of blockchain technology and smart contracts in the context of innovative approaches to commercial real estate. By the application of ADSR, the study provides a novel methodological approach for the exploration of this subject combining a systematic study of the literature, the subsequent development of a conceptual model, the practical application of the suggested model by the development of a prototype, and the empirical evidence of both artifacts in a qualitative and quantitative manner.

First, the study distilled the main insights from a wide range of academic literature in the field deriving the current state of play with regards to the role of blockchain in commercial real estate. Second, the study developed a conceptual model on this basis delivering a theoretical foundation for the renewal of commercial real estate transaction processes from human, paper-based, and prone to error solutions, toward fast, transparent, reliable, low-cost, efficient, and secure digital smart contracts. This can represent a key trust component for all the stakeholders. Third, the study transferred the insights gained by this model and developed a prototype to illustrate that the suggested approach for the application of blockchain technology for smart contracts in commercial real estate works in practice and yields advantages for both users and businesses. The study thereby contributes a practical use case demonstrating the formerly theoretically discussed potentials. Finally, the study embraces a triangulation approach using ADSR to frame a mixed-methods study. It combines qualitative, quantitative, and practical (coding) inquiries into the use of blockchain technology in the context of commercial real estate contracts.

From a practice perspective, the study contributes by providing guidance for a potential application of smart contracts based on blockchain technology in the commercial real estate sector. Related to the first research question, three concrete contributions can be derived: first, faster speed was performed within seconds. Transaction execution was done faster than through bank transfers as the transaction clearing is performed on the chain itself with only a few seconds for execution. Second, lower transaction fees, and low fees on transactions nationally and internationally (a blockchain is borderless) proved handy to reduce impact on yield. Recording transactions on the blockchain will certainly make notarized legal acts redundant in the future. We can imagine that notaries will start to simply stamp Ethereum transactions directly on the chain rather than producing lengthy paper documentation, but this must be accompanied by industry-wide changes related to Swiss and international regulations. The transaction cost paid during the experiment has amounted to a 2 Euro payment in the form of ETH during the execution of the smart contract. Third, regulation and compliance are supported by the KYC/AML blockchain-enabled preselection of the appropriate legal buyers and sellers. In the designed system, the buyer identity is linked to the specific Ethereum account and therefore its stake is traceable throughout time. There is greater control over who will ultimately own the share of the investment since the ownership mechanisms are embedded in the token program itself. No shares can be held by an account uncleared on the KYC/AML contract, and the accounts are cleared and written on the KYC AML contract only by the contract owner (creator of the system) and authorized operators (regulators).

This study explained the key findings and contributions in the context of practical implications for both the academic and business world. It contributes to business practice by providing a deeper understanding of the transaction process of commercial real estate that a variety of elements play within an organization, particularly related to innovation processes. The transaction process of commercial real estate is analyzed based on the design science methodology that involves iterative phases for the purpose of artifact development (i.e., Artifact 1 and Artifact 2).

5.1 Implications for the Real Estate Industry

The prototype solution developed in this study was based on the ERC-20 Standard with later extension upgrade to the ERC777 which offers a large investment possibility for the future and enables access to crowdfunding mechanisms for low-income target groups. It thus provides social participation in the real estate market in contrast to the traditional real estate contracts and transactions characterized by high market barriers, asset-illiquidity, and exclusivity for only quality investors with high capital. However, future trends of the blockchain technology go beyond the tokenization of the real estate properties. The trend goes in the direction of “tokenomics” where any type of asset could be tokenized. As an example, the tokens could be a future concept for the real estate eco-system where there could be cheaper access to capital for less demanding returns and, on the other hand, may provide a constant source of international capital for the general economy. The finance industry has been functioning with centralized exchanges for a significant length of time. Even in the context of cryptocurrencies, the underlying models facilitating the functioning have been centralized for a long time. Although most people are familiar with centralized models, many have also been the victims of its drawbacks and are now in search of decentralized models where they don’t have to trust a third party with their finances.

The future trend goes in the direction of the Decentralized Finance (DeFi). In the context of informing business practice, further research could also elaborate on investor protection and trust creation to identify the relevance of distributed ledger technologies for digital governments (Pignatelli, 2019). Furthermore, a wider approach to blockchain-based solutions (tokens) could potentially unlock incremental advantages to existing processes due to the nature of their higher liquidity, tradability/fungibility, and the automatization of the specified processes. One could argue that decentralization should be embraced by institutions to give back power and control to the people. Decentralized exchange platforms are the platforms for the cryptocurrency exchange, which does not require the users to deposit any funds to begin trading, as users can directly trade from their own wallets to make transactions. Hence, it facilitates P2P transactions.

6 Conclusion

This study was motivated to provide important insights into the transformative potential of blockchain technology and smart contracts in the commercial real estate sector. By decoding traditional processes into smart contracts and embracing tokenization, the industry can overcome barriers, reduce transaction costs, and realize increased revenues. The findings contribute to both academic discourse and practical implementation, laying the groundwork for a more efficient and accessible global commercial real estate market.

The key findings reveal that encoding commercial real estate processes such as ERC777 smart contracts results in reduced transaction costs and drive revenue and profitability through tokenization. Utilizing ADSR, this study amalgamates a systematic literature study, conceptual model development, prototype creation, and empirical evidence analysis. In doing so, this study provides a robust foundation for understanding the theoretical and practical implications of integrating blockchain technology and smart contracts into commercial real estate practices.

In this context, the scientific progress of this research, not only showcases the transformative potential of ERC777 smart contracts and tokenization in commercial real estate but also introduces a novel methodology for the exploration of this subject. By advancing theoretical understanding and providing practical insights, this study provides direction for further research within the commercial real estate industry. In doing so, this study provides an important platform for future scholars to contribute to the evolving discourse on tokenization, providing a deeper understanding of its implications for commercial real estate and uncovering new avenues for research and industry application.

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