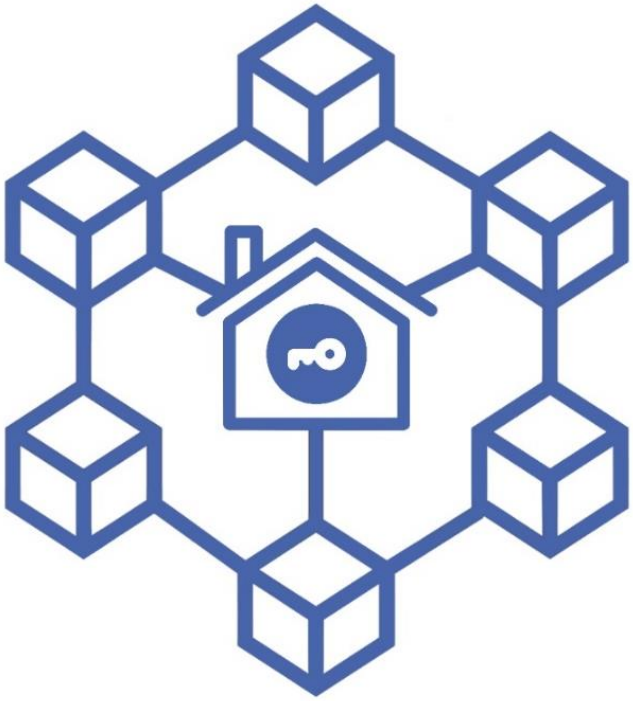
Non-fungible tokens and real estate:

exploring the possibilities for enabling a new market for real estate properties

Design Science research developing an artefact to use NFTs for Real Estate Transactions

Master thesis - MSc Business Administration and E-Business



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Abstract

This thesis aims to understand whether NFTs and blockchain technology can be utilised to decrease the obstacles young adults have to overcome to become homeowners. Innovations around real estate investing are happening, but seemingly none is focused on buying a property. Following the Design Science strategy, a design has been developed to solve the identified issues. The artefact is based on design principles obtained from the secondary data collected and direct feedback from potential users. The final iteration presented in the paper has been evaluated with data collected from experts on the housing market, real estate innovation, fractionalised real estate investing, and tokenised real estate. The artefact allows an individual, the *Managing Partner*, to own a fraction of a property and live there. In contrast, other individuals, the *Limited Partner*s, own the remaining fractions of the property, which are intended as an investment vehicle and do not grant living rights in the property. Such a duality is empowered by creating the *Managing Partner NFT*, representing a fraction of the property and living rights in it. On the other hand, the remaining part of the property is divided into regular ERC20 tokens.

The potential benefits users would have from using the solution has been confirmed to be increased liquidity, accessibility and a lower entry barrier to buying real estate. Furthermore, significant improvements to the real estate industry could be empowered by adopting blockchain technology, for which the solution could act as a driver.

Nonetheless, the successful future implementation of the proposed artefact relies on extensive continued research around certain areas, such as investment analysis, the willingness of users to use the solution, two-sided markets. Despite being out of the domain of this research, also legislative barriers are a significant barrier in the potential adoption.

Finally, it must be noted how only a portion of the whole property acquisition process has been demonstrated and analysed. Hence, future research is needed to analyse the missing steps. However, in its current status, the artefact could be used by individuals who trust each other and the technology enough not to need legal guarantees for its use, similarly to Bitcoin's first adopters.

Keywords: Non-fungible tokens; blockchain; real estate; real estate investing

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1 Introduction

The lack of affordable housing has become a significant talking point in Denmark, especially in and around Copenhagen and other large urban settings. Investing in real estate can be a hefty cost, especially for young people who might not have had many years to save for the high expenditure. Acquiring homeownership has long acted as a way of gaining and storing personal wealth, becoming a homeowner thus offers an immense potential to influence a person's wealth accumulation, but that also puts high importance on the loan terms available to the individual (Deloitte, 2018; Arundel R. , 2017)

When someone wants to finance a home in Denmark, they are required to put down at least 5% of the total expense of the property, as 80% of the total loan sum can be covered by a mortgage loan, while the remaining 15% can be financed through one's financial institute, these percentage points are fixed by the Danish law (Realkreditrådet, 2016).

A property can have a high value attached to it, both economically and emotionally, which makes the buying decision and process very important, and many variables and factors should be considered. In terms of the economic expenditure, many different variables should be regarded, such as tax rules, investment risk and the overall impact on the homebuyer's economy.

Regarding the technological advancement argued to potentially mitigate such issues, blockchain has been recognized to offer possibilities to drive change in the industry. Notably, thanks to the possibility of reducing high transaction costs and processing time caused by the several third parties involved in the transfer and funding of property ownership (Laurence, 2019). The main point of having these third parties in the proceeding is primarily to facilitate trust. In this regard, blockchain technology could offer a viable alternative as it removes trust as a central point of doubt. Hence, governments have backed investigating how blockchain can record land ownership and, potentially, make the process of transferring ownership instantaneous (Laurence, 2019). Another debated use of the technology is trading real estate and fractionalizing properties via "tokenization" (Karayaneva, 2021). Throughout 2021, a particular type of token, NFTs (Non-Fungible Tokens), have become famous and frequently mentioned in prominent media outlets. Currently, the most well-known use case of NFTs is to trade digital art. However, as popularity has risen, speculation has been created widely about what other areas NFTs could be used for.

Notably, since NFTs allow demonstrating ownership of digital goods, speculation regarding their potential for real estate tokenization has begun (Karayaneva, 2021).

This thesis sets out to investigate whether the technological advances offered by blockchain and NFTs can bring actual, tangible benefits to the real estate market, leaving us with the main research question of this paper:

How can NFTs and Blockchain technology allow better access to the real estate market for young adults?

Following a design science approach, our research aims to answer the research question by proposing a conceptual design for transacting real estate with NFTs and blockchain technology. Our focus will be on the solution being made for the Copenhagen housing market. This is the principal place for the identified problem and the immediate availability of primary data regarding the designed concept.

Despite the growing interest in NFTs, different challenges remain. Especially in real estate, due to the technical and financial implications of linking an NFT to a physical asset. Additionally, real estate could present emotional attachment. Thus, the conceptual design must offer users trust when using it, stressing the importance of having as high security and transparency as possible. In return, the design could potentially offer benefits, such as low entry barriers for investing and higher accessibility. Since the research revolves around real estate transactions, immediate investment implications will also be considered. These implications count elements such as an investment asset's liquidity, investment entry barrier, and overall accessibility. Consequently, to answer our main research question, we are presented with a subquestion that aids in doing just that:

How can a solution utilizing NFTs and Blockchain technology for real estate transactions add value for both home buyers and investors?

The Design Science Research strategy is followed to propose an artefact that could allow NFTs to be used for real estate transactions. Such artefact aims at investigating the benefits of NFTs and blockchain for real estate transactions for young people and investors.

2 Methodology

2.1 Research Philosophy

The research philosophy underpinning this thesis is **pragmatism**. This philosophy has been selected due to its focus on practical outcomes rather than abstract distinctions (Saunders, Lewis, & Thornhill, 2019, p. 151).

Pragmatist research starts with the identification of a problem and it considers practical solutions that can inform future practice as acceptable knowledge (**epistemology**) (Saunders et al., 2019, p. 151). This philosophy was considered suitable and well-tailored with the exploratory nature of the research and the novelty of the field under examination.

Pragmatist research can vary considerably in terms of how 'objectivist' or 'subjectivist' the research will be (Saunders et al., 2019 p. 151). In the case of this research, a high level of flexibility and personal interpretations (both from researchers and primary data sources) are predicted to be employed. Therefore, the view is explicitly **subjectivist**. For us as pragmatist researchers, the research originates from a problem, sensing something is wrong, originating from our views as researchers, further underlining the subjectivist perspective (Elkjaer & Simpson, 2011). Consequently, the circumstances deemed to be in the wrong place by us as researchers will be analysed and the conditions diagnosed to develop thoughts for action on the area and propose a possible solution (Elkjaer & Simpson, 2011). Further, following the pragmatic philosophy, reality will be considered as the consequence of ideas (**ontology**) and the research will be driven by researchers' doubt and believes (**axiology**) with a reflexive intent (Saunders et al., 2019, p. 151,). Following the objectives of this philosophy, the scope of this research is not finding the objectively best application of NFTs for real estate, but rather exploring how this technology could be applied in a successful way.

Following this research design philosophy, the research strategy employed in the research will be Design Science Research, which will be described in detail at a later stage. However, it is relevant to communicate such a decision at this stage since it has consequences on both the research approach and methodological design.

2.2 Research Approach

The research will use an abductive approach of reasoning. Pragmatic philosophy leaves researchers with the freedom of selecting the best approach following the research problem and questions (Saunders et al., 2019, p. 151). An abductive approach has been considered the best option for this research since both induction and deduction presented some drawbacks (Suddaby, 2006). Similarly to the choice of the design philosophy, the novelty of NFTs and mainstream blockchain applications made it difficult to find theory-derived premises from which logically derive conclusions, as a deductive approach would require. Moreover, following the pragmatic nature of the research, the goal of this thesis is not the formulation of a theory, often expressed as a conceptual framework, as an inductive approach would require. Therefore, abduction was considered the most appropriate option since it is based on real-world observation and theoretical concepts. Further, this approach is likely to be used by pragmatism and is common for design theorizing because design theory aims at enabling search for a satisficing solution for a given problem (Saunders et al. 2019, p. 151; Pries-Heje, Lee, & Baskerville, 2011).

Abductive logic implies that known premises are used to generate testable conclusions (Saunders et al. 2019, p. 155). To achieve this goal, data is collected to explore the phenomenon under investigation, identify themes and patterns, and locate these in a conceptual framework. Finally, the framework is tested through subsequent data collection. For this research, secondary data regarding blockchain, NFTs, blockchain applications such as DeFi, and the real estate market will be collected and reviewed to explore the realm of possibilities for NFTs in real estate. After the main concepts are identified, primary data is collected from trustworthy sources and experts in both technology and business to obtain an overview of the phenomenon as complete as possible. After the first iteration of data collection is completed, the gained concepts will be used in an inductive process to develop a solution. Such a process will be conducted holistically to explain both the technological and business implications and potential of the proposed solution. Finally, the proposed solution will be tested by analysing the primary data gathered from the experts.

2.3 Methodological Design

Pragmatists use the method or methods that enable credible, well-founded, reliable and relevant data to be collected that advance the research (Kelemen & Rumens, 2008). Therefore, pragmatism does not require researchers to adopt a specific methodological design. On the contrary,

pragmatism pushes research to select quantitative, qualitative, or mixed research methods according to the nature of the research (Saunders et al. 2019, p. 181). In the case of this research, a mono method qualitative study. As the research follows pragmatist principles, the importance is not on whether a multi or mono method is applied, but more on the method enabling reliable, relevant and well-founded data to advance the research (Kelemen & Rumens, 2008). Our study will be cross-sectional, studying a phenomenon at a particular time (Saunders et al. 2019, p. 212)

As we will discuss in the following section, the design strategy adopted in this research is Design Science Research. Despite this strategy has very specific features, on a broader level, we can generalize our approach to an exploratory research design. Such a generalization can be done since the goal of our thesis is to investigate the problem of investing in real estate for young adults with a proposed novel solution involving NFTs. Such a goal is fitting with the main goal of an exploratory study, which is considered particularly useful for researchers that wish to clarify their understanding of an issue, problem or phenomenon (Saunders et al., 2019, p. 186).

2.4 Strategy and Purpose: Design Science Research (DSR)

The design strategy used in the thesis is Design Science Research (DSR). DSR is a research methodology commonly used in information technology design. Compared with other type of research methodologies, DSR is outcome-based. More specifically, DSR aims at addressing unsolved problems in innovative ways or solving problems in more effective or efficient ways (Hevner, March, Park, & Ram, 2004). Design science approaches this goal through the construction of innovative artefacts aimed at changing or improving the analyzed phenomena (Hevner et al., 2004). As this research aims at solving a problem with innovative technology, this research methodology has been considered well-fitting with the purposes of research.

DSR offers different research approaches, depending on the nature of the designed artefact and the objective of the research. The following subsections will describe the strategy adopted for the research and its purpose with reference to the possibilities offered by DSR.

The first step in the analysis is defining which steps the research needs to take to find a solution to the problem identified. Among the different DSR methodologies proposed by researchers, Peffers et. Al (2007) in *A Design Science Research Methodology for Information Systems* proposed a viable model to structure DSR to optimize the chances to find and test viable solutions (Peffers,

Tuunanen, Ruthenberger, & Chatterjee, 2007). The six steps introduced by Peffers et al. are based on the work of Hevner et al (2004), which is recognized as the father of DSR (Hevner et al., 2004). Furthermore, Hevner & Gregor approved the six-step proposition and based further research on it (Hevner & Gregor, 2013). The six steps suggested by Peffer et al. are:

I. Problem definition
II. Solution's objective
III. Create the artefact
IV. Demonstration
V. Evaluation
VI. Communication

The following subsections will describe how the researchers intend to approach each of the steps so to outline and describe how DSR will be applied in this research. It is worth mentioning that despite the process is depicted in a sequential order, there is no expectation that researchers will proceed sequentially from step (I) to (VI) in a linear manner (Peffers, et. al, 2007). Figure 1 depicts the process.

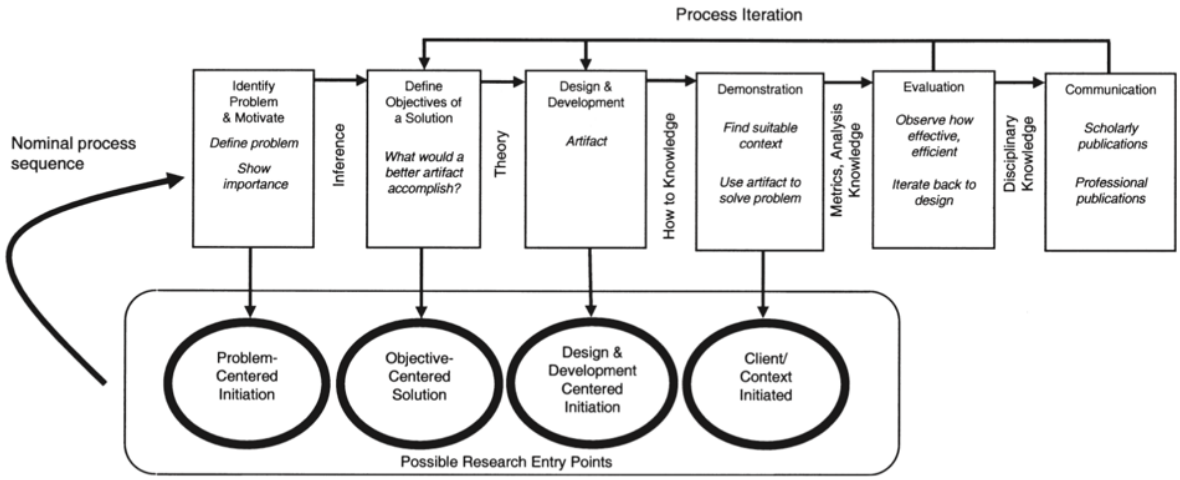

Figure 1. DSR Process Model (source: Peffers et al.,2007)

2.4.1 Problem definition

The first step requires not only to identify a problem but also to define its relevance. Regarding the identification of the problem, as stated in the introductory part of this thesis and in the literature review, the problem identified is the difficulty that young adults encounter when investing in real

estate. The detailed explanation of why the problem is considered relevant is provided at the beginning of section 4.

2.4.2 Solution Objective

DSR leaves researchers with freedom regarding the objective of their solution, which can be quantitative or qualitative (Peffers et al., 2007). Generally, quantitative solutions are expected to present artefacts that show how the proposed solution is better than the previous one. On the other hand, qualitative solutions aim at presenting novel artefacts that propose solutions for novel problems. Nonetheless, due to the various nature that artefacts can assume, identifying specific objectives can be difficult (Hevner & Gregor, 2013). To mitigate this issue, Hevner & Gregor (2013) introduced the '*DSR Knowledge Framework*' (Hevner & Gregor, 2013), depicted in Figure 2. The goal of the framework is to help researchers in choosing a research objective that allows a higher level of research contribution.

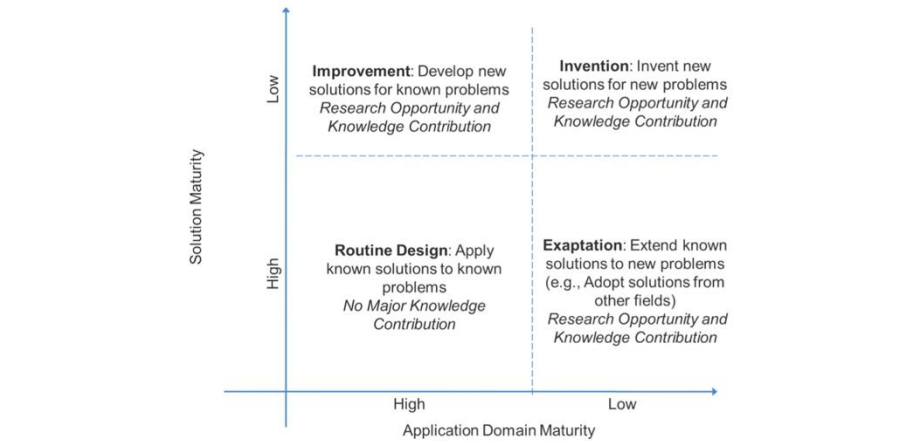

Figure 2. DSR Knowledge Framework – source: (Hevner & Gregor, 2013)

The framework introduces two main variables *Solution Maturity* and *Application Domain Maturity*. Concerning the *solution maturity*, the literature review section will present how several concepts and solutions of blockchain technology, NFTs and DeFi are already applied to a variety of fields and used by a good number of users. The aim of the artefact is to apply such concepts to the field of real estate. Therefore, it could be argued that the intended technological solution exists already, which will qualify its maturity as *High*. Regarding the *Application Domain Maturity* since little to no application of the inspected technologies has been applied to the field of real estate yet, it is qualified as *Low*. As can be seen in the framework, the solution corresponding to a high level of maturity and low level of application in the domain is **Exaptation**. Following the key features

of Exaptation (Hevner & Gregor, 2013), the objective of the solution will be to extend design knowledge that is already applied in other fields, namely DeFi and NFTs, to a new application area, namely real estate. Further, one of the requirements for Exaptation is that '*the new field must present some particular challenges that were not present in the field in which the techniques have already been applied*' (Hevner & Gregor, 2013), which is the case for real estate, as the field as intrinsic features and challenges as we will see in the literature review section.

2.4.3 Create the artefact

Before proceeding with the description of how the artefact will be created, it is relevant to explicate what constitutes an artefact in the first place. An artefact can be a construct, model, method, or instantiation (Hevner et al., 2004). More broadly, an artefact can be any designed object in which a research contribution is embedded in the design (Peffers et al., 2007). Therefore, it can be argued that the artefact does not need to be a functional prototype but, as long as its evaluation allows to create a research contribution, any artefact can be considered valuable. Despite these definitions help us to understand what the final scope of an artefact is, it could be argued that they are quite broad in describing what an artefact is (Peffers et al., 2007).

To mitigate this uncertainty, (Hevner & Gregor, 2013) presented three levels of maturity for artefacts. They argue that DSR can produce artefacts belonging to one or more of these levels of maturity. More specifically, level 1 artefacts are defined as those consisting of a working prototype and are tested in a precise use case, allowing us to test the technology in practice. However, since the application may be regarded as a specific case study, abstraction and extraction of underlying principles may be difficult or not possible (Hevner & Gregor, 2013). Concisely, level 1 artefacts could be argued to represent the 'how' a novel artefact would work. Often from a technical point of view. Level 2 artefacts are defined as '*the overall method description, the constructs, the design principles, and the implicit technological rules*' (Hevner & Gregor, 2013). They are more abstract than level 1 artefacts which allows them to be operationalized in several other unstudied contexts, thus greatly increasing the external validity of the research. As stated, the research objective is to study how NFTs could empower new possibilities for real estate. The intention for the artefact is to identify the main **design principles** required to develop a solution to solve the identified problem. Therefore, a level 2 artefact is the maturity level more suitable for the research.

Moving from the objectives outlined to the design of the artefact described in this section requires resources such as knowledge of theory that can be studied to propose a solution (Peffers et al., 2007). Therefore, in the literature review section, the main use cases and features of NFTs and DeFi in other fields will be studied to identify the key design principles and concepts of such applications. Such an analysis will allow creating a conceptual design aimed at understanding how new business possibilities and models could be introduced in the field of real estate with the use of the key principle discovered in the literature review section. A more detailed explanation of the process that led to the creation of the last iteration of the artefact presented in this research is provided at the beginning of section 4.

2.4.4 Demonstration

This phase aims to demonstrate the artefact's use to solve one or more instances of the problem. Following the broad definition of an artefact, the demonstration phase also presents a good amount of interpretation. The use of the artefacts can be demonstrated in multiple ways such as experimentation, simulation, case study, proof, or other appropriate activity (Peffers et al., 2007). Following this description, it can be noted how this step is practical in nature. To demonstrate the use of the artifact in this research, the level 2 artefact created from the concepts highlighted in the Literature Review section will be tested to verify that it can solve the identified problems. More specifically, it will be tested that the proposed artefact can help mitigate some of the applicability of NFTs on real estate investing and the business implications from both the perspective of real estate owners and investors. Section 5 of this research illustrates the methods adopted to properly evaluate the artefact.

2.4.5 Evaluation

Demonstrating the utility, quality and efficacy of the designed artefact is as crucial as the creation of the artefact itself (Hevner et al., 2004). Therefore, creating a well-executed evaluation method is vital. The evaluation is conducted by observing and measuring how well the artifact supports a solution to the problem by comparing the solution's objectives to observed results from use of the artifact in the demonstration (Peffers et al., 2007). The creation of an effective evaluation method requires considering the specific features of the business environment under examination. Therefore, evaluation should include the integration of the artifact within the technical infrastructure of the business environment (Hevner et al., 2004).

Depending on the nature of the problem venue and the artifact, the evaluation could take many forms (Peffers et al., 2007). In this research, the artifact will be evaluated by interviewing experts in the field of real estate, blockchain, and real estate investing to test its feasibility. A detailed description regarding the considerations taken to execute on holistic evaluation are reported at the beginning of Section 6. It is important to point out that this research is considered as a starting point in creating knowledge on real estate and NFTs. Consequently, direct feedback from potential users will be considered and discussed in both the discussion section and conclusion part of this research. However, no further iteration of the design phase will be conducted based on users' feedback.

2.4.6 Communication

The final goal of the DSR method is to communicate the knowledge gained throughout the process (Hevner et al., 2004). More precisely, it is important to describe in a clear manner which is the problem analysed, why it is relevant, which is the designed artefact, its utility, novelty, and effectiveness (Peffers et al., 2007). (Hevner & Gregor, 2013) offer a publication schema for a Desing Research Study. In these regards they offer the same steps proposed by (Peffers et al., 2007) but they split the Communication step into two different steps: Discussion and Conclusion (Hevner & Gregor, 2013). Since this further division is considered fitting the research domain of this research, it will be adopted for this research as well. Consequently, the communication step will be achieved in both the Discussion and Conclusion sections. This is believed to allow communicating the objectives and findings of the research in a clear manner.

2.5 Time Horizon

The research is cross-sectional as it evaluates the research at a particular point in time where the semi-structured interviews are conducted (Saunders et al. 2019, p. 212). Hence, the study does not re-evaluate the change in the phenomenon by collecting data over time.

2.6 Data Collection

2.6.1 Primary Data

Our primary data has been collected from semi-structured interviews with professionals in their respective fields and unstructured in-depth interviews relevant for different stages of our research. This chapter will outline the interviews' preparation, collection, and processing. The main reason

for the choice of semi-structured interviews is to gain a richer understanding of the research topic and chosen as it fits well with the exploratory nature of our research (Saunders et al. 2019 p. 444). Since our research has a subjectivist view, the data collected represents the meaning found between the view and interpretations of the individuals interviewed and us as researchers (Denzin, 2001). The semi-structured interviews consisted of experts within related fields. These fields are mainly the housing market, real estate innovation & fractionalized/tokenized real estate investing. We interviewed Marc Lund Andersen, senior economist at the Danish Knowledge Centre for Housing Economics, for the housing market area (Boligøkonomisk videncenter). Nadim Stub, former CEO at Proptech Denmark and current Group Vice President of Digital Ventures and Partnerships at DEAS group. To explore the topic of tokenized real estate investing, we interviewed Jonas Lodahl, who serves as a business developer at Digishares. Mads Harmsen, Head of Governance & Risk at The Many, gave us a perspective into the fractionalization of real estate investing already in place on the Danish market. Meanwhile, unstructured interviews were also added to the research to demonstrate our artefact to potential users and capture important feedback to incorporate them into the artefact design. These informal, unstructured interviews will be further explained later in this chapter.

2.6.2 Data Quality

Before each interview, we have carefully assessed specific data quality issues, and these variables related to the data quality has been taken into account when formulating the interview questions. An important thing to note here would be related to interviewee bias (Saunders et al. 2019 p. 447). To get a well-rounded overview of the housing market and potential elements holding back young people from investing in real estate, we sought to identify an expert with a low bias related to the subject but a sizeable overall knowledge on the matter. It was essential to explore all elements that could hold young people from investing, so we aimed to find a candidate with the least possible bias, making them reluctant to disclose any relevant information on the area fully. Consequently, the interview with Marc Lund Andersen was conducted, who works for the Knowledge Centre for Housing Economics (Boligøkonomisk videncenter). As a senior economist, he works for an organization with the purpose of being professional, impartial & neutral (Boligøkonomisk Videncenter Website, 2021).

As for the other three semi-structured interviews conducted to evaluate the potential of the artefact on real estate investing, the interview guides were also formulated in an exploratory manner to

keep the discussions very open, as the artefact evaluation would also be very exploratory. A fair amount of bias related to each interviewee, as they were all working for companies who would likely be influenced directly by the implementation of the artefact, which is also the main reason why the artefact was never presented to them. Consequently, the interviews with these three people working within the real estate investment realm consisted of relatively open questions to capture their general perception of the topic related to the specific questions. Due to the exploratory nature of our research, these semi-structured interviews lay the groundwork for testing the concepts identified based on the collected secondary data to capture a holistic overview of how these concepts and the artefact are affected by each other.

2.6.3 Preparation

Before the semi-structured interview and contacting possible interviewees, we carefully assessed specific elements related to the interview to gain the richest insight from each interview. This included considering our own knowledge on the subject, creating interview themes, and taking the appropriateness of the interview location into account (Saunders et al. 2019, p. 451). Due to offering as much flexibility and convenience as possible for the interviewees, we explained the possibility to do them either in-person or online. All interviewees, both for the informal interviews and the semi-structured, were conducted online via either Microsoft Teams or Zoom, except for the interview with Marc Lund Andersen, which was conducted at his place of work, Knowledge Centre for Housing Economics.

2.6.4 Interviewing/Processing

When we conducted the interviews, we discussed certain things beforehand about conducting the interview practically. These measures laid out our strategy for the execution of the interviews and were made to make sure that we tried to avoid bias to an extent, not to affect the quality of the answers provided by the interviewees (Saunders et al. 2019, p. 455). During our semi-structured interview, we made sure that the interviewees were informed and asked if the interview could be recorded. Other than making sure the practicalities were in place, to keep data validity high, we made sure to stick to the already formulated questions as much as possible to get answers to the exact areas where we were seeking them. However, importance was put on serving the interviewee follow-up questions when they offered an answer that we found served us new knowledge on the topic that we had not yet thought of or discovered throughout our preliminary research.

2.6.5 Seven stages of an interview inquiry

Other than already described measures for our interviews, to prepare, collect and process our primary data, we looked to a sequential guideline from the seven stages of an interview inquiry by Kvale (Kvale & Brinkmann, 2018). These stages are *thematizing, designing, interviewing, transcribing, analyzing, verifying & reporting* (Kvale & Brinkmann, 2018).

Thematizing stage

Thematizing was the first essential step of our planning of primary data collection. To thematize our data collection, we first had to clarify the purpose of the study, gain substantial background knowledge on the subject at hand for the specific interview, and verify that our data collection method matched the purpose of collecting it in the first place (Kvale & Brinkmann, 2018). Having gotten a clearer understanding of our study's purpose, an explicit explanation was formulated on why primary data collection was needed from a specific source, followed by a list of who/what suitable sources to gain this data from. A somewhat representation of our prior knowledge on each subject theme by us as researchers, however, should reflect the interview questions formulated, as for the interviewee to know that the knowledge we gain from their answers is new (Kvale & Brinkmann, 2018). Our study then boiled down to certain specific 'why' and 'who/what' these sources would consist of. Three separate themes were identified for our research, 1) real estate investment in urban settings for young adults, 2) innovation and market developments in real estate & 3) Tokenized/Fractionalized real estate investing.

Our research warranted a more in-depth and exploratory angle on the possibilities and prospects for young people to invest in real estate in urban environments to gain a clearer perspective on the knowledge we had acquired on the subject of private real estate investment. Following these initial thoughts on why and what kind of knowledge we needed to acquire, the theme for this specific primary data was pointed out as being real estate investments in urban settings for young adults. For this theme, various stakeholders of a real estate investment were considered. However, to keep data quality and relevance high, we looked to industry associations for our primary data source for this theme. This interview was exploratory, thereby following the structure of more flexibility, allowing new information and angles on the topic to be displayed (Kvale & Brinkmann, 2018).

Our research called for additional primary data collection themes besides real estate investment and young adults. Having gained housing market knowledge, we looked for professionals to evaluate the artefact's direct implications. This part of our research was identified with the theme being innovation and market developments in real estate. As we had the purpose of exploring how a solution based on NFTs and blockchain could answer the identified problems, talking to someone with knowledge on innovation & digitalization in the real estate industry was necessary. Since this interview were conducted to explore the effectiveness of the designed prototype in practice, they will follow the tendency of these interviews to be more structured, exploring certain elements (Kvale, 2019). For the first theme, "innovation and market developments in real estate", the primary data originates from a semi-structured exploratory interview with Nadim Stub, who currently serves as the Group Vice President of Digital Ventures and Partnerships at DEAS, a property and asset management company. Previously, Nadim had been the Managing Director and CEO of Proptech Denmark, which serves as an innovation hub for real estate in Denmark. Furthermore, he serves as executive advisor to different Proptech startups & real estate technology consultants while serving on the board for a few of them. Consequently, we viewed Nadim to have an extensive overview of the industry and specifically crucial for our research, previous knowledge and experience with the current movements and developments within the real estate market and innovation and digitalization.

For the third theme, tokenized & fractionalized real estate investing, we were fortunate enough to conduct semi-structured interviews, this time with Jonas Lodahl from Digishares and Mads Harmsen from The Many. The reason for reaching out and talking to Digishares as a company originated from our wish to understand the realm of tokenizing real-world assets. In this case, Digishares was the perfect example, as they were doing it with real estate properties. Jonas serves as a Business Developer for Digishares. He explained that he does not have a lengthy background in real estate. However, he has extensive knowledge of tokenization of real-world assets, blockchain and consequently a good overview of the use of NFTs in the area. Mads Harmsen works as Head of Governance & Risk at The Many and has a long history of working with banking and investment management. Thus, his contribution was deemed valuable, as he could provide us with insights into some of the aspects we wanted to explore related to fractionalized investment into real estate. The Many were chosen as they are already known to be doing this in Denmark.

Designing stage

After identifying different themes for our research needs, **designing** was the next pre-interview stage of our primary data collection. This stage revolved around our primary data collection (Kvale & Brinkmann, 2018). Besides the three overall themes identified to be needed for our research, under each overall theme, subthemes were pinned down to formulate a research interview guide better. For the theme of real estate investment for young adults, the subthemes and hereafter questions, developed for the research interview guide, can be found in Appendix 1. The exploratory nature of this specific interview reflects the interview guide to be more open and thereby allowing for more flexible follow-up questions, to gain richer insight into the area.

The interview regarding the theme of innovation and market developments in real estate, the interview guide was largely based on our design principles, as the main purpose here was to explore innovation and digitalization developments within the real estate market in order to evaluate the effectiveness of our designed artefact. The interview guide for this interview can be found in Appendix 2.

For the last theme, tokenized & fractionalized real estate investing, the interview guide for this theme was also formulated based on our design principles to understand the practical implications of the designed artefact. The interview guides can be found in Appendix 3 & Appendix 4. When designing our interviews, it is also essential to consider the number of interviews we would need for our research (Kvale & Brinkmann, 2018). For this last theme, it is valued to be essential to collect several interviews here compared to the other themes, due to the increased importance of this theme, as it is the closest to the purpose of our research in general, to explain what could be a practically possible solution, to the challenges faced for young adults to invest in real estate.

Interview stage

The **interview** stage revolved around the actual performance of doing the interview. We considered specific important points from Kvale's 7 stage model here. First off, we acknowledged the importance of setting a proper stage for the interview, where we both made sure that the social interaction between us and the interviewee would be as natural as possible, and that our interviewees were briefed accurately on the purpose of each interview, to make sure that the knowledge produced from the interviews would be as appropriate for our research as possible (Kvale & Brinkmann, 2018). As the purpose of the interview was exploratory, we recognized a more significant responsibility of ourselves as researchers, to react appropriately to the answers

provided, allowing pauses between answers, and come up with follow-up questions, to verify the answers given or to gain more information of the specific question (Kvale & Brinkmann, 2018). As these questions can fall under the category of 'elite interviews', it was furthermore important for us as researchers to be knowledgeable about the topic, use terminology specific to that topic, as demonstrating knowledge on the area has the potential to gain respect from the interviewee, in the hope of achieving the right symmetry for our interview relationship (Kvale & Brinkmann, 2018). To move forward with the knowledge gained from our interviews, each interview was recorded, but only after agreement from every interviewee individually.

Transcription stage

After recording our conducted interviews, we used these recordings for the transcription stage. The transcription was transcribed into a more formal, written language to simplify the interview processing and save time. Thereby, the importance was not to make the transcript word-by-word, directly as spoken. We carefully selected only to include words influencing the direct meaning. For example, words said multiple times in a row were not included in order to make the transcription more simple to read (Kvale & Brinkmann, 2018). This process will then result in a discrepancy in words spoken in the actual recording and the resulting transcription. However, the reliability of the transcriptions will still be high, as repeated words and other words spoken outside of the context of the actual subject is deemed not to change the reliability of the transcription. Furthermore, the validity of transcriptions provided from this study is then based on the answers provided, as they are then used for our analysis of the answers provided. The transcription of the interviews can be found in Appendix 6, Appendix 7, Appendix 8 & Appendix 9.

Analyzing stage

Analyzing the transcriptions from our interviews was the next sequential step. As our interview guides had already analyzed different themes, we used the transcriptions to process the interviews. As to make our analysis of the transcriptions easier, actions such as adding sentences verifying that the meaning behind the answer provided was correct, as follow-up questions for our interviews were discussed by us as researchers beforehand, and were added if found to be fitting, making following meaning analysis easier and for some of the actual analysis process to happen during the interview (Kvale & Brinkmann, 2018). As mentioned previously in this chapter, the overarching factor influencing the analysis of our data collected is our approach to work abductively due to our pragmatic research philosophy. This brings more flexibility in the data

analysis and allows for a more dynamic process (Kvale & Brinkmann, 2018). Thematic analysis was conducted to analyze the primary qualitative data collected, as it has been referred to by Braun and Clarke (2006) as a 'foundational method for qualitative analysis (Braun & Clarke, 2018). After the interviews conducted had been transcribed, a coding process was performed. To make the overall research more meaningful and find patterns in the meaning provided by our interviews, we coded the transcripts by finding keywords for the coding. We then attached sentences with meaning related to those specific keywords (Kvale & Brinkmann, 2018). It should be noted that the process was not done in a linear progression, as throughout the analysis of our collected primary data, we identified new meanings and looking back at the old data with the new knowledge, making for a very flexible and refining process, where new data continuously would add to and improve old data, and vice-versa (Saunders et al. 2019, p. 652). The coding was done in practice with Nvivo software.

Furthermore, this process was done to analyze the data found and then relate the primary qualitative data collected to the secondary data, select theories & literature identified for the research. As our research follows an abductive approach, specific codes were pre-labelled for the process, while others were identified throughout the coding (Saunders et al. 2019, p. 652). Finally, the coded interviews were clustered together based on the critical design principles identified for our designed artefact, then used to evaluate and analyze the potential effectiveness of solving the identified problems related to the proposed solution. All the codes identified in our study is available in the coding book, as seen in Appendix 10.

Verifying stage

The verifying phase for each interview has been a thorough process, as data reliability, validity and forms of bias have been considered, among others. Due to the subjective view of some parts of our research, the degree to which the interviewee would have potential bias were considered when data related to the interview were used. These considerations were carefully done, as mentioned previously in this chapter.

Reporting stage

The processed interviews would then make up an essential part of the overall research contribution of this paper. We made sure to check with the interviewees whether the data they provided would be confidential or not to share the knowledge gained further. An ending dialogue for ensuring data accuracy was introduced, so we as researchers could contact the interviewee if we had any doubt

of the way we interpreted the meaning of what they said. They also had the chance to contact us if they wanted specific parts not to be disclosed.

2.6.6 Informal unstructured interviews

To demonstrate our artefact and test it to limit potential problems and whether the problems we have identified within the real estate market and investing can be solved by using our solution, we conducted a series of unstructured interviews. As our knowledge base was limited regarding whether our identified users deemed the artefact suitable to use before the interviews were conducted, the informal, unstructured interview type was chosen. In practice, this was done by presenting the interviewees with a PowerPoint presentation visualizing using the artefact. At the same time, we explained how it would plan out in practice with words. After and throughout the presentation, the interviewees were encouraged to ask questions and provide feedback whenever they saw fit. Thereby, we capture feedback on initial first thoughts of the artefact from individuals we had identified as potential users of the artefact we had proposed to them. The interviewees were found by considering a shallow generalization of whom we would identify as possible users for the platform. One of the main criteria that we determined was a minimum of a slight interest in private investment to value investing criteria related to real estate. Other criteria for our selection were that the interviewees should have had experiences with some form of the housing market in Copenhagen, either through searching for places to invest and then live in or by the process of searching for a place to rent in the Copenhagen area. These conditions for choosing interviewees were not final, and either variable would not rule out the other.

The interviewees counted people in our inner circles privately and professionally. As the interviews were unstructured, in-depth interviews, emphasis was put on letting the interviewee provide as much of their opinion on the matter as possible to explore their opinions in-depth and engage in a dialogue about their standpoints and opinions throughout the interview make the answers provided richer. Consequently, the interviews were informal and exploratory. They helped us gain insights into what parts of the artefact suited the needs of the users they intended to, what possible areas could constitute problems for the users, what we needed to evaluate, how that could be mitigated. As the interviews were in-depth, no predetermined themes or questions were made. Instead, we had ideas about what areas we wanted to investigate and then let the exploration of those areas up to the interviewees (Saunders et al. 2019, p. 438). Therefore, it was essential to have the interview be led mainly by the interviewees, and they were allowed to talk as freely as possible,

to let them know that their opinions and standpoints had the highest priority in terms of figuring out their viewpoint about the artefact (Saunders et al. 2019 p. 439).

Due to the high variation in viewpoints from the interviewees, the reliability of these data sets would be viewed relatively low, as replication would be hard to count on (Saunders et al. 2019, p. 449). However, since generalization is not an aim of these interviews, reliability is deemed less critical, as the research revolves around specific viewpoints on investors in the Copenhagen area. The themes discovered in these interviews can be found in Chapter 4, see Table 1. All the unstructured interviews conducted to test the willingness to use the artefact and to aim to identify possible problem areas were thus unstructured in-depth interviews, meaning that the interviewees were to speak freely and guide the talk. However, the interviews' overall guidance was done by us at the beginning of the interviews to establish the overall focus on the interview.

The informal interviews were conducted over two rounds. Firstly, we conducted 21 interviews with potential users for the first iteration of the artefact. After the artefact had been modified with the insights gathered from industry experts, the last round of 16 informal interviews was conducted. This last round was done to capture the final feedback, which will be further elaborated in the evaluation section of this paper.

2.6.7 Secondary Data

The secondary data collected throughout writing this thesis consists of peer-reviewed academic literature, business publications, news articles, market & financial databases, publications from trade organizations, books, journal articles, published surveys and organisations' websites. For gaining an entry point into the real estate problems faced by young adults, a large amount of quantitative data was collected, as with these things, it is often easier to understand when put into perspective with numbers, but also combined with qualitative secondary data, mostly related to experts commenting on the quantitative data, to put things more into context.

As it is with secondary data, it gave us the option to acquire a lot of knowledge and data relatively quickly, compared to primary data. However, a significant emphasis had to be put on making sure it was of the right quality (Saunders et al. 2019, p. 351). In terms of the quality of the data, we had to keep in mind that the secondary data collected, in most times, was collected for a different purpose than ours (Saunders et al. 2019, p. 353). This is particularly prevalent when analysing a new field such as the one of NFTs. In terms of views of using technology, but also investing in

real estate, we were careful not to go too deep into the interpretations of data on views of investing, as we acknowledge that these types of opinions and views change over time, based off social norms and legislation, among other factors (Saunders et al. 2019, p. 354). Consequently, we were careful to remember that any data that were not from very recent years did not necessarily leave out things we wanted to include in the data since they might not have had access to other knowledge related to it.

To obtain the secondary data we used in this thesis, we carefully selected where to source these from. Google Scholar, Eurostat, Wiley Online Library, Sciencedirect, Springerlink & CBS Libsearch were the primary databases we relied on for our data collection.

3. Literature Review

3.1 The real estate market

A decreasing number of young people own property in Denmark, while more are considering entering the real estate market (Whitehead & Williams, 2017; Møller, 2021). Notably, owner-occupied households have fallen rapidly over the last 30+ years in Denmark, especially in the age group below 30, where the number was 25% in 1987, but has fallen to well below 10% in recent years, as seen in graph 1, but also the age group 30-39 years have fallen in the same period (Whitehead & Williams, 2017).

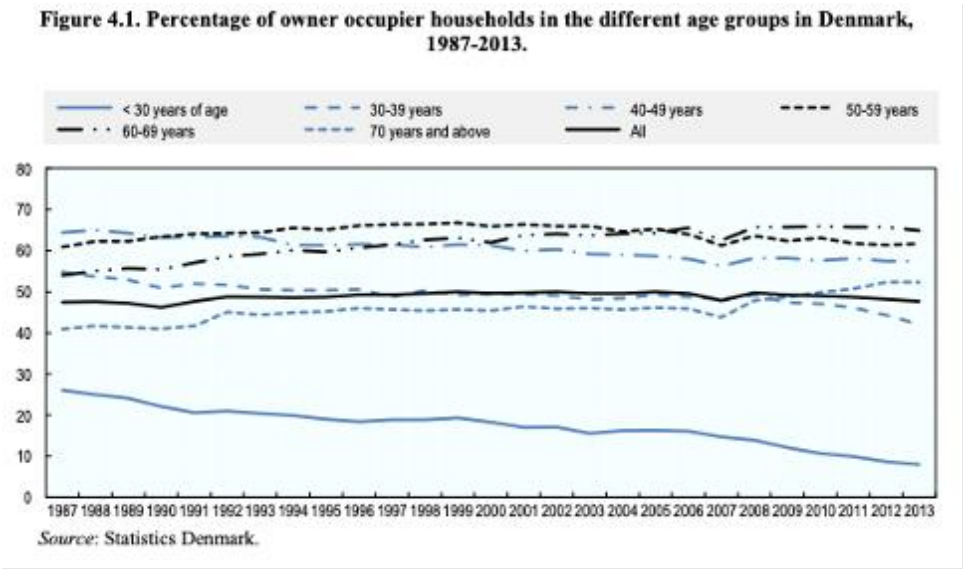

Figure 3 – Source: (Whitehead & Williams, 2017)

The following section of this thesis will review literature highlighting some concrete elements influencing whether young people can become homeowners for the first time. These elements mainly include the factors directly influencing whether buying real estate is possible. Aspects considered include housing affordability, overall housing burden, loan availabilities, ability to save up for a mortgage while renting and impact on down payment levels. Furthermore, the main idea behind modern portfolio theory, originating from "Portfolio Selection" by Harry Markowitz in 1952, will be incorporated to grasp how well investing into a house belongs with an investment portfolio composition (Markowitz H. , 1952). The concept of Housing Partnerships will be reviewed, as it offers a unique idea to innovate on decreasing the exposure to the investment one makes when buying a home (Chaplin, Tracy, Chan, & Freeman, 1997). Since REITs has been identified as a way to invest in real estate without buying real estate outright, literature highlighting characteristics of investing in these will also be included. Afterwards, to conclude this literature review, writings relating to clarifying blockchain technology, the evolution of NFTs and tokenization of real-world assets, notably real estate, will follow.

3.1.1 Housing affordability

The amount of capital a household spends overall on their housing held against the household's overall income is considered to assess young people's ability to save up for a mortgage to become homeowners. This metric, the housing burden, is included to stress the current income levels and housing prices. Denmark had the third-highest housing burden in the EU in 2020, as housing accounted for 26.4% of total household expenditure across total household disposable income, well above the EU average (Eurostat, 2020). The housing burden is exceptionally high in Copenhagen, and it has only increased in recent times – and lending rates have also increased (Hetland, Hviid, Pedersen, & Schmith, 2021).

The term housing cost overburden further underlines this, as it counts households, where the housing burden represents at least 40% of the household's disposable income. In 2020, the housing cost overburden was 9,7% in rural areas – and more than double in the cities, with 20,3% of households living in urban environments in Denmark paying more than 40% of total household disposable income for housing costs (Eurostat, 2020). Not only does Denmark have the third-highest housing cost overburden for households living in cities, but it also has one of the highest differences between living in rural areas or the cities for this metric (Eurostat, 2020).

When taking up a mortgage loan to finance buying a property in Denmark, individuals cannot exceed a loan-to-value (LTV) of 80%, which means that the traditional mortgage cannot exceed 80% of the total property value (Lunde, 2012). The remaining 20% can consist of a 5% downpayment by the loanee (the minimum required), while the additional 15% can be financed via a banking institute (Realkreditrådet, 2016).

During the COVID-19 pandemic, Danes have been looking to buy property more than ever, leading to a significant increase in real estate prices (Hetland et al., 2021). Research has shown that in the bigger cities, people attach a higher value to their homes as they are increasingly working from home (Davis, Ghent, & Gregory, 2021). The upsurge in employees working from home is expected to stay to some degree, further accentuating that individuals will value their home higher than they used to (Hetland et al., 2021). Research indicates that renting gives a housing situation that does not necessarily present an opportunity to empower individuals to save up for real estate but renting decreases the possibility of saving up to purchasing real estate (Forrest & Hirayama, 2015). It has also been found that a large part of the European population will struggle to achieve homeownership, in contrast to the widely believed thought that after the global financial crisis, homeownership would go back to growing rates again, following the significant decline throughout the crisis (Arundel & Doling, 2017).

Meanwhile, a study by Riley, Ru & Feng showed that low-income households from 2003 to 2011 would spend less on owned housing than renting an equivalent home (Riley, Ru, & Feng, 2013). Chiuri & Jappelli (2003) investigated based on international data from 14 countries on down-payment requirements and uncovered that younger age groups are significantly affected by mortgage finance availability (Chiuri & Jappelli, 2003). Consequently, increasing the downpayment requirement of a housing market lowered the homeownership rates directly (Chiuri & Jappelli, 2003). Andrews, Sánchez & Johansson (2011) confirms this, concluding that lessening down-payment requirement will increase homeownership rates among low-income households and pointing out the broader economic dangers of this, stressing the importance of having supervisory measures in place for loans when lowering the requirement for loans (Andrews, Sánchez & Johansson, 2011).

3.1.2 Modern Portfolio Theory

As it has gotten harder for younger people to purchase properties, especially in the larger cities, it is also relevant to consider the investment of purchasing a property to live in – in more economic terms of what the investment entails for a private fortune. Consequently, we are looking at the rationality of purchasing a home strictly in financial terms. Research has proven that purchasing a property for a person and his/her family is one of the best ways to acquire funds and build personal fortune (Arundel R. , 2017). Furthermore, we consider modern portfolio theory to grasp the investment into real estate held up against an overall portfolio composition. In 1952, Harry Markowitz published "Portfolio Selection", which stands as the beginning of what is now known as modern portfolio theory (Markowitz H. , 1952). It is seen as laying the foundation for what is known as Modern Portfolio Theory (Rubenstein, 2002). Markowitz's theory prescribed the optimal combination of assets for a portfolio selection by diversifying into different assets, achieving the optimal balance of investment return with risk (Markowitz H. M., 1991). Consequently, an investor should consider how one's assets are interrelated and not invest in assets whose value moves in similar fashions to spread risk and exposure, an example being stocks from the same industry or geographic region (Elton & Gruber, 1997). Therefore, the risk levels of a single asset are not the most important for a portfolio, but rather, which contrast that specific asset offers to the rest of a portfolio composition (Rubenstein, 2002).

Real estate has been proving to add excellent diversifying potential to a private portfolio, for example, through REITs, but are very similar to stocks and bonds in price developments (Andrew & Glenn, 2003). Due to the current difficulty investing in real estate directly originating from it being very illiquid, it is hard to include in a truly diversified portfolio today (Andrew & Glenn, 2003).

3.1.3 Housing Partnerships

In 1997, several American researchers wanted to investigate how to make home-buying a better purchase, in essence, solving the problem that "*... the second half of your home may be the worst purchase you will ever make*" (Chaplin et al., 1997). The authors suggested creating secondary markets, where shares can be bought into individual homes (Chaplin et al., 1997). A managing partner lives in the house, whereas limited partners can buy "the other half" (Chaplin et al., 1997). Their proposition is included as it brings a radically new way of buying a home. For one, the

pressure to save up large sums for a down payment becomes lower since the amount that needs to be saved is reduced when other investors buy a part of a property.

Furthermore, it means that the limited partner takes a significantly smaller risk in terms of investing in the real estate since their overall investment is smaller, making them less exposed to price movements during volatile market times and in general. As investors – both private and institutional, are always looking for new ways to add new asset types to their portfolios, in this case, investing in house price developments (Chaplin et al., 1997). The limited partner invests in the property and hopes for a price increase on the asset they have purchased, much like how investing in stocks works in practical terms (Chaplin et al., 1997).

3.1.4 Real estate investment alternatives to buying

As our research considers what options young people have regarding investing in real estate, literature around what current offers exist regarding real estate has been considered. Mainly, REITs (Real Estate Investment Trusts) have been identified as a way for investors to diversify their portfolios into real estate without buying a property outright. While literature regarding the actual performance of REITs will not be inspected, research regarding what this investment asset offers to investors, compared to traditional real estate, is considered. As an investment into the reliable income stream from rental, REITs offer a stable investment with modest risk, giving a chance to buy and sell real estate assets with the same ease as buying stocks, high liquidity and managed by experienced professionals (Block, 2011). REITs exist both as equity REITs, which revolves around trading and operating real estate properties, and sometimes sells them, and as mortgage REITs, making their profit from real estate collateralization with loans (Block, 2011). They offer great benefits, such as not needing to manage properties personally, and reducing the risk associated with total exposure to a single asset, even with the investor sharing profits with others (Block, 2011).

Other than REITs, another form of investing in real estate as an alternative to outright buying exists in Denmark, called co-operative housing (andelsbolig). The co-operative housing systems' main idea is that ownership of shares is issued, and then a shareholder is granted user-right to a home (Sørvoll & Bengtsson, 2020). The central thought behind the Danish co-operative housing system has been affordable apartments that are price regulated and influenced by limited profit (Sørvoll & Bengtsson, 2020).

3.2 Blockchain and its applications

The following section will analyse the definition of blockchain, the main features of this technology, how it operates and how it is currently applied worldwide. The section should not be considered as an exhaustive literature review concerning blockchain from a technical standpoint. The primary purpose of the sections is to provide an overview of the main features of the technology to identify its main concepts and how they could be used in the further phases of this research. Further, the purpose is to provide a simplified and brief explanation of the technology that empowers NFTs. The technical details are limited to those deemed strictly necessary to propose the application of NFTs for the real estate market under examination in this paper. More precisely, the first part of this section will depict what a blockchain is and how it works. Afterwards, the case of decentralised finance (DeFi) will be analysed to testify how blockchain applications have already allowed a previously centralised sector like finance to become more decentralised and how new business models and strategies have been developed while doing so. Further, this section will analyse the main features and applications of NFTs. Finally, the current applications of blockchain in the real estate sector will be analysed.

3.2.1 Blockchain, definition and main features

Following the definition provided by the World Economic Forum, a Blockchain, or distributed ledger technology (DLT), can be defined as a '*technological protocol that enables data to be exchanged directly between different contracting parties within a network without the need for intermediaries. The network participants interact with encrypted identities (anonymously); each transaction is then added to an immutable transaction chain and distributed to all network nodes.*' (Seffinga, Lyndon, & Bachmann, 2017). Despite being concise and correct, the definition provided by the World Economic Forum may be challenging to depict practically. Therefore, an example may help better understand how a blockchain works in practice. Among the possible example that could be chosen, the digital currency Bitcoin probably represents the best-known application of DLT. It can be argued to have been the catalyst that highlighted the potential of blockchain (Seffinga et al., 2017). Its anonymous creator (or creators), Satoshi Nakamoto, released the paper *Bitcoin* in 2008, establishing a new payment system based on blockchain principles (Nakamoto, 2008). Within this paper, Nakamoto established '*a set of rules—in the form of distributed computations—that ensured the integrity of the data exchanged among these billions of devices*

without going through a trusted third party' (Tapscott & Tapscott, 2018). Figure 4 depicts the process of how a bitcoin transaction would occur.

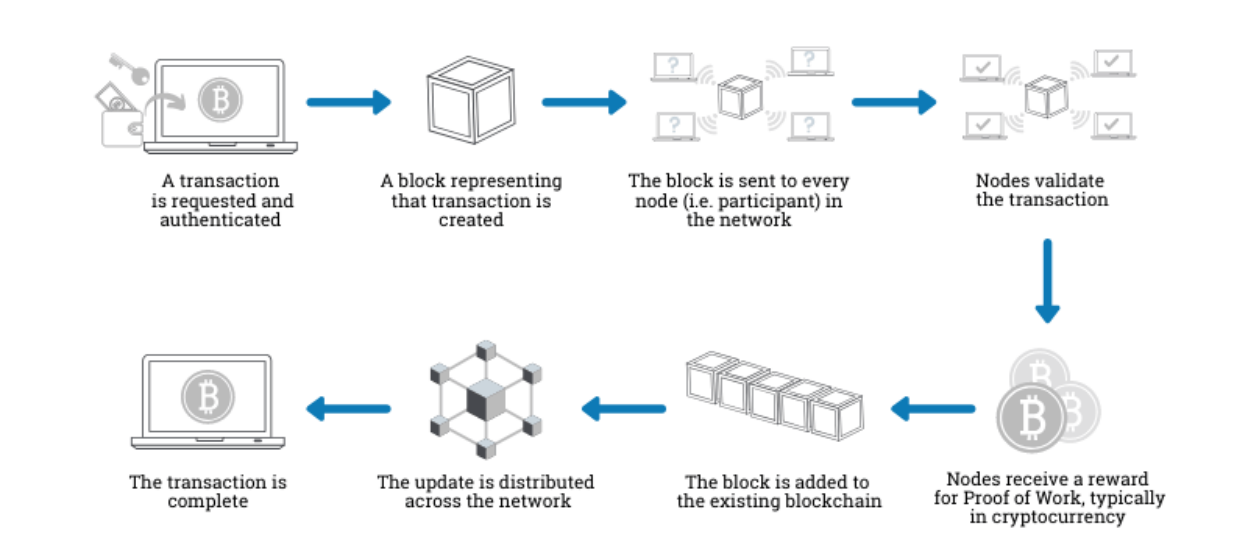

Figure 4. Process of a Bitcoin transaction - source: (Euromoney website, 2022)

(1) Person A wants to send a digital asset (Bitcoin, contract, data, etc.) to Person B, with what is called a **transaction**. (2) The transaction is added to a **block**, which contains multiple transactions, and waits to be validated. (3) The block is sent to all the **nodes** in the network and waits to get validated by. (4) Nodes **validates** the block. (5) Notably, in the case of Bitcoin, validation is done with the consensus mechanism, Proof of Work. (6) After being validated, the block is added to the blockchain. Blocks are connected to one another in what can be defined as a chain of blocks. (7) The updated version of the blockchain gets distributed across the whole blockchain network. (8) Once the blockchain is updated with the latest transactions, the initial transaction is completed, and B receives the digital asset sent by A.

After having looked at how the Bitcoin blockchain works, it is possible to extend this knowledge to all blockchain networks, identifying the following key features (Yaga, Mell, Roby, & Scarfone, 2018; Tapscott & Tapscott, 2018; Gupta, 2020) (Gupta, 2020): (I) it is a **shared distributed ledger**, (II) it is **consensus-based**, (III) it is **cryptographically secure**, and (IV) it is (almost) **immutable**.

Before analyzing those individual features in more detail, it is relevant to firstly introduce an essential distinction among blockchains, their permission level. Indeed, we can classify blockchain networks into two main categories: **public** (also called **permissionless**) blockchains

and **private** (also called **permissioned**) ones. The difference between a public and a private blockchain is that the public blockchain, as the name suggests, can be accessed by everyone. On the contrary, a private blockchain is accessible only to those who have access credentials for this blockchain (Gupta, 2020). Blockchain networks such as Bitcoin and Ethereum are the most used examples of public blockchains. On the other hand, private blockchains are mostly used for business consortiums since they allow to have more control over who can access the record of transactions on the blockchain network (Gupta, 2020). Because NFTs are exclusively traded on public blockchains, like Ethereum or Solana, only this typology of blockchain will be considered for the prototype development phase.

Shared distributed ledger

A blockchain is, in essence, a record of all the transactions across the network, and it is shared among all or several participants in the network (Gupta, 2020). This record of transactions is run by computers distributed worldwide and provided by volunteers, removing the need for a central institution (Tapscott & Tapscott, 2018). Although only nodes have the full copy of the ledger, all participants can access the entire record of transactions on the blockchain, ensuring complete transparency. The degree of distribution of a blockchain depends on its architecture, as covered in the following section. This means that, technically, a blockchain could also be run by a single node (Gupta, 2020). However, by increasing the number of nodes, the ability for a bad actor to impact the consensus protocol used by the blockchain is reduced (Yaga et al., 2018).

Consensus-based

In order to determine which block will be published first, different consensus models are adopted by different blockchains. In the case of permissionless blockchain networks, nodes compete to publish the next block to gain cryptocurrencies or transactions fees (Yaga et al., 2018). For example, Bitcoin miners are rewarded for block validation with Bitcoin. Different typologies of blockchain are better suited for different typologies of consensus models. In a permissionless blockchain network, the consensus model must consider the presence of malicious users and prevent them from harming the whole network (Yaga et al., 2018). Among the most used permissionless blockchains networks, which, as mentioned before, will be the sole focus of this paper, the most commonly used consensus mechanisms are the **Proof of Work** (PoW) and the **Proof of Stake** (PoS). Analysing how the two consensus mechanisms work is not the purpose

of this paper. However, it is possible to make a quick but satisfactory distinction between the two. PoW is based on a competition to solve a computationally intensive puzzle for users to validate the next blockchain block (Saleh, 2021). Differently, PoS replaces the need for high computational power with the need for validators to invest or stake in the system. For example, in the upcoming Ethereum PoS consensus mechanism, users will need to stake 32 ETH to become validators (Ethereum, Ethereum website 1, 2022). After this initial requirement is met, validators are randomly chosen to create blocks. They are responsible for checking and confirming blocks they do not create without the need for computationally heavy operations. The main idea behind PoS is that the more a user has invested into a system, the more likely the user will desire the system to succeed (Yaga et al., 2018).

The two analysed consensus mechanisms make tampering with a blockchain difficult and expensive. This difficulty made the term **immutability** become very popular when talking about blockchain networks. However, it is worth noting that no blockchain is indeed immutable (Yaga et al., 2018). With enough economic resources and computational power, it would be possible to attack a blockchain with a 51% attack. In essence, if someone would control 51 per cent or more of a blockchain network, this attacker could prevent the recording of new blocks (Frankenfield, 2021). However, such an attack would cost billions of dollars, and it would most probably cause the native cryptocurrency of the blockchain to drastically drop in value, creating little incentives to conduct such an attack (Greenspan, 2017; Ethereum, Ethereum website 1, 2022).

Cryptographically secure

An essential element that characterizes blockchain is its cryptographic security, which affects blockchain in two ways. On the one hand, we can find hashing. Hashing is a method where data of nearly any size (e.g., a file, text, or image) is given to an algorithm (the hash function), which returns a unique output (Yaga et al., 2018). Every block in a blockchain network has its own hash, which can be considered the block's fingerprint (Orcutt, 2018). This fingerprint creates a certain level of security within a blockchain network. First, it works as a seal for the block. Indeed, altering the block would require generating a new hash, making it clear that the block has been changed (Yaga et al., 2018). Secondly, each block contains the hash of the previous block's unique hash. This prevents any block from being altered or inserted between two existing blocks (Seffinga et al., 2017). So, if a malicious actor would want to change the data contained in a block, he would

need to calculate a new hash not only for the block under modification but also for any subsequent block (Orcutt, 2018). Such an action would require more computing power than the whole network, as seen in the previous section when discussing the concept of a 51% attack (Orcutt, 2018).

In addition to providing security and transparency to the blocks composing a blockchain network, cryptography also ensures security for **digital wallets**, which act as digital storage for blockchain assets (Gogel, 2021). Cryptography ensures the security of these wallets using asymmetric-key cryptography. Users are provided with two keys, a public key and a private key, which can be defined as long strings of numbers that are mathematically linked to each other (Tapscott, 2020). As the name suggests, a public key is meant to be shared with the other network members and can be seen as a public address. On the contrary, private keys are not meant to be shared, and they are used to sign users' transactions. This means that a sender uses his private key to encrypt a transaction. The receiver of the transaction, identified with the public key, can then decrypt it using his private key. Since the public and private keys are uniquely linked, only the owner of the private key linked with the public key can decrypt the transaction (Yaga et al., 2018). So, asymmetric cryptography prevents anyone but the private key holder from accessing funds stored in a cryptocurrency wallet, keeping those funds safe. This means that sharing the private key empowers other actors in the network to access those funds.

3.3 Smart Contracts and Decentralized Applications

Smart contracts are one of the most important innovations brought by blockchain technology. A *smart contract* can be defined as '*an application that runs in a distributed and trust-minimized manner on a blockchain*' (Szabo, 2017). Following the decentralized nature of blockchain, such an application is often referred to as a *decentralized application* or *Dapp*. The definition of a smart contract stated above brings up a crucial feature offered by Dapps, their capacity of running in a trust-minimized manner. Specifically, Dapps do not require any third party to run. Once the code is built efficiently, trust among the two parties signing the smart contract is not required. It is relevant to notice that being code dependent means that the code needs to be written securely to avoid flaws or hacks.

3.3.1 Decentralized applications in practice, the case of DeFi

This section will analyse the main principles and applications of one of the most employed blockchain applications, Decentralized Finance (DeFi). Before tackling such a description, it is worth mentioning that the section does not want to provide an exhaustive overview of DeFi. Such a goal would exceed the spatial limitation of this paper and be out of scope. Previous research has analysed in more detail the potential and limitations of DeFi (Gogel, 2021). This section will be limited to analysing the concepts considered relevant for the development of the artefact object of study in this paper.

Among the various fields of applications of Dapps, one that has seen exponential growth in the last decade is finance. Dapps applied to financial services have become one of the most debated and applied use cases of blockchain technology (Pawczuk, Walker, & Tanco, 2021). Indeed, they have become so popular that the term **DeFi** has been coined to identify them. Has mentioned, DeFi is a term that identifies Dapps focused on providing and enabling financial services on a blockchain (Gogel, 2021). Among the primary services offered by DeFi, we can identify payments, lending, trading, investments, insurance, and asset management (Gogel, 2021). The main difference between DeFi and traditional financial services lies in the lack of centralised institutions and intermediaries. DeFi does not rely on central authorities, and stakeholders create together a permissionless ecosystem with the primary goal of removing any entry barrier applied in traditional finance (Dain, Hays, Yorke, & Rosenberg, 2020). In traditional finance, intermediaries such as banks and big corporations have been historically required to ensure trust between two parties, while in DeFi, they are replaced by Dapps.

The following features are the ones defining DeFi and setting it apart from traditional finance (Gogel, 2021; Dain et al., 2020):

1. **Financial Services**: the Dapp directly mediates the transfer and exchange of value.
2. **Trust minimised operations and settlement**: DeFi apps are typically built on public and permissionless blockchains such as Ethereum, Solana, and similar solutions. All the transactions are executed and recorded on the public blockchain and visible to everyone.
3. **No third parties**: Dapps rely on smart contracts instead of humans for operations. Therefore, as long as the smart contract functions and the blockchain on which the smart contract runs is available, the process is automatised and always running.

4. **Non-custodial design**: in DeFi apps, users retain complete control over their assets by holding them in non-custodial wallets or via smart contract-based escrow. This allows users to always be in control of their assets and decide when to sell or exchange them.
5. **Open, programmable and composable architecture**: Thanks to the broad availability of the underlying source code and a public application programming interface (API), components can be programmed to create new financial instruments and services dynamically. Many DeFi applications and protocols are open source, allowing community developers to add features and build new apps.
6. **Governed by users**: The community-driven features depicted in the previous point also impact platforms governance in DeFi. Since one of the main features of DeFi is moving towards decentralisation and empowering platforms users, users can vote on platform governance decisions, which can include, for example, decisions regarding new features to be added. More about this can be found in the 'NFTs and DAOs' section.
7. **Low entry barriers**: Several DeFi platforms do not require Know Your Customer (KYC) procedures. Therefore, the only requirement for starting using the DeFi platform is connecting their digital wallet and having funds available to do operations. It is important to notice that this is true for decentralised exchanges (DEX). In contrast, centralised exchanges (CEX) require customers to conduct KYC procedures, and users need to provide their personal data and proof of identity by uploading personal documents such as a passport.

After describing the key features of DeFi, it is worth analysing its main fields of application. Despite being a relatively novel technology, DeFi has seen some major fields of applications in recent years. The primary use cases will be briefly identified here. However, only the relevant ones for this research will be analysed in more detail to gain an overview of their primary features and potential applications.

Overall, the following use cases for DeFi can be identified: (I) Stablecoins, (II) Decentralized Exchanges, (III) Credit, (IV) Derivatives, (V) Insurance, (VI) Asset Management. (Gogel, 2021; Dain et al., 2020; Schär, 2021). For this paper, the most relevant use cases are **Decentralised Exchanges** and **Credit**, and they will be further analysed in the following subsections.

Exchanges - Trading and Liquidity Providers

The trade of assets is one of the core features of DeFi. As mentioned in the previous sections, the trade of digital assets can happen on both DEX and CEX. The two typologies of exchanges present differences (Dain et al., 2020). In this paper, the focus will be on DEX and how they manage liquidity. Notably, **Liquidity Providers** and **Staking**.

Liquidity providers are essential for a DEX. Their function is to share their supply of tokens with the exchange so that the exchange can offer them to trade with other users (Dain et al., 2020). Having users providing liquidity avoids the exchange being in the position of needing to buy millions of tokens itself. The tokens collected from liquidity providers are collected in so-called **liquidity pools**, which allow other users to trade the tokens in the liquidity pools. In exchange for providing liquidity to the exchange, liquidity providers are rewarded with interests that come from a percentage of the transaction fees charged by the exchange (Schär, 2021).

Staking is similar to providing liquidity. Its main distinction lies in the fact that staking implies placing tokens into a smart contract or platform and not in a liquidity pool. This means that token owners must surrender control of their funds, which are transferred to the smart contract and held there. The main purpose of staking is to secure the network, provide liquidity for other purposes, or simply stabilise the token supply. Indeed, if the tokens are staked, they are not anymore in the owner's wallet and must be unstaked before being sold. In return for their services, user staking tokens gain passive income, often in the form of a traditional annualised percentage (APR), governance tokens, or both.

Lending and borrowing

Similarly to traditional finance, DeFi allows essential finance operations such as **lending** and **borrowing** assets. However, in DeFi no third-party intermediary is required between two users to perform a credit check is required (Schär, 2021). The entire process is automated thanks to blockchain. Loans are secured with **collateral**, which is locked in a smart contract. Once the debt is repaid, the collateral is released from the smart contract.

DeFi loan platforms currently present three main variations: *Collateralized debt positions, pooled collateralized debt markets*, and *P2P collateralized debt markets* (Schär, 2021). The main difference between these typologies lies in the nature of the collateral. Collateralized debt positions (CDP) platforms issue new tokens backed by the collateral, generally in the form of a stablecoin.

On the contrary, both pooled and P2P collateralized debt markets allow borrowing existing crypto assets (not necessarily stablecoins) from someone else rather than creating new tokens. For this research, no further investigation regarding the different mechanisms is required.

To further explain what a borrowing procedure may look like, we will use *MakerDAO* as an example (Makerdao website, 2022). MakerDAO is a decentralized protocol used to issue the USD-pegged *Dai* stablecoin (Makerdao website, 2022). In order to get a loan, a user firstly deposits ETH, which will act as collateral, in a smart contract. After the ETH is locked in the contract, the users can withdraw a certain amount of Dai. The amount of Dai depends on the minimum collateralization ratio, which is currently 150 per cent. So, with 100 USD worth of ETH locked in the contract, the user can withdraw a maximum of 66.66 Dai, corresponding to 66.66 USD. After obtaining Dai, the user can use it for buying other assets. To close his debt, the user must send the borrowed Dai, plus interest, to the smart contract. Once the debt is repaid, the initial ETH used as collateral can be withdrawn. The smart contract will **liquidate** the collateral to repay the lender if the user fails to repay his debt. Liquidation can also happen if the value of the assets locked in the protocol declines beyond a certain level. In this case, the smart contract automatically liquidates those assets and repays the lender (Tapscott A. , 2021). For example, if the price of ETH had to fall in value to a large extent compared to its price when the debt was started, the smart contract can liquidate the borrower to protect the lender (Schär, 2021). MakerDAO represents an example of loans executed with CDP since Dai is created in the process. The procedure for loans with pooled collateralized debt markets and P2P collateralized debt markets would be similar. As previously mentioned, the main difference compared to a CDP will be that the borrower would lend an already existing cryptocurrency from an owner who is willing to lend it in exchange for an interest rate (Schär, 2021).

3.4 Tokenization

Discussing the main features of blockchain networks and DeFi allowed us to understand how the term **token** in a blockchain is often associated with a native cryptocurrency for the network, such as ETH for Ethereum. All those digital tokens are native to the blockchain network and only exist in the digital realm. However, a concept that has become increasingly popular in recent years is the **tokenization** of real-world assets (Stefanoski, et al., 2020). Tokenization could potentially allow bridging any real-world asset and the digital world. Concisely, tokenization converts the

value of a fungible or non-fungible object into a token that can be traded on a blockchain, like any other token (Smith, Vora, Benedetti, Yoshida, & Vogel, 2019). An important concept related to tokenization is that real-world assets can be digitally represented with multiple tokens rather than an individual one. Therefore, the real-world asset can be **fractionalized** into smaller parts, whose sum represents the entire asset. Due to this reason, tokenization is argued to have the potential to allow retail investors to participate in novel investment opportunities due to the lowering of the entry barriers for specific categories of assets (Woo & Thiel, 2020). Simultaneously, this allows asset owners to access new sources of liquidity, which could be argued to have great potential (Woo & Thiel, 2020).

Among the various categories of tokens, **asset-backed tokens** are one of the possible results of this application of blockchain technology. Asset-backed tokens are a digital version of an asset, backed by the asset itself (Schweifer, 2020). Therefore, the value of an asset-backed token is directly affected by the underlying asset's value. Hence, if the asset appreciates value, so does the token. And vice versa. Assets such as '*Gold, crude oil, real estate, equity, soybeans or just about any other real, physical asset can be tokenized and become an asset-backed token*' (Schweifer, 2020).

3.5 Non-fungible tokens

A particular typology of tokens is represented by non-fungible tokens (NFTs). An NFT is a unique and non-interchangeable unit of data stored on a digital ledger or blockchain. In more simple terms, an NFT can be considered a certificate of authenticity for a real or virtual asset (Dean, 2021).

In general, both real-world and crypto assets can be *fungible* or *non-fungible*. *Fungible* assets can be considered interchangeable. Their name comes from the Latin term *fungi* meaning 'to perform as a substitute'. An example of this could be a $1 bill. There is no difference between a 1$ bill or another; their value and usage are the same. Further, five 1$ bills can be considered equal to one 5$ bill. The same concept can be applied to any cryptocurrency in the crypto space. One Bitcoin has the same utility and value as any other Bitcoin. So, cryptocurrencies like Bitcoin, Ether, and the Dai stablecoin are all fungible since their currency units are identical (Vauplane, 2018). On the other hand, *non-fungible* assets each have characteristics and properties that uniquely distinguish them from any other asset (Majer, 2019). An example of this in the real world could be an apartment. Although apartments can have the same square footage and spatial distribution, they

all have unique features such as floor, exposition, or layout. The same can be applied on the blockchain with non-fungible tokens. NFTs represents assets that can belong to the same category, but all have individual features combined in unique ways.

From a technical point of view, fungible and non-fungible tokens adopt a different standard. The Ethereum blockchain will be used as the exemplary blockchain network to depict this example since it was the first blockchain to create and adopt such standards. The **ERC-20** standard represents fungible tokens (Ethereum, Ethereum Website 2, 2021). This standard is coded so that every unit of the token created from the smart contract that generates them is equal to any other. On the contrary, NFTs adopt another standard, the **ERC-721** standard. This standard allows each token to be unique and to have a different value than another token created by the same smart contract (Ethereum, Ethereum Website 3, 2021). Therefore, the difference between fungible and non-fungible tokens is not only conceptual but also technological.

As mentioned in the blockchain literature review, one of the primary features of blockchain is recording a public history of transactions that is computationally impractical for an attacker to change (Nakamoto, 2008). Therefore, if NFTs are stored on a public blockchain network, it is easy to verify their authenticity and any changes in ownership by a worldwide network. Consequently, an NFT is completely traceable on a blockchain network till the network itself exists, making it practically impossible to create a fake (Dean, 2021).

3.5.1 NFTs main features

Starting from the overview in the previous section, it is possible to identify the following unique and features characterizing NFTs:

1. **Uniqueness**: NFTs are not interchangeable, and no NFT is equal to another. Each NFT has a unique identifier directly linked to one blockchain address. Thanks to the blockchain record, it is easy to track previous owner and transaction history.
2. **Ownership**: Once a person buys an NFT, this is transferred to his wallet. Since each NFT is unique, it is easy for the rightful owner of the NFT to verify the ownership since this person is the only one who has access to the wallet. This specific feature solves the so-called ‘copy/paste’ problem, which, especially in digital art, represents the possibility of saving the digital image by anyone. Any image associated with an NFT could indeed be easily downloaded and saved by millions of users from the auctioning website. However,

having the file stored on any computer does not bring any value. Only ownership of the asset, which is unique and recorded on the blockchain, allows accessing the benefits of owning a specific NFT.

3. **Transparency and Authenticity**: NFTs are generally issued on public blockchains. As seen previously, those distributed ledgers are immutable, decentralized, and fully transparent transactions history. Therefore, token issuance, transfers and activity can be publicly verified. This is crucial because it means that buyers can trust and verify the authenticity of a specific NFT.
4. **Interoperability**: NFTs are born on the blockchain. Therefore, they inherit the same main features as any other crypto asset, like bitcoin.
5. **Scarcity**: Scarcity is a common feature among NFTs but not an essential one. Generally, NFT collections (especially in art and collectables) are limited in number. The maximum amount of token ever to exist is coded in the smart contract that creates the NFTs. Therefore once the smart contract is deployed, the number cannot be increased even if the creators would like to. In the case of digital art, this scarcity drives the price of each asset up in the case demand increases since supply cannot be increased.

(Geroni, 2021; Hedera, 2021; Rawat, 2021; Ethereum, Ethereum Website 4, 2022)

3.5.2 The 2021 NFT craze

In 2021, NFTs had an incredible increase in transaction volume and popularity. Although not all the information reported in this section will be directly connected with any application of the technology in the field of real estate, it was considered relevant to report the current market status of NFT to give an overview of the potential market related to them and how they are currently traded.

In February 2021, the total NFTs transactions volume of 2020 was reached already (Behrens, 2021). In March 2021, the famous auction house Christie's auctioned and sold the work of the digital artist Mike Winkelmann, known as Beeple, for around 70 million dollars (Sherman, 2021). This was the highest sale for an NFT to date and the third biggest sale of any artwork by a living artist (Copeland, 2012). The most popular marketplace for NFTs can be considered **OpenSea**. OpenSea is a digital platform that allows artists and buyers to meet in one place and to buy and sell NFTs. Since all the transactions are recorded on the Ethereum blockchain, is it easily possible

to track the volume, number of items sold and the number of unique active traders. The data reported in Figure 5, referred to as on-chain data, draws a precise picture of how much NFTs increased in 2021.

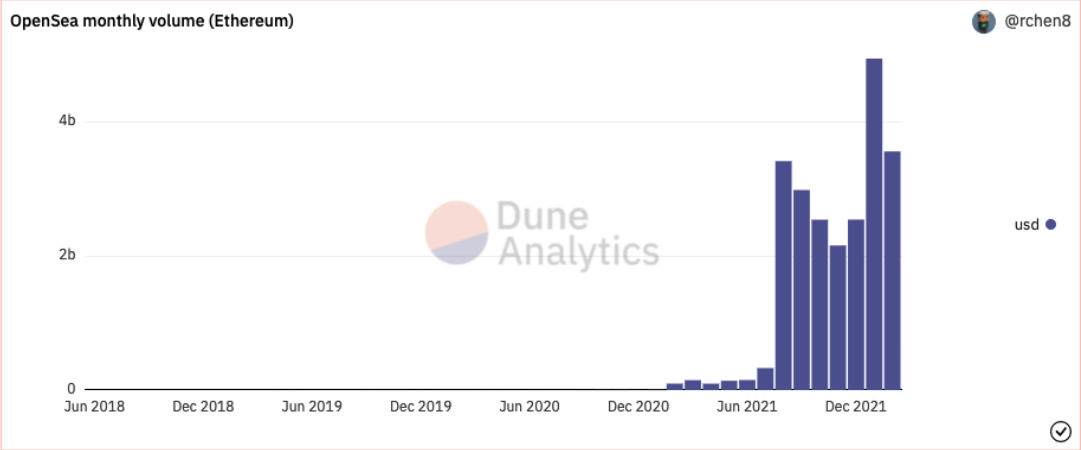

Figure 5. NFT transaction volume on OpenSea – Source: (Analytics, Dune, 2022)

As mentioned before, by February 2021, the entire volume of 2020 was already reached and overtaken, with a figure of around 103 million USD. Further, volumes have reached high levels after August, with the lower one registered in November at 2.6 billion USD. The highest volume was registered in January 2022 with almost 5 billion USD. It is worth mentioning that most of the volume registered in NFTs sales during 2021 is strictly related to either digital art, like the example showed at the beginning of this section, or to what can be defined as *avatar projects*. Despite those are not strictly related to real estate, it is relevant to understand how wealth is distributed among their owners, which are the models used to generate wealth for both users and creators, and if those can be applied to real estate.

3.5.3 Use case for NFTs

After the previous brief introduction to what NFTs are, it is now worth exploring their fields of application up to this point in time. The main reason to conduct this analysis lies in the possibility of understanding if any model to generate value for NFT holders is crated and, if so, how this could be applied to this research.

Digital Art

Digital art could be argued to follow the rules of the traditional art market. Digital art has seen a rise in volumes, supply and demand. From a revenue perspective, such NFTs follow a traditional business model where the artists sell their work to the highest bidder or the first one to buy the piece for the requested price. Some collections may include a percentage of future sales sent to the original artist as a way of paying royalties and keeping artists in the value chain loop. This feature could be argued to be the most distinguishable difference between digital and regular art from a business point of view. However, such a feature is also one of the most discussed and anticipated blockchain applications (Heap, 2017; Tapscott & Tapscott, 2017).

Avatar Projects

Avatar projects can be considered a sub-category of digital art, and they are the most mainstream application of NFTs. They take their name from the original use of this form of digital assets, being used as an avatar on social media. Generally, they are collections ranging from 3.000 to 10.000 unique characters randomly generated from a list of characters, each with a unique combination and ID. Due to the scarcity element typical of the NFT asset category, the most known collection of avatar projects have seen a remarkable rise in price during 2021. Notably, CryptoPunks, Bored Ape Yacht Club (BAYC), and CyberKongz. Notably, in May 2021, a collection of 6 CryptoPunks, was sold for 16.9 million USD (Kastrenakes, 2021). Some may wonder what makes them so valuable. Since a debate around the fair evaluation of digital art extends the purpose of this research, the short answer could be argued to be that they became a status symbol for a specific audience that is keen to spend such an amount of money on this category of asset (Chayka, 2021). Further, celebrities like the famous rapper Jay-Z bought them and started using them as profile pictures on their social media (Copeland & More, 2021). It is possible to identify some correlation between avatar projects and business theory correlated to their success. On the one hand, as previously mentioned, there is a scarcity element, which previous research has proven to increment the perceived value of an asset (Verhallen & Robben, 1994; Wu, Lu, Wu, & Fu, 2012). On the other hand, they have gained a status symbol and celebrity endorsement, which previous research has shown to be effective as well (Spry, Pappu, & Cornwell, 2011).

Price consideration aside, these projects have been considered relevant to mention because they introduced novel value-generating models empowered by the features of blockchain and NFTs.

Notably, BAYC has been the first avatar NFT to provide its owners with ownership and commercial usage rights given to the consumer over their NFT (Bored Ape website, 2022). This could be argued to push new ways of perceiving a brand, with each owner becoming a potential ambassador for the brand and exploiting his NFT to its fullest. Further, CyberKongz was the first NFT collection allowing owners to earn passive income. Holders of Genesis Kongz receive daily income in $BANANA tokens, which can be then traded as any regular token on a DEX in exchange for other cryptocurrencies (Coingecko website, 2022).

NFTs for gaming and digital rentals

Among the most anticipated use cases for NFTs, the videogames industry is argued to be one of the most suitable ones for their application. NFTs and gaming have several implications and ways of use that this paper will not discuss due to spatial and topic limitations. However, among the different use cases for gaming and NFTs, one could be interesting for this research, the concept of **NFT rentals**. Play-to-earn (PtE) games introduced the concept of earning money by playing games. Players are compensated for their time in two ways. On the one hand, by playing or winning, players earn in-game cryptocurrencies that can be traded for real money. On the other hand, to progress within the game, players are required to own characters with a minimum experience level. At the very beginning, players need to buy some characters to start playing, or the game offers some basic characters that allow players to start playing without putting in any money. However, to progress in the game and reach levels that allow earning more money, users need to buy more advanced characters, often pricey. This represents an entry barrier for new players due to the increasing price characters (Quiroz-Gutierrez, 2022).

An example of this can be found on Axie Infinity, the first crypto game to reach mainstream adoption and coverage. The game does not provide any starting character. Hence, players must buy some from the marketplace. However, at the time of writing, creating a basic team would require 2.000$, compared to 10$ in 2019, limiting the possible number of users due to financial constraints. NFT rentals are argued to offer a solution to this problem (Quiroz-Gutierrez, 2022). Players that already own characters can rent them out to newcomers in exchange for a fixed price and a percentage of the virtual currency they will earn while playing. Inheriting the features of blockchain and DeFi, the rental process is executed by a smart contract in a transparent and decentralized manner (Lama, 2022). Similarly to lending processes in DeFi previously explored,

the process can involve the use of collateral in the lending process or not, depending on the platform used. This specific use case of NFTs was considered relevant for this research since it testifies the use of **NFT collateralization** and **renting**.

3.5.4 DAOs and NFT-based DAOs

This section will briefly analyse the concept of decentralised autonomous organisations (DAOs) and how NFTs can be integrated with these organisations. A DAO is a blockchain-based organisation that enables people to coordinate and govern themselves using a set of self-executing rules deployed on a public blockchain via smart contracts and decentralised governance (Hassan & De Filippi, 2021). In essence, a DAO can be imagined as an organisation that mimics the function of a traditional corporation, but in a decentralised manner and with a smart contract as its skeleton (Hassan & De Filippi, 2021; De Filippi & McMullen, 2018). Since a DAO relies on a blockchain, it inherits more properties than decentralisation alone, such as transparency and cryptographic security (Hassan & De Filippi, 2021; Beck, 2018). This distributed entity can be a legally registered organisation or not (Hassan & De Filippi, 2021). There is no indication regarding the minimum size of the group of people creating this decentralised organisation. Instead, what is important is that the members of the DAO work together to achieve a common goal as a distributed entity. To achieve this common goal, members can suggest proposals and steer the direction the DAO should take by voting (Ethereum, Ethereum Website 5, 2022). Such voting process is typically referred to as **governance** of the DAO (Hassan & De Filippi, 2021). DAOs have built-in treasuries that, thanks to the smart contract deployed on the blockchain network at the moment of the DAO creation, no one can access without the group's approval, achieved via vote.

As seen, DAOs allow their members to coordinate and self-govern themselves online (Hassan & De Filippi, 2021). How this self-governance occurs depends on the so-called *DAO membership* model (Ethereum, Ethereum Website 5, 2022). The most known model is a *Token-Based membership*, where holding DAO allows access to voting. It is worth pointing out that the voting power depends on the quantity of tokens held by a member. Therefore, members with the most tokens have greater influence over decisions (DuPont, 2017).

With the rise in popularity of NFTs, a new membership model has risen, **NFT-based membership**. The basic principle of this novel typology of DAO is relatively simple, NFTs replace tokens. So owning an NFT allow one to be part of the DAO, and one NFT allows one vote. The

owner of the NFT can visit a website and express their preference regarding the subject undervote. An example of this is the Gutter Cat Gang DAO (Gutter Cat Gang Dao Website, 2022). This DAO is linked with a legal entity, Gutter Labs, that interacts with existing companies, while the DAO achieves the decision-making via voting (Gutter Cat Gang Dao Website, 2022). NFTs communities can also create DAOs to steer the project's direction and raise funds to develop it further. An example of this is the Meetbits DAO, whose goal is '*to create a vehicle for funding innovative projects that will develop the ecosystem around Meebits'* (Meebits DAO Website, 2022). Finally, another type of DAO that has gained popularity with the increasing popularity of NFTs is a *shared ownership* DAO. In this typology of DAO, members gather funds together to buy NFTs that they would not be able to afford otherwise (Ravi, 2021). An example of this type of DAO is PleasrDAO (PleasrDAO Website, 2022).

It is worth mentioning that such a system, which is often declared to be democratic, does not prevent members with the most assets to have greater influence over decisions (Ethereum, Ethereum Website 5, 2022; DuPont, 2017). Indeed, a member of the DAO owning a single NFT would have less decision power than a member owning several NFTs. This is important to be declared since it could imply that wealthier individuals can steer the direction of projects more decisively. Further, a DAO is an arguably new concept. Therefore, complete safety is not possible yet. A clear example of this has been the hack of the first mainstream DAO, called *The DAO* (DuPont, 2017; De Filippi & McMullen, 2018). *The DAO's* smart contract presented a code flaw that allowed a malicious actor to steal 3.6 million Ether, corresponding to one-third of the total treasury (De Filippi & McMullen, 2018). Therefore, the main feature of a DAO, which is based on a smart contract, can also be its main pain point if the code presents flaws (DuPont, 2017). Indeed, if a security flaw is spotted in the code, this cannot be corrected until the majority of the DAO approves changes in the code via voting. In the meantime, malicious actors can continue to exploit the flaws in the code (Hackl, 2021).

3.5.5 NFTs and fractionalization

One of the drawbacks of the rise in the value of digital art and avatar projects is the consequent inaccessibility of these assets for the less wealthy retail buyers. The most famous collections have minimum prices (often called *floor price*) of hundreds of thousands of dollars. Therefore, acquiring these assets implies facing a high entry barrier price. In order to potentially solve this issue and

make NFTs accessible to more buyers, various mitigation measures to lower such high entry barriers are being proposed regularly. One way, already covered in the previous sections regarding DAOs and NFTS, is creating a DAO to join forces and buy an asset together. However, as previously explored, DAOs have some drawbacks and pain points that make them not completely safe yet.

An alternative solution that has been recently developed is the concept of **fractionalization platforms**. The DeFi section shows that fractionalization is not a novel concept within blockchain technology applications. In the first exploratory theses about this topic, however, researchers imagined the pieces of digital art fractionalized and owned by different individuals being famous portraits rather than newly born NFTs (Stefanoski, et al., 2020). When focused on NFTs, fractionalization has slightly different implications than seen for real-world asset tokenization. In the case of NFTs, which are ERC-721 tokens, tokenization means locking the ERC-721 token in a smart contract and creating its fractions in the form of ERC-20 tokens, therefore fungible (Peaster, 2021). More about how the process works in practice will be found in the Artefact Demonstration Section.

Since NFTs are a relatively novel form of asset, some elements linked with the fractionalization process are still unknown, especially from a legal point of view. In particular, as seen in the avatar projects section, some NFTs bring with them Intellectual Property (IP) rights. It is yet unclear whether every owner of a fraction can claim such IP rights. Further, there is the possibility that financial regulators could consider the ERC-20 tokens resulting from the fractionalization of an ERC-721 token as securities. (Shawdagor, 2021).

3.6 Tokenization and real estate

After presenting the current issues of the real estate market and the main applications of blockchain technology, some may argue that blockchain could offer solutions to some of the problems afflicting real estate. Therefore, it is no surprise that both real-life applications and previous research have already covered such potential applications. In regards to real-world applications, different companies, such as Digishares, started proposing Security Token offerings (STO) as a form of investment in fractionalised real estate.

Previous research debates that the tokenisation of real estate assets could bring some relevant benefits to the real estate market. More specifically, it is believed that investors would benefit from this new class of assets due to a higher level of liquidity in the market, a lower entry barrier and the ability to have a more flexible portfolio (Smith et al., 2019; Baum, 2020; Liu, Duncan, & Chapman, 2020). Also, a more transparent model where all the transactions are publicly available and permanently recorded on a blockchain network has been identified as a significant benefit (Baum, 2020; Liu et al., 2020). Regarding the typology of products that are believed to have higher market demand, it is argued that large funds offering a variety of properties could be more successful than single properties tokenised by retail investors (Smith et al., 2019; Baum, 2020). Further, it is also pointed out how the current models of tokenised real estate assets do not support actual fractional ownership (Liu et al., 2020). Indeed, the tokenisation of real estate assets is established off-chain via a Special Purchase Vehicle (SPV). Therefore, each security token represents the ownership of a fraction of the SPV, not the property directly. Therefore, it could be argued that, presently, the difference between REITs and security tokenisation is not too big. However, unlike REITs, STOs are less costly to create and offer greater flexibility to token holders (Liu et al, 2020).

Previous research has also identified that various actors playing relevant roles in the real estate market may be highly impacted by the broad adoption of a decentralised real estate market (Smith et al., 2019). Notably, the main actors believed to be negatively affected by the tokenisation and fractionalisation of real estate are large institutional investors, which can count on favourable economies of scale at the moment; debt servicers; major intermediaries such as brokers; law firms that charge transactions linked to real estate transactions (Smith et al., 2019).

Despite the novelty of the application of fractionalisation on real estate investing, recent research has provided the first empirical examination of its potential (Swinkels, 2022). Despite the geographical and numeric limitations of the research conducted primarily in Detroit on 58 residential properties, the initial results seem to support the expected positive outcomes outlined by previous research and explored at the beginning of this section. Notably, higher liquidity of the assets was proven. Furthermore, most investors participated with an amount of USD not superior to 500, supporting the idea that small retail investors could be a plausible target audience for the

product. Following these findings, the authors concluded their paper, expressing their expectation that tokenisation will act as a disruptor in the future market (Swinkels, 2022).

3.7 Learnings from literature review and research direction

The literature review conducted allowed understanding the domains of this research topic better. Among the most remarkable concepts concerning real estate, the increasing house burden has been depicted as one of the significant challenges affecting younger investors' ability to acquire a property (Forrest & Hirayama, 2015). It has been documented how renting, which could be argued to be the only alternative to buying, often does not help individuals save sufficiently capital to buy a property. On the contrary, some figures have been presented on how in recent years, renting has been proven from previous research to be more expensive than owning (Riley et al., 2013). Due to the high expenses induced by renting, saving to meet the down-payment requirements can be claimed to be challenging.

When looking at real estate as an investment vehicle, it has been interesting to notice how fundamental concepts of modern portfolio theory, such as diversification and risk minimisation, are not typical for real estate assets.

Chaptlin, Tracy, Chan, Freeman & Tracy (1997) introduced the concept of opening the real estate market with a new duality in terms of both buying and investing in real estate properties (Chaplin et al., 1997). One of the major points extracted from their work is acknowledging that the house partnership model was difficult to adopt at the release date due to technological limitations. Despite such limitations, the researcher has found the work of Chaplin et al., still relevant. Starting from the technological limitations presented in the release year (1997), the research aims at verifying if blockchain technology and, more specifically, NFTs could be the technological gap that Chaplin et al (1997) were hoping for (Chaplin et al., 1997).

The reason to pick blockchain as a technology to analyse lies in its expected disruption potential in various industries, including real estate. Further, markets that could be considered as highly regulated as real estate, like finance, have been highly impacted by blockchain with the arrival of DeFi. The possibility of trading assets without geographical limitations and without the need to trust the other actors involved could be argued to provide relevant help to mitigate some of the issues identified in the real estate market. Most notably, DeFi empowers solutions such as

tokenisation, fractionalisation, and lending protocols have features that could help revolutionise the real estate market. Their impact on the finance market could be used as a benchmark.

As presented during this review, previous researchers and publications have already proposed and debated such suggestions. However, it is worth highlighting how all the research conducted so far has considered only real estate tokenisation solutions concerning empowering novel investing methods rather than novel buying procedures. Therefore, the above-mentioned new applications have been offered only from an investment perspective and, to the researchers' knowledge, never from the perspective of enabling new buying opportunities based on blockchain-empowered solutions. Therefore, the presented concepts related to blockchain and DeFi will be adopted to propose an artefact that wants to mitigate the issues related to buying real estate properties.

Furthermore, another finding considered fascinating by the researchers is the similarity between real estate and NFTs. Moreover, NFTs can be argued to have become an increasingly popular asset class in the recent past. They enable the trade of unique assets (which, as mentioned, real estate can relate to) among strangers. Consequently, the similarities between NFTs and real estate brought the researchers to question their potential in solving the identified challenges of the real estate market. Another reason that, among the available blockchain applications, led to focus on NFTs is that, to the researchers' knowledge, little research is available regarding their use in real estate investing. As seen, solutions and proposals have been developed that use fungible tokens. However, adopting NFTs in the field of real estate can be argued to still be in its infancy, which led to the decision and the hope to contribute to current knowledge with the present research.

4. Design of the artefact

As described in the methodology section, the artifact's design requires a precise sequence of steps to comply with DSR. In this section, the first three steps of the process suggested by Hevner & Gregor, 2013 will be executed to create the artifact (Hevner & Gregor, 2013) Namely, the steps executed in this section are: problem identification, solution's objective, and artefact creation.

4.1 Problem Identification (step 1 DSR)

With decreasing levels of homeownership levels for young adults in Denmark and an increase in the housing burden for owner-occupied homes in Copenhagen in recent years, this paper aims at designing an artifact that could present possibilities to change these circumstances (Whitehead &

Williams, 2017; Hetland et al., 2021). Specifically, blockchain technology has already been identified as having the potential to bring large positive change into the real estate market with tokenization (Smith et al., 2019; Baum, 2020; Liu et al., 2020). However, these positive changes do not necessarily consider the potential for improving homeownership levels or decreasing the housing burden but is strictly centered around facilitating investing into real estate in a different way. Since the need for utilizing a SPV to facilitate the tokenization of real estate is present for legal compliance reasons, it does not give an easy way to include the resident of the property, which the designed artifact will aim to.

During the recent decades, a decline in the percentage of owner-occupied households in Denmark occurred for the younger age groups, specifically a notable development happened for the percentage of owner-occupied households under 30 years old, decreased from 26.1% in 1987 to 8% in 2013, where other age groups except 30–39-year old's saw a rise in the same period (Whitehead & Williams, 2017). As homeownership rates among young adults are decreasing, the term "Generation rent" has been labelling the younger generations, and developments since the financial crisis in 2007 does not seem to indicate a future with mass homeownership (Arundel R. , 2017). Research indicates that although renting has been seen as a great way to save and accumulate wealth to later become a homeowner, it does not present young people with a favorable position to later become a homeowner (Forrest & Hirayama, 2015).

Due to the extreme level of exposure to a single investment asset with investing in real estate for young people and low-income households, investing into the asset class becomes irrational in a diversified portfolio context, as you are effectively gearing your investment by 19, if a home was financed with a 5% down payment, combined with a 80% mortgage loan and a 15% bank loan, and not much is done to increase diversification on the housing market (Andersen, 2020).

As research has shown, using blockchain and tokenization for real estate investing presents a large number of potential benefits for developing the asset class, and give more incentive for retail investors to invest in properties, such as increased liquidity, lower entry barriers and thereby an improved chance of market diversification combined with decreasing exposure to the single asset (Smith et al., 2019; Baum, 2020; Liu et al., 2020). These changes could be significant to the historically illiquid real estate market, with very high entry barriers as an investor. However, it does not seem to solve much for the homeowners at first sight, leaving the young people with a

desire to become first-time homebuyers with the same high entry barriers as before any of these developments with real estate tokenization. Therefore, adding to the tokenization benefits allowed by using blockchain technology, NFTs has been identified as they are characterized as giving a unique way of recording and transferring ownership of an asset, allowing to combine the concept of real estate tokenization with the housing partnership model, where the artifact aims at introducing a managing partner to the investment scenario, in combination with the traditional investors, termed limited partners (Chaplin et al., 1997).

REITs currently offer a diversification potential for individuals wanting to add real estate to their investment portfolio without buying a property outright, however, they currently do not offer a direct full exposure to house price developments, since they depend a lot on performance of the professionals operating the REIT, and the revenue income from rentals of the properties within the REIT (Block, 2011). Consequently, one must consider that with the solution of investing through REITs, there is a limited direct correspondence with the housing market, seen through the many different variables influencing the return on your investment, such as whether the assets that are invested in gets rented out, rent levels, how many investors the organization handling the REIT is able to acquire among others.

4.2 Solution's Objectives (step 2 DSR)

After having identified the problem that the artefact wants to solve, the objectives of the solution must be declared. As seen in the methodology section, the solution of the artefact belongs to the domain of Exaptation (Hevner & Gregor, 2013). This means that knowledge already applied in fields such as DeFi and Blockchain applications such as NFTs will be extended to the field of real estate to attempt to solve the identified problem.

4.3 Create the artefact (step 3 DSR)

This section aims at describing the created artefact and illustrate its underlying principles. The themes explored in the Literature Review section that have been considered the most relevant are the ground upon which the artefact underlying principles have been initially based. To increment the credibility of the artefact, Hevner & Gregor (2013) also suggest including the process that led to its discovery (Hevner & Gregor, 2013). In this regard, they suggest different possible approaches, including '*an iterative design with intermediate test stages'* (Hevner & Gregor, 2013). As introduced in the methodology section, the researchers adopted such an iterative design by

conducting informal interviews with potential users of the artefact, as shown in Figure 6. This allowed presenting, and later demonstrating, an iteration of the artefact that has already received feedback and revisions. The interviews permitted identifying relevant themes deemed necessary to steer the direction of the design phase and improve the artefact. Further, it was possible to identify concerns affecting the previous solutions and base the new iteration of the artefact on principles aimed at empowering the suggestion offered by interviewees.

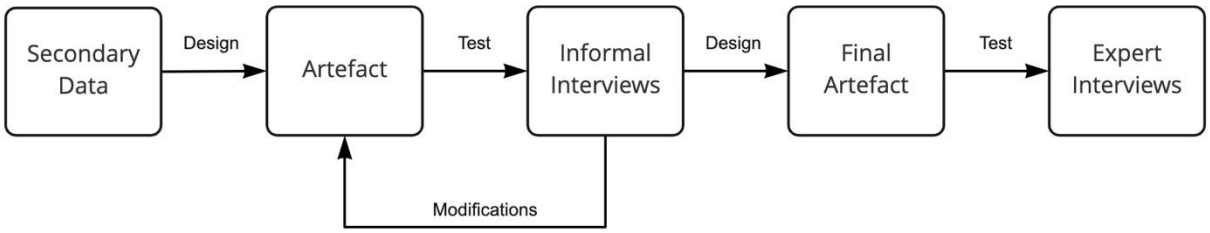

Figure 6. Iterative design process (own creation)

Table 1 outlines the feedback received by the second iteration of the artefact. Also, it depicts the designed principles identified from the secondary data that have been affected by the themes gathered thanks to the informal interviews. By looking at the table, it is possible to notice how not all the themes have been addressed in the artefact creation phase. Such a choice was taken because some identified themes were considered out of the scope of this research. Notably, the topics related to the maintenance and operational feature of the artefact. The decision to not tackle these topics has been taken to keep the focus of both the research and the artefact on solving the issues outlined by the research question rather than solving all the issues identified in the informal interviews. However, all the most relevant themes are reported in the table. Although some themes have not affected the design phase, they will be further discussed in the discussion section of this paper. The researchers selected the benchmark for a theme to be considered relevant to it been mentioned at least in five interviews.

It could be argued that the sample of interviews collected by the researcher is not big enough to provide statistical significance to the feedback received. Therefore, another audience could find previous artefact designs better suited to solve the identified problem. Nonetheless, considering the difficulty of reaching a statistically significant sample, the researchers have iterated the design according to the feedback received from the selected interviewees, and the concept learned in the literature review section.

Theme	Recurrency	Affected principle(s)
Full ownership	16	3, 4, 5
Number of fractions	15	2, 6
Resident minimum share	13	3, 5
Moving out	12	1, 3, 4
Total years	12	*Not addressed*
Number of investors	11	3, 4
Price of fractions	11	6
Doubts on crypto space	10	2, 5
Maintenance/Modifications	8	*Not addressed*
Diversification of investors	6	1, 2, 4
Modifications	5	*Not addressed*
Taxation	5	*Not addressed*
Use of cryptocurrencies	5	*Not addressed*

Table 1. Design themes identified in the preliminary interview stage and their implications (own creation)

Further, to give the reader a better understanding of the artefact design process, the first two design iterations can be found in the Appendix of this research. In the appendix, it is also possible to see the benefits and drawbacks concerning the first two versions of the artefact identified in the interview phase. Although this section focuses on introducing the latest version of the artefact, proposing the previous versions in the appendix was considered informative for the reader to see the iterative process adopted.

4.3.1 Design Principles

The design principles described in this section represent the main objectives that the artefact is intended to accomplish with its creation. Firstly, such principles have been created from the literature review and then tested on potential users via informal interviews. The insight gathered from the informal interviews allowed identifying the primary considerations and observations coming from potential users of the artefact. After the feedback has been received, the design principles have been adjusted, removed or added. Such an iterative process makes it difficult to clearly separate which principle came in which iteration phase. Therefore, the decision was taken to present the principles on which the final iteration of the artefact is based. These can be considered the final result of the adopted iterative process, which allowed selecting them from the initial pool of propositions. Then, secondary data has been collected to address their implication in the most informed manner.

Each principle and its relevance for the artefact is described below. Notably, six fundamental principles; 1) Dual-sided artefact, 2) Trust among participants, 3) Increased accessibility of real estate properties, 4) Increased liquidity of real-estate assets, 5) Unicity and Authenticity, 6) Link between NFT price and real estate price, have been identified as necessary to develop an artefact that would permit NFTs to solve the identified problem potentially.

Principle 1: Dual-sided artefact

In the literature review section, it has been reported how some blockchain empowered solutions are currently available on the market, including fractional investing in real estate (Smith et al., 2019; Baum, 2020; Liu et al., 2020). However, some features could be argued to be missing in the current market landscape. Most notably, the solutions explored in the literature review target retail investors wanting to invest in real estate rather than retail buyers looking to buy a property as their primary residence. The concept depicted by Chaplin et al. (1997) is the only one suggesting a solution that creates a meeting point between potential investors and potential buyers (Chaplin et al., 1997). Particularly, the researchers considered the concept of managing partner and limited partners as a valid starting point to start developing the artefact. Consequently, the artefact will be designed to facilitate the interaction between two main actors, managing partners and the limited partners.

Principle 2: Trust among participants

The designed artefact aims at enabling the trade of a valuable asset like real estate among strangers and without third parties involved. Thus, its design must replace the security given by a third party. As previously analysed, such a feature is among the key characteristics of blockchain (Tapscott & Tapscott, 2018). The artefact will empower the parties involved to exchange fractions of real estate properties, which does not differ from other blockchain transactions (Smith et al., 2019). Further, users would benefit from a fully transparent and shared unique source of truth regarding the history of the transactions of an item, the precedent transaction values, and owners. Once more, blockchain's main features allow accomplishing this (Tapscott & Tapscott, 2018). As it will be described, the iteration of the artefact presented in this paper does not imply a legal entity attached to every fraction. Hence, to achieve the maximum level of trust, a permissionless blockchain will be adopted. Such a solution will provide a high level of decentralisation and tamper-proof resistance (Dain et al., 2020).

Principle 3: Increased accessibility of real estate properties

For the artefact to help mitigate the identified problem, one of its primary intents is to empower novel options in real estate investing. In this regard, DeFi's main applications could provide new possibilities for real estate. Notably, two main DeFi applications have been considered relevant: tokenisation and fractionalisation. Tokenisation allows creating a digitalised version of real estate properties (Smith et al., 2019). As seen in the literature review section, solution adopting tokenisation in the fields of real estate has been studied already (Smith et al., 2019; Baum, 2020). However, none of these uses NFTs. Tokenisation and fractionalisation are believed to empower retail investors to participate in investment opportunities without needing large amounts of capital (Liu et al., 2020). Simultaneously, this allows asset owners to access new sources of liquidity, which has immense upside potential in terms of house-buying affordability (Woo & Thiel, 2020). Therefore, the artefact should allow both parties to access real estate investing with new and more affordable methods.

Principle 4: Increased liquidity of real-estate assets

Another identified problem of the real estate market is its scarce liquidity (Andrew & Glenn, 2003). The artefact could help mitigate the issue in two ways. On the one hand, fractionalization could decrease risks, demanding a lower minimum investment from buyers and investors. Another DeFi application that could benefit real estate liquidity is collateralization. As described in the literature review section, DeFi empowers digital assets to be collateralized to borrow money (Gogel, 2021; Dain et al., 2020). Applying the above mentioned DeFi methods to real estate properties could open new opportunities, transforming real estate into a more liquid asset and reducing switching cost (Baum, 2020). Further, together with the fractionalization principle described above, asset owners could access new liquidity sources, which is argued to have immense upside potential (Woo & Thiel, 2020).

Principle 5: Unicity and Authenticity

As the artefact could potentially create a more liquid market for real estate, it is crucial to guarantee easy traceability of the fractions' owners. Due to the record on transactions of NFTs being publicly accessible on a public network, they grant the real-time knowledge of fraction owners (Hedera, 2021). Further, it is granted that every NFT asset is unique, and its authenticity can be easily verified (Rawat, 2021; Ethereum, Ethereum Website 4, 2022). Such features are considered crucial

for the artefact. Therefore, it is relevant that the artefact employs these features to ensure a safe solution for both managing and limited partners.

Principle 6: Link between NFT and real estate price

A crucial principle is the value correlation between the real estate asset and its digitalized version. Concerns regarding an increase in the value of fractions and, consequently, the overall asset occurred during the informal interview phase. Therefore, it is considered relevant to link the value of each fraction to the value of the real estate property. In these regards, the concept of asset-backed tokens can help prevent any speculative increase in the price of the NFTs. As previously mentioned, asset-backed tokens are a digital version of an asset, backed by the asset itself (Schweifer, 2020). This principle will be applied to the artefact's design to guarantee the link between the digital and real-world assets.

4.3.2 Assumptions

After introducing the main design principles of the artefact, it is relevant to present some of the necessary assumptions to investigate the designated principles. It is known to the researchers that the proposed design is not solving all the issues preventing a real-life application of the artefact in the short term. However, this is expected. In his work design science in information systems research (2004), Hevne, March, Park & Ram declare that '*Furthermore, artifacts constructed in design-science research are rarely full-grown information systems that are used in practice. Instead, artifacts are innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, and use of information systems can be effectively and efficiently accomplished*' (Hevner et al., 2004). Consequently, the artefact is not supposed to be ready for practice. What is needed is to provide innovative solutions to a given problem and prove how the artefact could solve or mitigate the identified problem. Hence, some assumptions had to be made to analyse how the artefact could work in a real-life scenario and evaluate it.

Firstly, it is assumed that there is demand from both managing and limited partners. Previous research has shown that demand may not be currently present due to a series of factors (Liu et al., 2020). As this research is more interested in the technological feasibility of an artefact using NFTs to offer tokenised real estate, the demand from both sides is assumed to exist.

Also, some legislative limitations must be considered. Previous research has already pointed out the lack of legislative clarity concerning the legal validity of ownership via blockchain (Smith et al., 2019; Governatori, Idelberger, Milosevic, & Riveret, 2018). Further, it seems that a shared solution among European countries is difficult to achieve due to the different legislative frameworks of each country (Finck, 2018). This barrier has proven challenging for several blockchain applications, and no solution is predicted to be available shortly. Therefore, a crucial assumption is that the artefact designed and demonstrated in the present and the following section is not meant to prove legally verified ownership to the managing partner or the limited partners. This assumption was considered necessary to explore such a novel topic and its ramifications. Some companies working in real estate and blockchain, such as Digishare, claim to have solved the legal matters. However, these companies use instruments such as SPVs rather than NFTs (Digishares Website, 2022). Therefore, such solutions cannot be assumed to apply to NFTs. Further research may be conducted regarding the compliance of these solutions with NFTs. However, such an analysis exceed the spatial limitation of this paper.

Another assumption is that both limited and managing partners are tech-savvy users who are comfortable using a technology that has not been fully developed yet. This implies a certain degree of trust in the underlying blockchain technology to commit to the artefact proposed economically. Therefore, with the initial round of informal interviews, the researchers have assumed that the hypothetical users of the artefact are what previous research defines as ‘early adopters’ and that they are aware and comfortable with the degree of uncertainty that is involved with the artefact (Moore & McKenna, 1999). Further, the users are supposed to know, or be willing to learn, how to buy NFTs using a digital wallet such as Metamask and the security measure required to store their private keys safely. This last assumption is also caused by the current legislative limitations. Indeed, since fractions of real estate in the form of NFT would not have legal value in Denmark at the moment, there is no possibility of creating a company that would manage digital wallets for its customers and provide assistance. For these reasons, it is also assumed that this first iteration of the artefact would not be used by thousands of users but rather by a limited niche that meets the above description.

Concerning tech-savvy users, it is also assumed that users of the artefact are not necessarily strangers. On the contrary, the limitations here reported led the research to assume that it could be

likely that a solution with so many unknown elements like the one here presented may be adopted by users that know each other. In this sense, we can imagine a group of trusted individuals that decide to adopt the solution to overcome the identified issue in the real estate market. Significantly, such an assumption will become relevant in the artefact evaluation phase.

Finally, one of the design principles indicates that the price of the property and the fractions can be determined promptly. However, presently real estate evaluation is mainly conducted when the property is placed on the market. No solution known to the researcher allows calculating the price of a real estate property in real-time whenever needed. Hence, the initial price is known when the property is acquired. Contrarily, variations in prices according to market fluctuations can be argued to be less precise. Such a limitation is relevant because the artefact implies that the fractions of the property are relatively liquid assets. Since the real estate market has proven to be a stable asset class, the assumption that the initial price is valid for two years is made. After that, the value can be re-calculated to keep (Arundel R. , 2017). If the solution would see mass adoption, an AI-driven tool that gives real-time data regarding the evaluation of each property could be deployed to limit the amount of manual work and time required to update price values.

4.4 Proposed artefact

After explaining the concepts and the assumptions the artefact is based on, it is now possible to introduce its design. This first introduction will focus on depicting how the (known) principles are applied to a (novel) field such as real estate in respect of the DSR framework selected. The technical implications of the artefact will be analysed and discussed in the Demonstration section to exhibit that the proposed artefact could also work in practice.

4.4.1 Infrastructure layer: Ethereum

Among the different public and permissionless blockchains currently available, Ethereum has been selected as the one used for this research. Despite some known issues with scalability and network congestion, Ethereum is the most used and decentralised blockchain currently in use (Bez, Fornari, & Vardanega, 2019). Further, NFTs were born on the Ethereum blockchain. This aspect makes the comparison between fungible and non-fungible tokens in this section and the following one more feasible. As mentioned earlier, NFTs are a novel technology that is currently starting to gain mainstream fame and still has limited adoption. For this reason, using the blockchain with the most shared knowledge available on the topic was considered a balanced choice in between the

applicability of the artefact in a potential real-world scenario and academic knowledge obtainable from this research. Figure 7 represent the distribution of layers in the Ethereum blockchain.

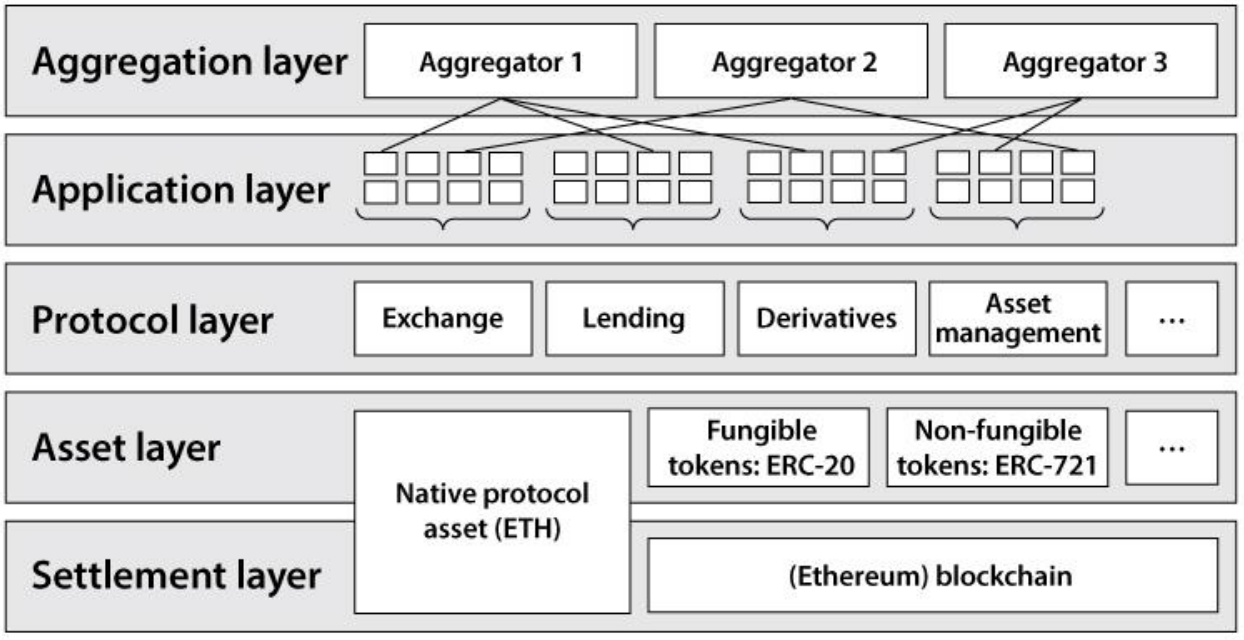

Figure 7. Ethereum's layers Source: (Schär, 2021)

4.4.2 Artefact

Before presenting the artefact, it is helpful to review the concept of **managing partner** and **limited partner**, the two main parties involved in using the artefact (Chaplin et al., 1997). A managing partner can be defined as a home seeker who will use the artefact to find and finance a property of his desire. For each property, only one managing partner can exist. This type of partner will be the one who will live in the real estate property. The primary responsibility of the managing partner is the maintenance of the property. On the other hand, a limited partner can be defined as an investor, either retail or institutional, who decides to invest in the property identified by the managing partner. Multiple limited partners can invest in each property. This type of partner does not live or have access to the property. Theoretically, being the platform a decentralised exchange, the two parts do not need to know each other.

The artefact will serve the two typologies of partners in diverse ways. Therefore, a double-side explanation will be conducted to analyse the perspective, goals, and functioning of the platform for each of the two partners. Exploring both sides is considered necessary to provide a comprehensive overview of how the artefact could help solve the identified problem. Although the research question focuses on the managing partner, the artefact can be argued to be functional and

working only when limited partners are successfully involved and stimulated in using the solution. The main conceptual design is described before offering the detailed examination of how the artefact operates for the two parties. The researchers believe that this overview will allow the reader to follow the more exhaustive explanation better.

4.4.3 Conceptual Design

Figure 8 depicts how the artefact would allow young adults to buy property using blockchain technology.

Figure 8. Artefact proposed process (own creation)

In its most simplistic form, the process will look as follows. (1) The managing partner searches the marker for a property that satisfy his needs and budget. (2) The managing partner uses the platform to publicize the property and looks for limited partners to invest in the property. (3) Limited partners see the property and decide to invest in it. (4) The necessary funds to buy the property are raised. (5) The property is acquired. (6) The property is tokenized and fractionalized in a set amount of fractions. (7) Each of the limited partners receives one or more fractions of the property, according to the amount of money they invested. (8) The managing partner receives the

Managing Partner NFT, which gives him the right to move into the apartment and lives there till he decides to move out. Before explaining the process in more detail, it is paramount to declare that with the term *platform*, the researcher intend a digital place where limited and managing partners can meet and conduct transactions. The nature of such a platform is hypothetical, and in reality, it could assume different shapes such as a website, an actual entity, a company. The nature of the platform was not considered relevant for this paper since the main goal of the paper is to explore it NFTs can be used to make real estate more accessible for young adults rather than defining all the details of the hypothetical platform.

The process starts when the future managing partner look on the real estate market for a property to buy (1). This search is traditionally conducted on real-estate web portals or through real-estate agents. Therefore, the property research phase is neither innovated nor disrupted by the artefact. Once the future managing partner has found the property he would like to buy, he posts it on the platform (2). When posting the property on the platform, the managing partner sets the amount of the property for which he requires limited partners. For example, the managing partner could set the quote available to limited partners to 90%, 50%, or the number he prefers. Once this decision is made, the property is listed on the platform with the quote available for limited partners. In this regard, the platform act as a promoting website. The property is listed with all the required information such as price, address, dimensions, year. Also a link to the real estate portal or the information contact of the real estate agent could be linked. In this way, potential limited partners can verify the truthfulness of the offer. Once the property is posted on the platform, it is visible to everyone. Therefore, potential limited partners can browse the available options and identify properties they would like to invest in (3). Once a limited partner identifies a property he wants to invest in, he can pay via credit card or bank transfer to lock DKK and 'book' property shares. We talk about 'booking' a share of the property rather than 'buying' it because for the order to go through, enough investors must be found within the time frame set by the managing partner. If this does not happen, the limited partner's funds are unlocked and given back to him. If the total capital required is raised, the funds are taken and used to acquire the property (5). Once the property is acquired, the managing partner will be given a *Managing Partner NFT* and the limited partners will receive their fraction of the *Limited Partner NFT*. As will be further explored in the demonstration section, the two tokens differ in name and from a technological standpoint. Indeed, the Managing Partner receives an NFT in his wallet. On the other hand, the limited partners receive

a fraction of the *Limited Partner NFT*; such fractions are not NFTs but fungible tokens. More details regarding this can be found in the Demonstration section of this paper.

As mentioned in the Assumptions section, associating ownership deed to an NFT is not supported from a legislative point of view yet. Despite this limitation, it is still possible to depict how the artefact would work.

4.4.4 Managing partner

The description in the previous section highlighted the procedure followed by a managing partner in searching, founding and acquiring a property using the platform. However, such description covers only the steps required till the point in which the managing partner move into the newly acquired property. After that event, the managing partner can choose an array of possibilities. First and foremost, the limited partner can live in the apartment for as long as he pleases. Once the *Managing Partner NFT is* acquired, the managing partner is granted the right to live in the property until he decides to leave. Regarding leaving the property, one of the selected design principles implies making real estate a more liquid asset. So, the managing partner is free to put his *Managing Partner NFT* on the market at any time. However, a binding period should be present to prevent any exploitations of the system. After the binding period is expired, when the managing partner wants to move out, he can list the *Managing Partner NFT* on the platform and wait for someone to buy it. Once the new managing partner acquires the NFT, the two parties use the platform to arrange the moving in and moving out dates. An anti-fraud system could be introduced where the new managing partner, instead of buying the NFT directly, has its funds locked in a smart contract. The same goes for the *Managing Partner NFT*. Only once the new owner verifies that the old managing partner has moved out, the smart contract executes the transaction. Figure 9 depicts the selling process.

Another possibility offered to the managing partner is acquiring the remaining fractions of the apartment from the limited partners. Hence, over time, the managing partner could become the owner of more (or all) the apartment's fractions, becoming its sole owner. Keeping such a possibility open for the managing partner is considered relevant since it allows acquiring the entire property of the apartment if desired. Further, the case in which the managing partner also owns some *Limited Partner NFT*'s fractions opens interesting possibilities in terms of liquidity. Indeed, as seen in the literature review about DeFi, crypto tokens are often used as collaterals. Therefore,

if the managing partner also owns fractions, those could be used as collateral if he needs liquidity for other expenses. In this case, the platform would act as the borrower, freezing the collateralized tokens in a smart contract in exchange for liquidity. If the debt is not paid, the tokens are liquidated, repaying the debt. This case could be relevant, especially if the managing partner is keen on acquiring the whole property over the years. So, in case liquidity would be needed, having the possibility of collateralizing one fraction rather than selling it would be preferable. Also, the case for collateralizing the *Managing Partner NFT* could be made. However, it was considered safer to avoid this option. The main reasoning behind this choice is that if the managing partner would not repay his loan and the NFT would be liquidated, a new managing partner would have to be found. Figure 10 depicts how the managing partner could acquire the whole property over time.

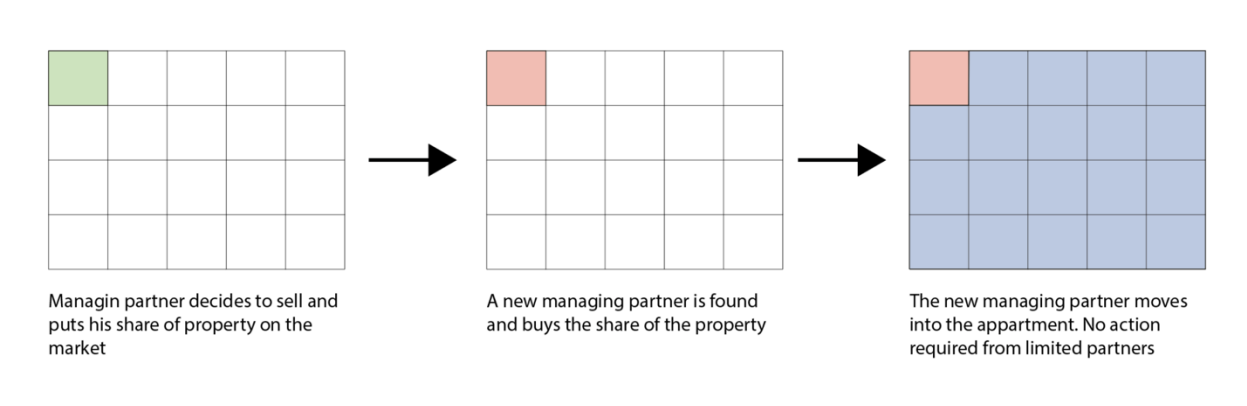

Figure 9. Managing Partner NFT selling process (own creation)

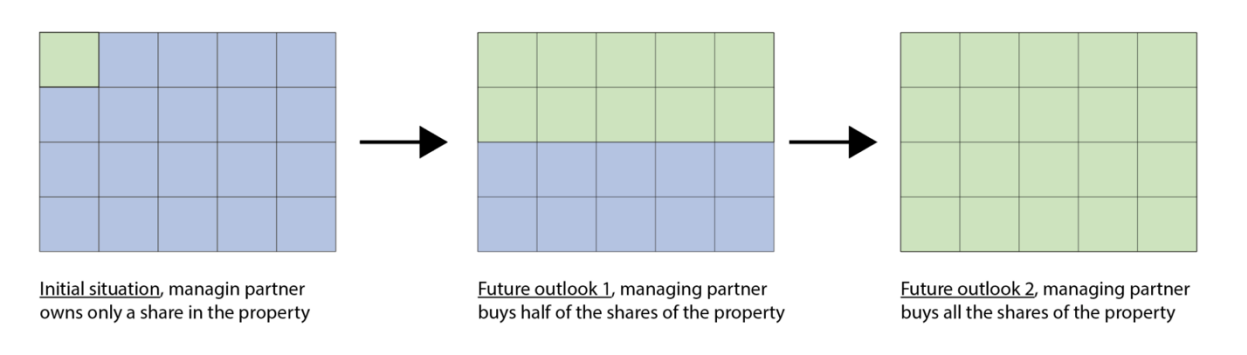

Figure 10. Acquisition of the whole property process (own creation)

4.4.5 Limited partner

The artefact presents some features that concerns limited partners more than the managing one, which will be analysed in this section. As previously depicted, limited partners can scout the properties available on the platform and invest in the ones they find more appealing to them. In

return, the obtain a token that represents their share in the property. Differently from the managing partner, limited partners do not have binding period when it comes to selling their share. This means, that, as long as they find someone willing to buy their fraction, limited partners can always sell their token(s). Further, this means that limited partners are also able to increase the quantity of tokens they own by buying them from other limited partners willing to sell.

As in the case of the managing partner, ownership of tokens allows access to some blockchain-empowered solutions. Firstly, similarly to the managing partner, the possibility of collateralising the investor tokens can be exercised. Secondly, the platform could entitle limited partners with voting rights, a concept explored in the literature review concerning DAOs (Hassan & De Filippi, 2021; Ethereum, Ethereum Website 5, 2022; De Filippi & McMullen, 2018; Hackl, 2021). If the managing partner wants to sell his *Managing Partner NFT*, limited partners could vote regarding the future of the property. On the one hand, they could decide to find another managing partner. On the other hand, it could be decided to put the property on the traditional market. This second option would imply selling it as a whole in a regular manner. After the property is sold, each limited partner would receive his share of the value, based on the number of fractions he owns. To do so, when the property is put on the market, tokens would be frozen via a smart contract. Once the property is sold, the smart contract would pay fractions' owners based on their holdings. The decision regarding selling the property or finding a new managing partner will be based on the vote taken by all the limited partners on the platform. As previously explored, this scenario would allow the partners with the higher number of shares to have more decision power regarding this decision, as they would have more votes (Hassan & De Filippi, 2021; Ethereum, Ethereum Website 5, 2022; De Filippi & McMullen, 2018; Hackl, 2021).

4.4.6 Additional potential applications

As stated at the beginning of this section, the artefact's primary goal is lowering the barriers to buying real estate. Therefore, the connection between manager and limited partners is the vital core of the artefact. However, considering the array of solutions potentially offered by blockchain applications to real estate, other models could be empowered on the platform. Those additional options concern limited partners more than managing ones. For this reason, they will not be further discussed in the demonstration phase. However, it was considered relevant to present them as a point for further research and, in general, as a way of explaining the potential of the technology on real estate.

A potential application of the concepts explored this far for retail investors could be the idea of buying undervalued properties, refurbishing them and reselling them for a profit. Usually, for retail investors, this would require the capital to acquire the property in the first place and the ability to refurbish it or the knowledge of trustworthy sources to do it. Using the platform, retail investors could raise funds and then acquire undervalued properties to refurbish them and then sell them for profit. Once the apartment is sold, each investor would receive his profit based on the number of shares they own. Further, after the property is sold, it would be possible to start the cycle again. As in the case of the main artefact, a voting system could be used to select the next property to be acquired.

5. Demonstration of the artefact (step 4 DSR)

Hevner et al. (2013) declare that the Demonstration phase aims at '*demonstrating the use of the artifact to solve one or more instances of the problem*'. In this research, the problem that the artefact aims to demonstrate is the possibility of using NFTs to allow managing and limited partners to meet and enable novel buying and investment opportunities in the real estate market. Due to the broad scope and research methods in DSR, the demonstration phase can assume various shapes (Hevner et al., 2004). Hevner & Gregor (2013) declare that the demonstration phase can involve using the artefact *'[…] in experimentation, simulation, case study, proof, or other appropriate activity*' (Hevner & Gregor, 2013). The first part of this section will experiment by practically creating the NFTs representing the parts of the property for both the limited and managing partner. Later, the simulation of the fractionalization process will be conducted to prove its viability in a real-world setting. The thought process leading to the decision of using a different approach for the two phases will be discussed in the individual section.

Before continuing with the demonstration, some consideration regarding the steps covered must be stated. As briefly introduced in the previous paragraph, the demonstration phase will cover two specific phases of the design concept rather than the entire process. More specifically, only step (6) and (7) of the presented *Design Concept* will be examined. This decision was taken due to spatial constraints and some of the assumptions highlighted in Section 4. Notably, this research will not cover all the steps before the property acquisition. This is due to the legislative limitations pointed out in Section 4. Thus, the assumption was taken that enough limited partners are found to buy the property.

Finally, the artefact demonstration will not cover concepts such as collateralising the tokens or their trade. There are two main reasons why this decision was made. On the one hand, due to the spatial limitation of the paper, not every phase of the artefact can be demonstrated practically. On the other hand, as seen in the literature review section, the concept of collateralisation, DAO voting and trade of digital assets on a blockchain network have plenty of real-world applications already in use. Due to this fact, a demonstration of such features has been considered unnecessary. Indeed, it could be argued that the existence of real-world applications proves the viability of these features.

5.1 Infrastructure layer: Ethereum and Ropsten

In the literature review section, blockchain networks and NFTs were covered broadly to offer a general overview to the reader regarding their feature and current applications. Such concepts and information concerned the NFT space in general, in what could be considered a 'blockchain-neutral' conversation, which was considered the best option to introduce the topic. However, since this section aims to demonstrate the technical feasibility of the proposed artefact, it is necessary to closely discuss the Ethereum Network and how NFTs are defined in such a network. Due to the novelty of NFTs on other blockchains, those were not considered to have a record of practical use cases sufficiently large to be academically relevant. Further, the proven reliability and distribution of the Ethereum network, combined with the vast amount of Dapps built on it, were considered relevant elements to fulfil the design concepts of trust.

Nonetheless, the knowledge gathered from the demonstration can be argued to apply also to other blockchains from a conceptual and business point of view. According to the different blockchain networks considered, other technological elements, such as smart contracts and coding language, may need adjusting. However, the applicability of the main concepts depicted in this section can be argued to be shared among different blockchain networks.

A final clarification before continuing with the demonstration of the artefact is necessary. The first part of this demonstration has been conducted on Ropsten, the test network for the Ethereum blockchain. A test network represents a simulation of the actual network and shares the same coding language and functioning principles with it. The reasons why the test network has been preferred to the actual Ethereum network (also known as Mainnet) are twofold. On the one hand, this demonstration's purpose is to show the applicability of the proposed solution. Therefore, as

the test network and real one share the same code, the validity on the test network will have the same validity as on the main network. On the other hand, deploying smart contracts on the main network can be costly. Consequently, due to the low added academic validity of the option, the test network has been preferred.

A digital wallet will be used to interact with the smart contract and the created NFTs on the Ropsten network. Digital wallets are software interfaces that allow managing assets stored on a blockchain. With a non-custodial wallet, the user has exclusive control of funds through their private keys. With custodial wallets, private keys are managed by a service provider (Gogel, 2021). For the artefact creation, the non-custodial digital wallet **MetaMask** will be used. MetaMask is a software cryptocurrency wallet used to interact with the Ethereum blockchain, and it allows users to interact with decentralized applications (Metamask website, 2022).

5.2 Artefact layer

5.2.1 Tokenisation of the property

Once the property is acquired, an NFT representing the property digitally is created. As noted in the literature review, NFTs are ERC721 tokens. The creation process of an NFT, usually referred to as minting, creates a unique token on the blockchain. In the case of the real estate property under examination, after having raised funds and bought the apartment for the Managing Partner, the platform would mint a digitalised version of the property. More specifically, two NFTs will be minted: the **Managing Partner NFT** and the **Limited Partner NFT**. Their functions will be explained in the next section, while this section will be focused on their creation and deployment. In short, the *Managing Partner NFT* is a unique token representing the fraction owned by the managing partner and, as explained in the concept section, it also allows its owner to live in the property. The *Limited Partner NFT* represents the remaining fraction of the property (intended as the amount of property that the managing partner does not own). It will then be fractionalised into smaller parts and distributed to all the limited partners that contributed to the acquisition of the property.

On the Ethereum blockchain, the minting process of ERC721 tokens is based on the Solidity coding language. The first step necessary to mint the NFT is creating the smart contract. As seen in the previous section, NFTs, also known as ERC721, are a standard form of token in the Ethereum blockchain. This means that public libraries are available for deploying smart contracts

in a standardised manner (Ethereum Website 6, 2021). Due to its standardisation, this part of the process will not be described in detail in this section as it merely covers the deployment of a simple smart contract created for research purposes. However, the implications of deploying the smart contract on the blockchain will be briefly examined to highlight its relevance in terms of traceability and authenticity of any NFT minted from the created smart contract.

The following pictures depict the Etherscan for the Ropsten test network. Etherscan is a blockchain explorer for the Ethereum network, which allows seeing and tracking all the transactions on the network. In the literature review, a blockchain has been defined as a decentralised record of transactions. Such a record is entirely explorable on Etherscan. Notably, Figure 11 depicts the smart contract on the Ethereum blockchain test network. At the bottom of the picture, it is possible to see the unique contract address, which is 0x50F2D7dc98f1dF6eEdC759801046aF05CBb70787, and all the transactions executed using this smart contract. As can we see, only one transaction is present in association with the smart contract, the **contract creation** transaction, where the smart contract has been deployed on the testnet. Further, under the voice **creator**, is possible to see the public address of the creator of the contract.

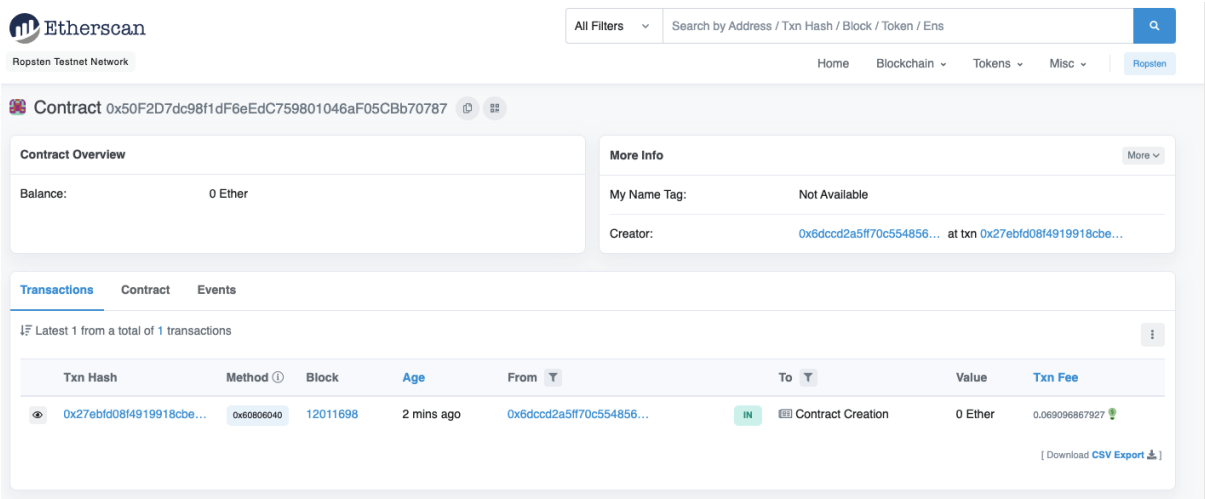

Figure 11. Contract creation of Etherscan (own creation, (Etherscan website 1, 2022) transaction)

By looking closely at the *contract creation* transaction, it is possible to see some relevant details, as depicted in Figure 12. (I) **Timestamp** clearly indicates when the contract has been deployed and acts as immutable proof of the date and time of the creation. (II) **From**, shows the public address of the creator of the smart contract. This is particularly important because, in the case of a

hypothetical platform offering this service, the platform could communicate his public address, verifying that the smart contract was indeed created by the platform and not by a malicious actor.

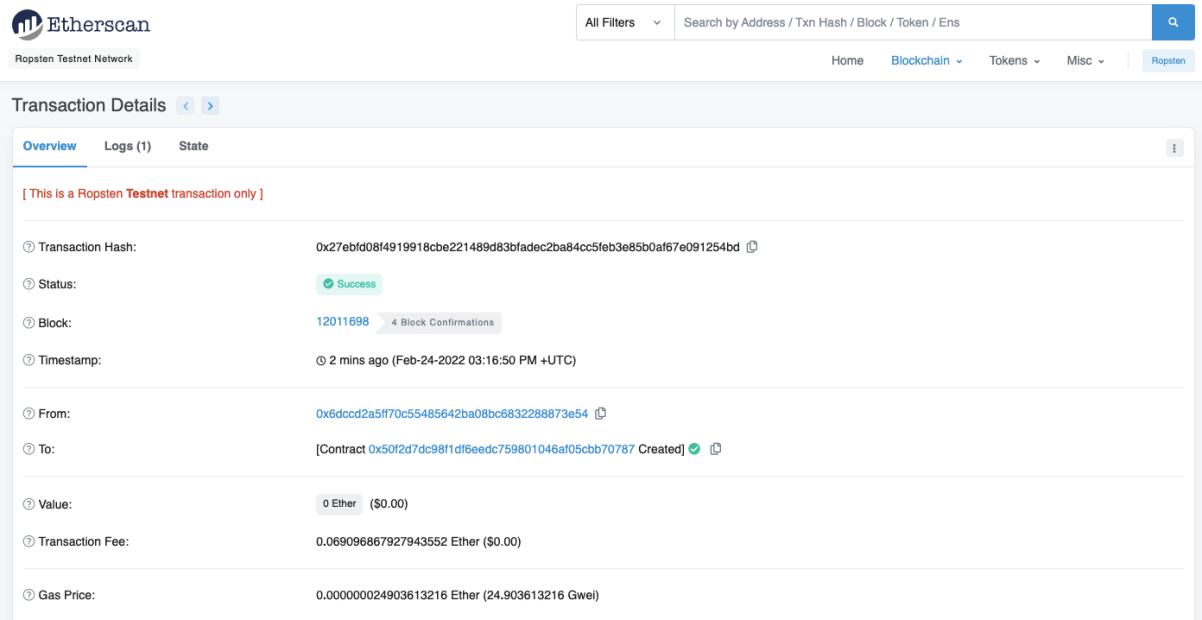

Figure 12. Contract details including creator address (own creation, (Etherscan website 2, 2022)contract address)

Therefore, being the contract deployed on an immutable distributed ledger, its authenticity can be easily verified. Further, the smart contract requires both the *public* and *private* keys of the creator's address. As the private key is never shared, the creator is the only one who can use this smart contract's functions since he is the only one with access to his private key. We can assume that the contract creator is the platform enabling the managing and limited partners to meet. Therefore, if the platform discloses his public address and the contract address (which are both unique), it is possible to verify without any doubt that any NFT created by this contract was indeed created by the platform.

After the smart contract has been deployed on the blockchain is possible to use it to mint NFTs. Before minting, the properties of the NFTs have to be determined in what is defined as NFT's metadata. The metadata can be considered a file containing the property of the NFT. Such properties will be displayed on the marketplace where the NFT will be listed for sale. Figure 13 depicts how a marketplace uses the metadata and the contract address to show the provenance and features of NFTs.

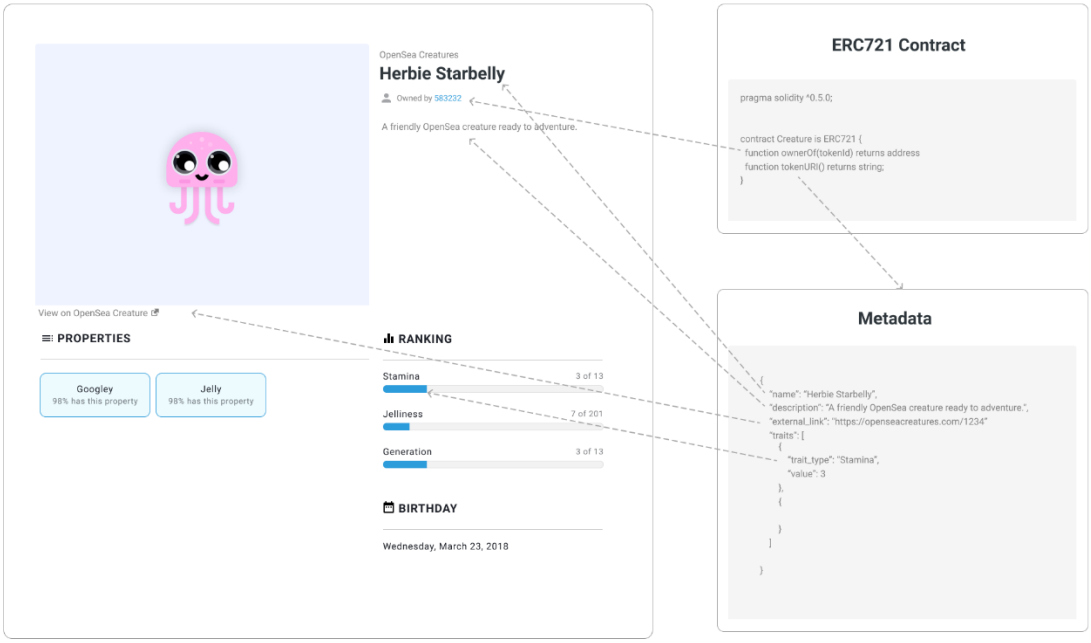

Figure 13. Metadata and contract displayed on NFTs marketplaces (source (Opensea Website, 2022))

For the two NFTs created for the artefact demonstration, some basic attributes have been selected in the metadata of each NFT, as shown in Table 2.

Attribute	**Description**
Partner type	Indicates if the NFT is the managing partner NFT or the Limited partners NFT
Property type	Indicates the type of property that has been tokenized, can include categories such as: apartment, house, commercial, etc
Address	The address of the property including town, postal code, and street number
House number	The house number of the property
Number of rooms	The number of rooms that the property has

Table 2 Metadata attributes of the created NFTs (own creation)

It is relevant to note that these attributes have been chosen for explanatory purposes. Therefore, it is possible to either add other properties or add some other if a more detailed description of the property will be required in a digital form. However, the most relevant element to notice here is that once the properties have been inserted in the metadata file, the NFT can be minted. Since the metadata is in the form of a JSON file, it is possible to 'freeze' it for added security. Once the metadata is frozen, no one, even the creator of the NFT, can modify it, achieving the so-called immutability in a blockchain network. After the NFT's metadata attributes have been decided, it

is possible to mint the NFT. In the case of this research paper, two hypothetical NFTs have been created.

Figure 14. Managing partner and limited partner NFTs metadata (own creation)

Figure 14 shows the metadata of the two NFTs, it can be seen how they use the same structure but have different values. Once the metadata has been created, it is possible to mint the NFTs on the blockchain via the smart contract previously deployed. In essence, what the minting function does is call the contract, verify that the private key that deployed the contract is the same one that is trying to mint the NFT (so to allow only the creator of the contract, in this case, the platform, to mint NFTs from it), and calling the metadata previously compiled so to create this token in the blockchain network. As it is possible to see in Figure 15, when the minting procedure is completed, the created token automatically receives a unique **ID**. In this case, the number 1 since it is the first one created. Figure 15 also depicts other information considered relevant from the minting transaction. (1) **Timestamp**: as seen in the contract example, the timestamp allows to have proof of when the token has been created. (2) **From**: indicates the address that created the NFT. In this way, it is easy to verify if the address has also created the contract. (3) **Interacted With (To)**: specifies the smart contract that has been used to mint the NFT. In this way, similarly to the creator's address, it is possible to verify the authenticity of the contract.

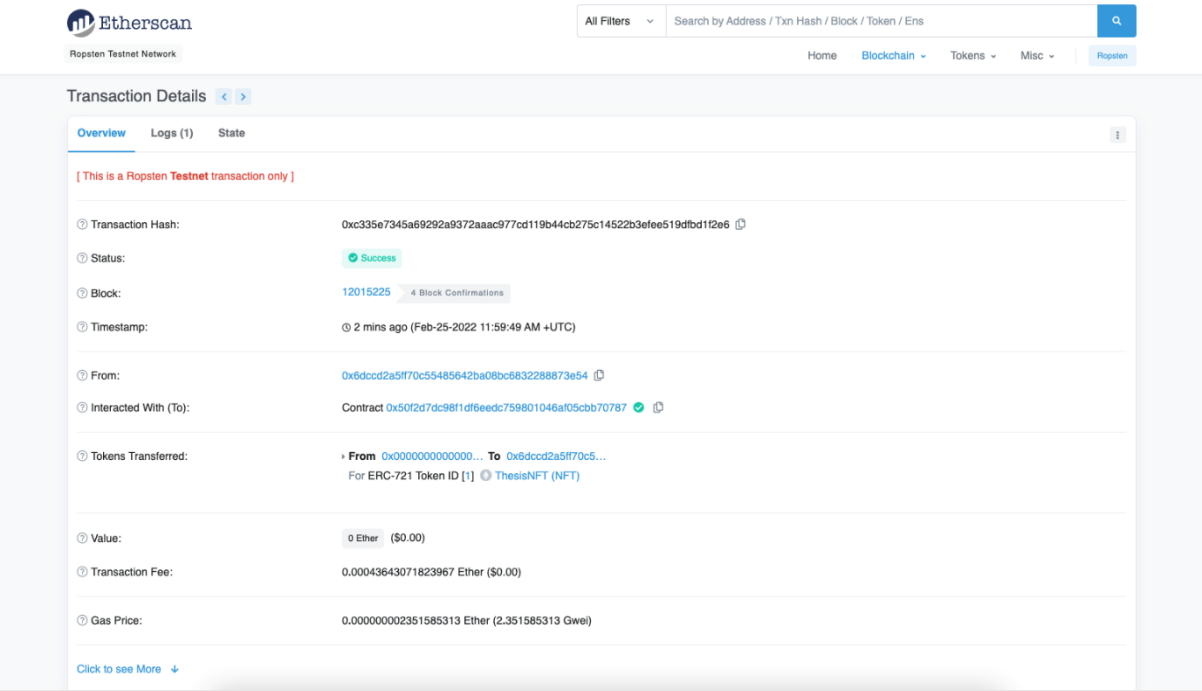

Figure 15. Mint transaction for NFT #1 (own creation, (Etherscan website 3, 2022) transaction)

The blockchain scanner also allows keeping track of any transaction executed by the smart contract. Thus, it is possible to verify if any new NFTs has been minted from the smart contract, as shown in Figure 16.

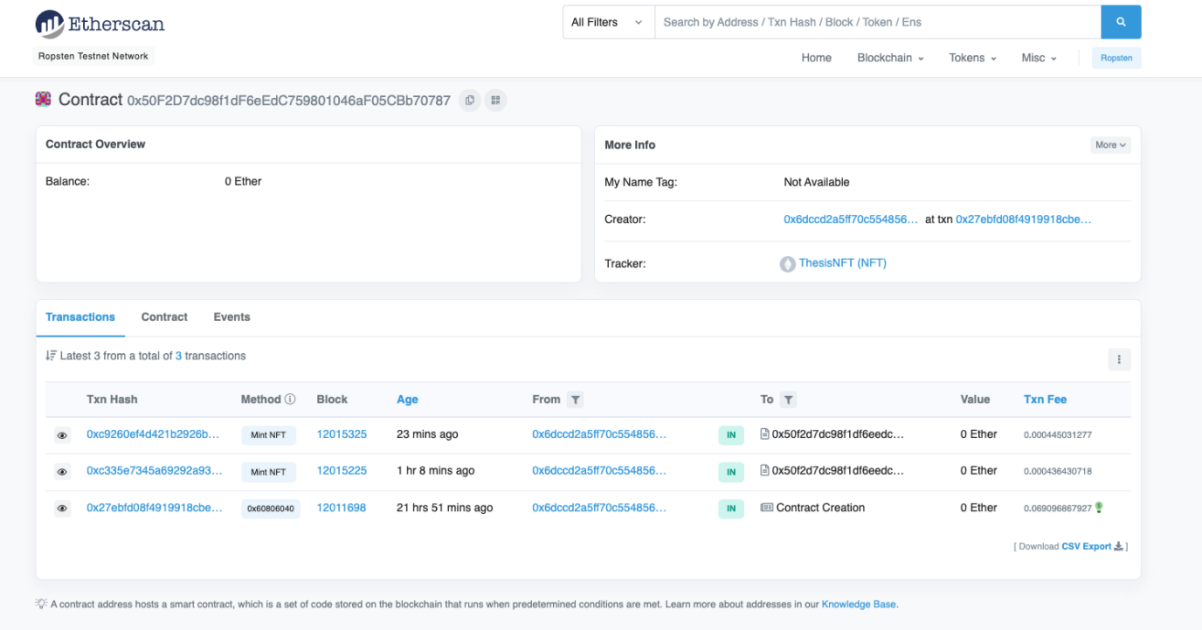

Figure 16. Contract transactions history (own creation, (Etherscan website 4, 2022) contract address)

Once the NFTs have been minted, they can be transferred from one address to another, like any other token. In the case of this research, the minted NFTs are found in the digital wallet of the researchers. Besides seeing the NFTs on the blockchain explorer, it is also possible seeing them in a digital wallet, in this case, Metamask, which has been used to create an Ethereum address on the Ropsten network. Since the representation of the NFT is mainly visual, a sample picture has been selected for the NFTs in the minting phase. It could be argued that such a visual representation could be meaningless for an NFT representing a real-world asset. However, replacing the image with a QR code linking to a digital page with all the property details could be a possibility.

More importantly, after deploying the NFTs on the blockchain, they are in the digital wallet, proving the ownership of the digital asset. Figure 17 shows the two NFTs, named *Managing Partner NFT* and *Limited Partner NFT*, in the digital wallet of the researchers. The mobile version of Metamask has been used for the example as the desktop version does not allow yet to visualize ERC721 tokens.

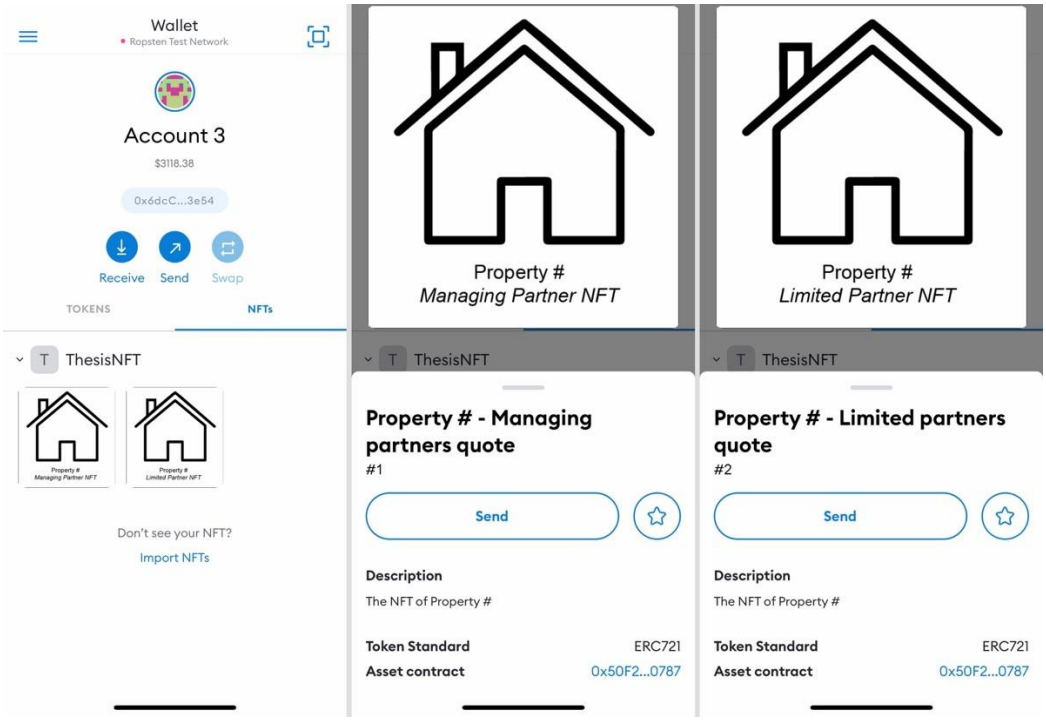

Figure 17. NFTs of the two property types in the researchers' wallet (own creation)

5.2.2 Fractionalization of the Limited Partner NFT

After presenting the creation and deployment of the digital representation of hypothetical properties in the form of NFTs, the researchers will show how such tokens can be fractionalized.

Fractionalization of NFTs is a relatively recent option. The array of possibilities to do so ranges from developing a proprietary smart contract to using decentralized protocols. Since this section's purpose is to demonstrate that NFTs can be fractionalized, regardless of the option decided, the latter option is selected. The reason for not fractionalizing the NFT in practice, as done for the NFTs creation in the previous section, lies in technical reasons. As mentioned at the beginning of this section, fractionalization is a relatively new and complex procedure, which requires an understanding of smart contracts that go beyond the knowledge of the two researchers. Contrarily to the deployment of ERC721 on a testnet, which is a fairly standardized procedure, fractionalization is a more complex procedure involving a high level of coding. Therefore, using an already developed decentralized protocol seemed a more viable and reliable way for the artefact demonstration.

Furthermore, the already existing protocol that will be used to demonstrate the viability of fractionalizing NFTs is deployed only on the Ethereum blockchain and not in the Ropsten test network. Consequently, for the researcher to use the same procedure on the test network, the whole protocol would need to be rebuilt. Such a procedure is not considered necessary since the protocol's existence and its use by other users on the Ethereum network is considered enough to demonstrate its functioning. Therefore, the following section will introduce the main concepts used by the protocol and illustrate how a hypothetic platform could apply the same principles for real estate properties fractionalization. The decentralized protocol taken under examination here is Fractional (Fractional website, 2022).

Before proceeding, it is worth mentioning how the Fractional platform, is mainly focused on the fractionalization of NFT art. However, the same principles can be applied to any typology of NFTs. Thus, the platform has been selected as a reference method to fractionalize NFTs. Figure 18 represents how the fractionalization process would occur. At first, the NFT owner uses the platform smart contract to create an **NFT Vault**. As the name suggests, the vault acts as a safe storage space for the NFT. This means that the smart contract 'locks' the original NFT into the vault, and then it creates a desired amount of fractions. These fractions can then be traded, while the original NFT remains locked in the smart contract and cannot be traded anymore until the fractions are available. It is crucial to notice how the input source, the NFT, is an ERC721 token, while the fractions are ERC20 tokens. This means that the fractions are not anymore NFTs, but

they are regular and fungible tokens, and each token is equal to any other. This seems feasible also for the case of real estate properties. Indeed, the original property is different from any other in the real world. Thus it is digitally represented by an NFT. However, if they would exist, real-world fractions could be argued to be considered all equal.

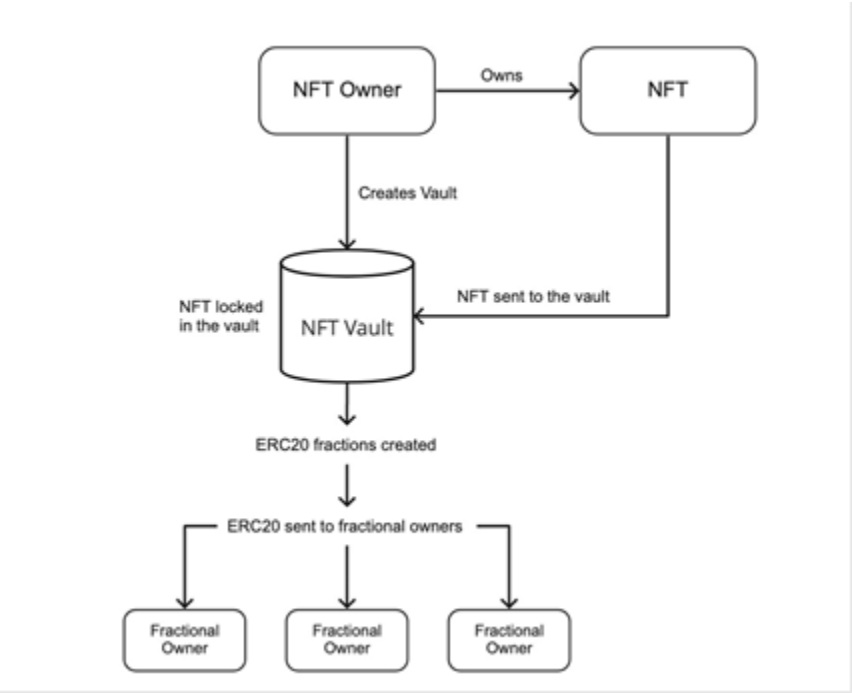

Figure 18. NFT fractionalization process (own creation)

The smart contract for creating an NFT Vault is publicly accessible on the Ethereum blockchain, which means that the use of Fractional's platform is not necessary to create a vault (Etherscan website 5, 2022). Hence, the smart contract allows any user with a digital wallet, like Metamask, to connect directly to the contract and use its functions. As shown in Figure 19, the contract offers several functions. The mint function is the one studied in this demonstration. Such a function allows creating an NFT Vault starting from an NFT. To create the vault, the function requires inputting some parameters, which are reported in Table 3.

Some parameters, such as **supply** and **listPrice**, are interesting from a functional perspective. Notably, *supply* allows defining the number of fractions (or better, of ERC20 tokens) in which the property would be divided. Tush, depending on the number of tokens made available, the entry price for a fraction would be higher or lower. Indeed, if the value of a hypothetical property is 1.000.000 DKK, selecting a supply of 10 tokens would make each of the ten fractions less

accessible than the case when 100 tokens would be created. Thus, this function has a vital role since it allows to decide how accessible the price for a limited partnership fraction will be. Further, since the artefact's case, the real property is acquired before being tokenized (as previously depicted in Figure 7), the token supply would need to be linked to the initial crowdfunding quotes exercised on the platform.

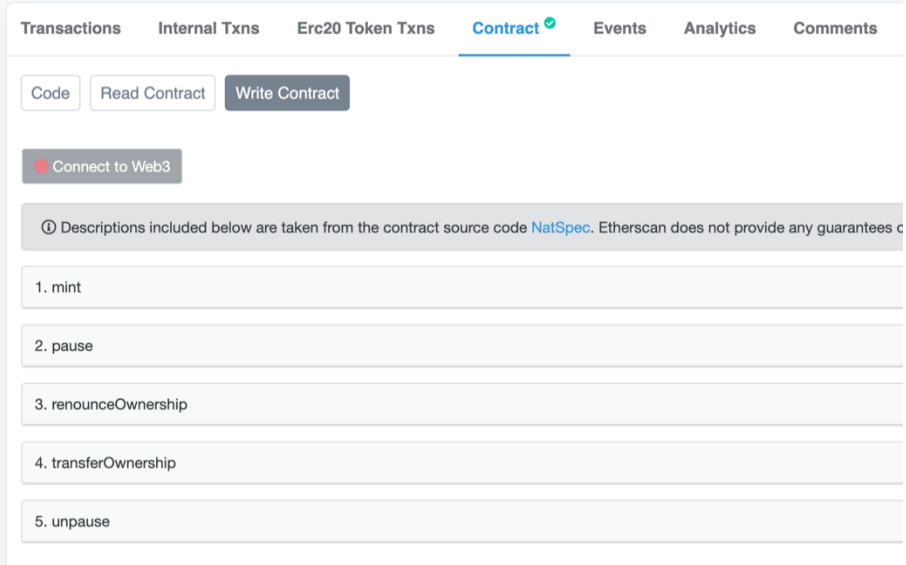

Figure 19. The Vault creation smart contract functions (Etherscan website 6, 2022)(contract address)

Parameter	**Description**
name	the selected name for the ERC-20 token that will represent the fractional ownership of the vaulted NFT
symbol	the desired symbol (e.g., PR1) for the ERC-20 fractions
token	the ethereum contract address of the NFT that will be fractionalized. In the case of the demonstration, the contract created in the previous section would be used
id	the unique identifier used for your ERC-721 NFT in its respective smart contract. In the case of this demonstration, property 1 would have ID 1 and property 2 would have ID 2
supply	the desired total supply of the ERC-20 token. There are no limits, meaning that fractions can be very small
listPrice	the initial price at the start of ERC-20 fraction ownership. In the case of the artefact under examination here, this value would correspond to the value of the real estate property
fee	the curator fee (from which is paid to the owner of the fractional asset (enter a value between 0 and 0.1, any values greater than 0.1 will return a failed transaction)

Table 3. Mint function attributes (own creation)

Another relevant parameter from Table 3 that deserves to be analysed briefly is the **fee** parameter. *Fee* allows determining the so-called 'curator fee', a reward received by the NFT owner for his

availability in fractionalising the NFT. In the case it is not considered necessary, such a fee can be set to 0. However, if a platform would be the one creating the NFT vaults, starting from the initially created property NFTs, inserting a fee value directly in the smart contract would allow the platform to receive fee payment for its services in an automatised manner.

Once the new ERC20 tokens are created, they can be listed and traded like any other token on a blockchain network. If they had to be listed on a platform that exercises KYC procedures before allowing users to trade them, the list of transactions would be similar to the one we previously saw on Etherscan regarding the creation of smart contracts and minting NFTs (Figure 16). However, instead of having a list of anonymous wallet addresses associated with timestamp and transactions ID, a list of names could potentially be displayed.

By looking at the smart contract, and the possibility of fractionalising NFTs, one may wonder if creating two types of NFTs for the property is necessary. The main reasoning behind this choice is that the *Managing Partner NFT* is arguably unique since it is the only one that grants the right to live in the property. For this reason, having only one NFT that gets fractionalised will not work. Since all the fractions created are ERC20 tokens, it would be impossible to distinguish the managing partner from the limited partners on the blockchain since all the tokens will have the same properties. Therefore it was considered essential to ensure the unicity of the *Managing Partner NFT* and not divide it into fungible tokens. Figure 20 summarises the actors involved and the tokens adopted in the fractionalisation process.

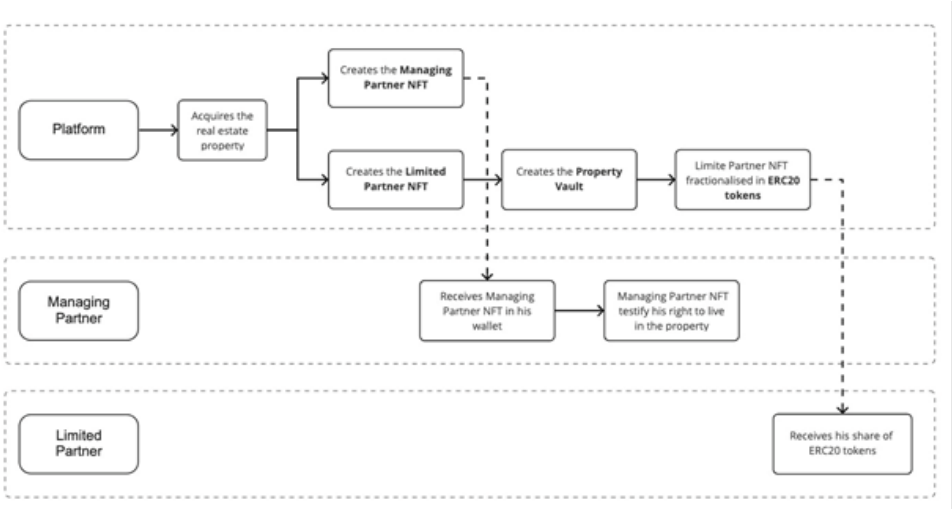

Figure 20. Fractionalization and ownership actors (own creation)

The summary depicted in Figure 20 was considered helpful to conclude this section. In the following section, the validity of the here presented artefact will be evaluated.

6. Evaluation (step 5 DSR)

6.1 Evaluation methodology

After creating the artefact following the design principles gathered from previous research and informal interviews and demonstrating its functioning principles, the following section aims to evaluate the proposed solution. As seen in the previous section of the paper, the demonstration of the artefact has been limited to only two steps of the overall design process. Further, it has been conducted by adopting both experimentation and simulation procedures. Consequently, one may wonder how the artefact can be evaluated due to its experimental nature. However, evaluation could take many forms depending on the nature of the problem venue and the artefact (Peffers et al., 2007). Among the different Design Evaluation Methods depicted by Hevner et al. (2004), we can find **descriptive** evaluation methods (Hevner et al., 2004). This evaluation method implies the '*Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility' (*Hevner et al., 2004). Therefore, such descriptive evaluation will be adopted and will be based on the design principles depicted in the artefact creation section. Starting from these principles, the researchers will evaluate how well the artefact performs and how it supports a solution to the problem (Peffers et al., 2007). Finally, it is worth mentioning that DSR grants a certain level of flexibility in evaluating the artefact, particularly with very novel artefacts (Hevner & Gregor, 2013).

Before proceeding with the evaluation, it is appropriate to point out that, at the end of the evaluation phase, DSR provides researchers with two choices (Peffers et al., 2007). On the one hand, researchers can iterate back to the design phase to attempt to improve the effectiveness of the artefact. On the other hand, researchers can consider the findings satisfactory for the research, continue to the communication phase, and leave further research to future research. The nature of the research venue may dictate whether such iteration is feasible or not (Peffers et al., 2007). In the case of this research, an iterative process has been already adopted by the researchers during the informal interviews conducted in the creation of the artefact phase. Consequently, this section reports the evaluation of the final stage of such an iterative process. Nonetheless, topics for future research and improvements will be identified and will be communicated by the researchers in the

discussion phase. The time, spatial and scope constraints of this research have not allowed the researchers to address them directly.

In the case of the artefact here evaluated, the best evaluation procedure has been considered interviewing experts in the field of real estate, real estate investing, and fractionalisation of real estate and using their knowledge to evaluate whether the artefact helps solve the identified problem. The main reason for this choice is that the real-world applicability of the artefact is presently limited due to the assumptions described in the artefact creation section. However, thanks to the pool of experts in the field interviewed, it has been possible to asset the current status of real estate tokenisation and identify the benefits and drawbacks of the developed artefact and its overall utility. The interviewees' background and the reasons behind their selection have been covered in detail in the methodology section. Regardless, they will be briefly re-introduced to help the reader better understand this evaluation. Marc Lund Andersen is a senior economist at the Danish Knowledge Centre for Housing Economics (Boligøkonomisk videncenter) (BVC Website, 2022). Nadim Stub is the former CEO at Proptech Denmark and current Group Vice President of Digital Ventures and Partnerships at DEAS group, a property & asset management company (DEAS Website, 2022). Jonas Lodahl serves as a business developer at Digishares, a company offering tokenized real estate investments (Digishares Website, 2022). Mads Harmsen is the Head of Governance & Risk at The Many, a company offering fractionalized real estate solutions (The Many website, 2022).

To better evaluate the artefact, the analysis has been split into the different design concepts to asset their points of strength and weakness individually. This was considered a reasonable practice to identify subjects worth exploring in the discussion section. It is worth mentioning that the artefact itself has not been presented to the experts during the interviews. Instead, a more exploratory interview approach, connected to the design themes, has been preferred. As said at the beginning of the artefact creation section, there are multiple ways the artefact could have been created. Thus, it was believed that conducting interviews with a more general outlook on the topic could have improved their academic validity. By presenting the artefact directly, as witnessed while conducting the informal interviews, the concern was that the focus would have been on the *operational aspects* of the artefact rather than its impact and opportunities in reference to the research question and topic. Consequently, the interviewees have been questioned on the main

topics surrounding the use of NFTs for real estate fractionalisation. Their answers have been later used to assess the benefits and drawbacks of the artefact. In this way, it was considered possible to use the expert knowledge to evaluate the artefact and be faithful to the exploratory nature of this thesis.

6.2 Evaluation of design principle 1: Dual sided artifact

One of the main aspects of the current offerings in terms of tokenized real estate that the artefact aims to solve is the possibility of enabling an offer where both real estate buyers and investors can meet and transact with each other. Hence the introduction of the concept of managing partners and limited partners. During the initial artefact evaluations executed through informal interviews, one of the main concerns identified was the idea of not fully owning the property if using a similar solution. However, the collection of primary data has offered an interesting point of view regarding what can be defined as a *sense of ownership* of real estate properties. Notably, Stub pointed out that such a solution offers multiple similarities to the Danish cooperative housing (Andelsbolig), where a buyer owns a fraction of a total property amount, not necessarily the actual property they reside (Personal communication, Nadim Stub, 2022). This resemblance indicates that Danes are already accustomed to the concept of investing considerable capital in the property in which they reside while not owning the space outright in reality. This could be argued to be a place to live within the shared cooperative housing space. However, the Danish cooperative housing model presents some significant differences in the way it is traded since the evaluation of the property traded is not necessarily decided on market forces. Instead, the "Andelsforening" decides the prices at which the owned portion must be sold. The designed artefact has a significant difference in these regards since it would allow deciding to invest in a property that the investor would have more decision power on, more similarly to acquiring a property via traditional methods. Consequently, while Stub pointed out that Danes are already used to the psychological idea of shared investments with others, the designed artefact differs in the degree of how much decision power an investor has in the asset they wish to invest in.

Speaking of some of the opportunities offered by having real estate being tokenized, Lodahl emphasized how tokenization has the potential to make real estate investing more cost efficient, removing intermediaries and automating most of the setup around real estate investments by making issuing, managing and trading more seamless (Personal communication, Jonas Lodahl,

2022). Nonetheless, it could be argued that current solutions with tokenized real estate offerings consider only real estate as an investment vehicle. In contrast, the artefact designed for this paper also incorporates the managing partner to offer opportunities to both investors and buyers looking for a home rather than an investment opportunity. So the artefact seems to take the current offering a step further by creating a two-sided market where both parties can meet and transact. Although the artefact seems to offer an improvement and a new solution currently unavailable in the field of real estate tokenization, some legal implications may be at the root of this offering not having been made before. Further about this topic will be addressed in the discussion section discussing this concept.

6.3 Evaluation of design principle 2: Trust

The literature review showed how individuals are willing to transact NFTs and how some are traded for large amounts of money. However, real estate properties could be argued to be a costly asset, and for many people, an asset with much emotional value, in the way of their home. Therefore, the designed prototype must induce trust in people and encourage them to use the system. In these regards, the technical properties of NFTs could help provide a level of trust and control of the asset that is not offered by the other tokenised solutions currently available. On the one hand, as showed in the artefact demonstration, the users would have complete control of their fractional ownership by having them in their digital wallet, being able to trade it with other users directly. The relevance of this aspect seems to be aligned and confirmed in line with the benefits highlighted by Lodahl. In regards to the main difference between tokenised assets and REITs, he mentioned '*So I think for a lot of people that's quite appealing, instead of just blindly trust, trusting some other self-proclaimed financial experts, and who additionally also charge a fee for sort of managing your funds*' (Personal Communication, Jonas Lodahl, 2022). Direct ownership and tradeability of digital assets could be argued to be the main difference between the artefact and the solution proposed by The Many, where the investment fund has the control over the fractionalised assets, making it more difficult to have direct control over them or selling them (Personal Communication, Mads Hamsen, 2022).

Even while this paper does not directly tackle the legal implications of trading with real-world assets as tokens and NFTs, this area is critical in increasing trust from potential users. This was highlighted in the informal interviews conducted to design the artefact, where concerns regarding

fraud were raised, and in the interviews with experts. Notably, Lodahl pointed out how the crypto space has seen a vast number of scams, emphasising the importance of having a legal framework and guidelines that the issuer needs to adhere to (Personal Communication, Jonas Lodahl, 2022). Regarding tokens and real estate properties, the main pain point related to trust in the system identified by Lodahl is verifying the ownership of the property. In regards to offering a property to investors in the form of token, referred by him an issuance, he said: '*so if you do an issuance, you want to make sure that that they do, in fact, own the house and not just say, I own a house without having to prove it. So they need to prove it in some way that they own the house. So there's still need, everything cannot be done by the blockchain*'(Personal Communication, Jonas Lodahl, 2022). In the case of the artefact under evaluation, it could be argued that the property acquisition process allows avoiding the problems pinpointed by Lodahl. The *Conceptual Design* section showed that the property is acquired with the fund raised by soon-to-be limited partners before being tokenised. Therefore, the issue could be argued to be related only to properties already fully owned that are then issued in the form of tokens.

A further implication of the conceptual design of the artefact is that it could empower parts that already trust each other to achieve collective investing in a decentralised manner. Notably, by looking at the merely technical point of view, which has been the main focus of the artefact developed in the paper, the use of NFTs could be argued to provide a safe solution to trade fractions of real estate properties. As shown in the demonstration, thanks to the Ethereum blockchain, the created NFTs are entirely transparent regarding previous transactions, prices and their creator. Consequently, a group of trusted individuals could adopt this solution to create a shared investment recorded on an immutable ledger. The trust among individuals is considered crucial for using an artefact as the one presented in this paper due to the legislative barriers currently present. However, the transparency offered by blockchain facilitates trust among known parties to adopt the solution offered from the artefact. In order to expand this solution to a broader audience and increase the level of trust even among unknown parties, which could be argued to be the primary value offered by decentralised blockchain networks, some steps seem to be necessary. More notably, the recognition of the exchange of the property deed via blockchain (Personal communication, Jonas Lodahl, 2022) (Liu et al., 2020). Further, suppose digital wallets, which are currently anonymous, would be transparently linked to the real-life identity of the users, as suggested by Lodahl. In that case, issues such as lost tokens and hacks could be managed more efficiently (Personal

communication, Jonas Lodahl, 2022). The implications of these elements will be discussed in the discussion section.

6.4 Evaluation of design principle 3: Accessibility

An essential element throughout the research has been evaluating the artefact's ability to increase the accessibility of the real estate market for young adults. When investing in real estate in Copenhagen today, young people rely heavily on financing, which means a significant priority is put on their ability to have enough capital for a down payment. This acts as one of the main barriers, making it harder for young people to invest in housing when compared to people who are older and wealthier than them (Personal communication, Marc Lund Andersen, 2021). These indirect circumstances make the financing options for young people even more essential to invest in real estate. During our interview, Andersen pointed out particular elements that could prevent younger people from financing a property. Notably, the restricted access to financial products that could help young people service their loans better, like instalment free and variable rate loans (Personal communication, Marc Lund Andersen, 2021).

In terms of innovations on the market making housing more accessible, Andersen said: "*I don't see any initiatives actually in place. Other than building more? There are some things that people are working on, for example. Well, again, it would be proposals for what it could do, but I haven't heard anyone in Denmark speaking seriously about it…*" (Personal Communication, Marc Lund Andersen, 2021). Despite the skepticism expressed by Andersen, the interview with Nadim Stub allowed attaining insights into some global developments influencing innovation in the area. Stub pointed out that real estate as an industry has not seen considerable innovation over the past thirty years. However, developments in the last five years may indicate some changes, mainly in the American market, with the introduction of "lease to buy" and other initiatives increasing the number of available options for investing in the housing market. Stub pointed out that using blockchain technology in real estate could make a difference for both investors and homeowners. According to Stub, the main area that blockchain could improve concerns the entry barriers to the real estate market. He then mentioned the The Many as an available solution where the minimum investment requirements are lower than traditional methods (Personal communication, Nadim Stub, 2022). However, as mentioned before, the cited company offers no solution for buying a property. Further, although Stub mentions The Many as a solution reducing entry barriers to real

estate, it is worth specifying that the product offered by the company does not involve owning any part of the properties available. Instead, investors own a share of the revenue the property generates. As Harmsen described during his interview, '*it is more buying into the cash flow from the operations of the properties that we manage, at the same time you are and as that one I consider fairly safe given the properties that we invest in*' (Personal communication, Mads Harmsen, 2022). This is true also for the option provided by security tokens, where an SPV owns the real estate property, and then it issues shares on the blockchain in the form of tokens. The investors, therefore, own a share of the company rather than a share of the property (Personal communication, Jonas Lodahl, 2022). In this sense, the artefact explored in this research offers a different exposure to the real estate market, offering a fraction of the actual property rather than a share of the revenue stream created by the property. Further, when compared to the security options currently available, the tokens created starting from the *NFT Vault* are backed by the *Limited Partner NFT*. Therefore, it can be argued that the owner of such tokens owns a share of the property.

Regarding the accessibility of real estate financing in Denmark for buyers, some barriers that could compromise the applicability of the artefact in real life have been identified. To begin with, Andersen declared that Denmark probably has the best mortgage system in the world (Personal Communication, Marc Lund Andersen, 2021). Consequently, the system could be relatively hard to change due to the perceived effectiveness of the current. This thought was also confirmed by Hamsen, who expressed doubts regarding the possibility of improving the Danish financial system due to its current efficacy (Personal Communication, Mads Hamsen, 2021). Despite the efficacy of the mortgage system, the issues regarding the down payment requirements have been identified and confirmed as a problem. Therefore, it could be argued that the artefact would allow mitigating such issues by allowing users to reduce their exposure to the property they intend to acquire. The Managing Partner could start his housing partnership with the limited investors by owning only 15% of the property. In this case, if the soon-to-be managing partner would need a mortgage to finance that 15%, the barrier imposed by the down payment would be significantly easier to overcome. Indeed, the artefact would allow the managing partner to reduce the down payment for a financing option from 5% of the total value to 5% of a fraction of the total value (15% in the example here presented).

Finally, Lodahl, Stub and Harmsen offered an interesting perspective regarding the current accessibility of fractional ownership in real estate. Although several options are already available, retail investors cannot widely use them due to the high economic and legislative barriers. Harmsen identified the cost caused by the expenses for legal compliance as one of the main barriers to a broader digital innovation in real estate (Personal Communication, Mads Harmsen, 2021). Similarly, Lodahl declared that creating an SPV is expensive and complex due to the unclear legislative environment surrounding real estate tokenization (Personal Communication, Marc Lund Andersen, 2021). Stub declared how another entry barrier is also given by the current difficulties in managing many fractional investors. He argued that increasing the number of investors would compromise the ability of the development company to serve all investors at the same time (Personal Communication, Nadim Stub). Further, this aspect seems to be worsened by the usage of IT systems that are outdated (Personal Communication, Nadim Stub).

Referring to the problems highlighted in this paragraph, the artefact can be argued to mitigate some of the barriers identified. Notably, two main alternatives can be identified. On the one hand, whether the property deed could be transferred with the NFT. In this case, every actor investing in the property would own a fraction of a property rather than a share of an SPV. This option could solve the issue related to the high-cost barrier induced by the creation of an SPV. Lodahl recognized this option as the most compelling use case for NFTs for tokenized properties (Personal communication, Jonas Lodahl, 2022). On the other hand, if the property deed would not be transferable via NFT, it could be possible to transfer the deed to the managing partner but, at the same time, offer some guarantee to the limited partners. This could be achieved either via a smart contract or by instituting a third party giving this guarantee. However, as said by Stub, Harmsen and Lodahl, achieving legal compliance for a third party can be costly and complex. This aspect could be less crucial in a solution where the parties know each other. However, it is arguable that such an option would limit the use cases for the artefact to people trusting in each other without the need for a third party since the solution offers limited guarantees to users.

6.5 Evaluation of design principle 4: Liquidity

All interviewees agreed that fractionalization could potentially solve the illiquidity that currently characterizes the real estate market. Further, everyone seemed optimistic about its possibility of making the real estate market more liquid. Making real estate more liquid as an asset class could

bring various opportunities, both for retail and institutional investors. Globally, investments into real estate assets are effectively tied up into brick and mortar, which, if become liquid, could represent possibilities for many new investment opportunities both for private retail and institutional investors (Personal communication, Nadim Stub). Speaking of the opportunities brought by having real estate as a tokenized asset, Lodahl mentioned that historically real estate has been a renowned illiquid asset. Therefore, empowering new levels of liquidity in the market could make the assets more available and demanded by both retail and institutional investors (Personal communication, Jonas Lodahl, 2022). Additionally, having a secondary market that enables parties to trade real estate assets in the form of tokens could offer another advantage. More liquidity implies more straightforward exit possibilities from the market. Therefore, investors and buyers could enter and exit the market more efficiently instead of having their investment locked into the property for a prolonged period (Personal communication, Jonas Lodahl, 2022).

Lodahl pointed out how NFTs, if intended as a digital representation of the whole property, could be restricted in how much improvement they offer in terms of liquidity. Indeed, having NFTs representing the entire property rather than its fractions would arguably have liquidity barriers similar to regular offerings since the price would still be inaccessible for several people. Therefore, security tokens can be considered a much more liquid asset since, by default, they represent fractions of the property (Personal communication, Jonas Lodahl, 2022). However, in the artefact designed for this research, the NFT representing the property is fractionalized. Therefore, this drawback seems to be avoided. Further, Lodahl identified a benefit of NFTs compared to security tokens. Suppose the asset had to be split into a set and not modifiable amount of fractions. In that case, NFTs offer a better solution since security tokens can always be fractionalized in smaller fractions (Personal communication, Jonas Lodahl, 2022). This was a significant result in the evaluation of our research since investing made available through fractionalization is deemed essential for the designed artefact.

Lodahl explained how Digishares expects to introduce later this year different De-Fi procedures such as a lending protocol, the possibility for investors to use their tokens as collateral in decentralized peer-to-peer lending, and a decentralized exchange (Personal communication, Jonas Lodahl, 2022). This aspect is considered highly relevant since it could be argued to acknowledge the validity of the artefact's design concept and the idea of allowing DeFi related features so to

create more liquidity for fractional real estate assets. Concerning using real estate assets as collateral, Stub highlighted how banks carry a relevant role at the moment, '*You know, I have a house, I can go in and say, Well, I want to I want to I want to take 20% loan in the freehold of that house, and then the bank will pay that out to me. So that that is the bank, obviously capitalizing on me wanting to have liquidity. They're not going to give me the 20% for free. They're going to make money off of it.*' (Personal communication, Nadim Stub, 2022). Therefore, the option presented by the artefact and soon-to-be adopted by Digishares aims at achieving the same result but in a decentralized and smart contract-empowered manner.

Another relevant matter discovered during this analysis is that using SVP to create fractionalized properties can be argued to have significant implications on the market's liquidity. The individual properties indeed become more liquid thanks to being tradeable in fractions. However, it is also true that each SVP has an individual legal entity which causes segmentation in the market. Thus, each SVP can be considered as a separate marketplace, an aspect that was also considered by previous literature (Liu et al., 2020). In this regard, a solution where the fractions are traded on a DEX on the Ethereum network, as the artefact could empower, could arguably limit market fragmentation. Similarly to platforms mentioned in the literature review section, like OpenSea, trading NFTs on an open marketplace could foster an even more liquid market.

A final relevant finding encountered during the primary data collection phase is the intention from The Many to change the typology of funds offered to customers. Presently, most of the funds are open-ended, so the company is obliged to pay out investors that want to quit the investment within one and a half months (Personal Communication, Mads Hamsen, 2022). However, the company is moving towards so-called closed funds, where customers have their investment locked in for a long time, for instance, ten years (Personal Communication, Mads Hamsen, 2022). Hamsen explained that the reason for such a choice, which arguably impacts the liquidity of this typology of fractionalized investments, lies in the liquidity risk. Notably, he said '*if you want to manage the open ended, or the open end funds where you're allowed to get out, you need to hold a significant cash buffer in order to give the investors a sufficient degree of certainty that they can always get out and we can meet those obligations*' (Personal Communication, Mads Hamsen, 2022). This seems to highlight a pain point of a solution where a company directly allocates and manages tokens, which seems to cause liquidity-related issues. In this regard, the artefact could be argued

to mitigate the problem. Indeed it offers a more decentralized solution where the platform allows users to fractionalize and trade tokenized properties but does not own them. Thus, the centralization caused by a company owning the property deeds would be avoided, and the liquidity problems that The Many seems to face could potentially be avoided.

6.6 Evaluation of design principle 5: Authenticity & Traceability

The concept of Authenticity and Traceability is strictly related to the main features of NFTs, especially uniqueness, scarcity and verified ownership as depicted in the artefact demonstration section. This principle assumes an inherited similarity between the nature of real estate properties and NFTs. The aspect of the artefact, the use of a blockchain empowered solution like NFTs, is the one that received the most criticism during the interview phase.

As previously mentioned, Lodahl was declaratively skeptical in using NFTs for tokenized properties for various reasons. (Personal communication, Jonas Lodahl, 2022). Among those reasons, in Lodahl opinion, the use of ERC-721 tokens over ERC-20 ones for fractionalization is redundant since fractions are all the same. Therefore, the only way NFTs representing fractions will be different from each other is by their ID. According to Lodahl, it is better to use regular ERC-20 tokens. Therefore, it seems like the uniqueness feature was not considered relevant enough. However, Lodahl also mentioned that NFTs could become relevant in the future whether the property deed could be legally attached to them. This makes the solution proposed by the artefact more likely to be relevant. Indeed, it could be argued that the introduction of the managing partner figure makes the use of NFTs more critical. Indeed, it is relevant to ensure that only one token representing the real estate property empowers the holder to live in the property, a function achieved by the *Managing Partner NFT*. Furthermore, the artefact seems to follow Lodahl's suggestion of not using NFTs in fractions intended for investors. Indeed the *Limited Partners NFT*, which is vital to remind, represents the totality of the property's part not owned by the managing partner, is fractionalized in a set of ERC20 tokens. Furthermore, the fractionalization of the NFT and its locking into the *NFT Vault* permits what could be defined as automated reversibility. If the managing partner would acquire all the ERC20 fractions, he can 'burn' them and unlock the Limited Partners NFT from the NFT Vault. Another element Lodahl found in favour of security tokens is their safety for investors. Notably, the possibility of reissuing tokens if the user loses his tokens or has his wallet hacked (Personal Communication, Jonas Lodahl, 2022). He also

mentioned how it is not possible to reissue NFTs as they are non-fungible and unique by nature. In the case of the designed artefact, this is true for the *Managing Partner NFT*, which has all the features on NFTs and is therefore unique. However, the situation is slightly different for the *Limited Partner NFT*, and reissuing tokens can be argued to be achievable. *The Limited Partner NFT* is never offered to investors as an ERC-721 token, but it gets first fractionalized and then sent to the limited partners in the form of ERC-20 tokens. Therefore, in cases similar to the ones depicted by Lodahl, a snapshot (which can be defined as a record of users holding based on blockchain wallets) of current holdings could be taken. Then, the ERC-20 tokens' liquidity pool would be removed, making the tokens not tradeable and arguably worthless. Finally, the NFT would be unlocked from the vault and re-fractionalized. Thanks to the snapshot, which would be a record of holding based on blockchain wallets, the holders would receive the same amount of fractions they held before. It is worth pointing out that such a solution is not viable for the *Managing Partner NFT*. Due to it being an NFT, the problem highlighted by Lodahl could potentially affect users if they would lose access to their wallet.

Another objection against the applicability of NFTs in real estate came from Stub. During the interview, when asked to assess the potential benefits of blockchain empowered solutions on the real estate market, he expressed a personal belief that blockchain technology will not be used to facilitate user transactions in the short term. However, he considered it more likely that the technology could be adopted in a more administrative-related manner. Examples included tracking property developments and renovations, creating transparency and, most notably, building more sustainably (Personal Communication, Nadim Stub, 2022). Despite the short term skepticism regarding a wide usage of token transactions in real estate, Stub highlighted two interesting points that the artefact could potentially mitigate.

On the one hand, Stub emphasized how the methods adopted in registering real estate properties (including property size, renovation history, and related features) in the land register are still manual and prone to human error. As Stub puts it: *"... So they were just, you know, basic calculators, you can say, or excel sheets, and that's what they look like, they look like excel sheets, but these type of sheets, they obviously are prone to a lot of human error*" (Personal Communication, Nadim Stub, 2022). Further, he mentioned how it is not rare to find inconsistencies between the data reported in the land register and the actual traits of a property.

The relevance of ensuring high data quality when adopting blockchain empowered solution was also highlighted by Lodahl, who said: *'And yeah, so certainly, it's not sufficient just to have the blockchain because you still need to make sure that whatever data is put on the blockchain is done in a proper way*' (Personal communication, Jonas Lodahl, 2022). In this regard, it could be argued that the artefact offers mitigation to this issue. As shown in the demonstration section, every NFT created contains metadata that can be personalized in the minting phase and later becomes transparent and accessible to read on the selected blockchain network. Some problems would still be present. For example, the manual insertion of metadata during the NFTs minting phase would be manual and prone to human error. However, the metadata would be easier to access, and, in case of need, it could also be modified if changes in the property happen. In the future, whether a land registry would be available on the blockchain, the data insertion procedure could become automatic, further reducing the human error possibilities. However, it could be argued that representing properties via NFTs could help slowly create a digital archive of property recorded on a blockchain, possibly favouring the institution of a broader digital registry.

Another intriguing point introduced by Stub is the traceability of building parts. Notably, he mentioned how potentially the digitalization of real estate could allow tracking building parts in a granular manner (Personal Communication, Nadim Stub, 2022). Further, this could enable the transaction of building parts. Notably, Stub said, '*I'm not saying that's gonna happen, but I'm just trying to illustrate the granularity, right*' (Personal Communication, Nadim Stub, 2022). Therefore, Stub does not seem skeptical regarding the possibility of having parts of properties individually listed on a blockchain network and potentially tradeable. The main pain point he stressed regarding this possibility is the viability in the short term and the potential demand for it, which has yet to be assessed. The latter point, in particular, seems to reflect the opinion of previous researchers (Liu et al., 2020).

6.7 Evaluation of design principle 6: link between NFT and real estate price

The last design concept tested during this evaluation regards ensuring that the value of the NFTs stays connected with the value of the real estate property without taking any parabolic separation between the two assets. Due to the concerns expressed by interviewees during the design phase, this concept was considered relevant to be tested. However, after collecting primary data, this was not confirmed as a concern by the experts. Notably, Harmsen highlighted how tokenized real estate

should not be considered a volatile investment type (Personal Communication, Mads Hamsen, 2022). Consequently, a real-time price detection mechanism was not highlighted as crucial.

Similarly, Lodahl declared that currently, there is neither a standardized method to offer evaluation nor a standard period to conduct such an evaluation. More precisely, he mentioned how the issuers decide the timespan. Some offer a valuation of properties in timeframes between three months and one year, while others currently do not offer that option (Personal communication, Jonas Lodahl, 2022). However, in terms of the value of the underlying asset, he declared how today, in the world of legacy finance, assets can be exploited in terms of liquidity due to having the ability to take out a loan on the same asset several times. This is not possible within the crypto world, where double spending is impossible due to the inability to duplicate assets (Personal communication, Jonas Lodahl, 2022). Therefore, the connection between the prices of the NFTs and the property was not identified as a problem by the experts.

An interesting finding regarding the property price topic was found in relation to the effect of tokenization on the price of real estate as an asset class. During our interview with Stub, he predicted that large-scale adoption of fractionalized investing solutions into real estate could largely change real estate prices. In his opinion, lowering the entry barriers to the estate market for investors would allow much more capital to flow into the market (Personal Communication, Nadim Stub, 2022). Lodahl took a more conservative approach by declaring that the complexities of the price development of wide-scale fractionalization investing of real estate are immense. Notably, he emphasized the complexity of the aspect due to the large variety of variables that would need to be considered to provide a clear answer (Personal communication, Jonas Lodahl, 2022). Lodahl further added that the concept of Liquidity Premium should be considered. The concept describes how the same asset can be considered more or less valuable according to its liquidity. Therefore, a more liquid real estate market could imply an increase in the value of properties due to increased liquidity (Personal communication, Jonas Lodahl, 2022).

6.8 Learnings from the evaluation

The evaluation phase has allowed evaluating the design principles adopted to create the artefact with the primary data collected from various experts. Thanks to this process, it has been possible to identify the strengths and weaknesses of the artefact and its contribution to solving the research questions posed at the beginning of this paper. Before proceeding to the next section of the

research, it is considered beneficial to depict how the artefact has been found to impact the different actors involved in its use. More specifically, during this analysis, it has been possible to verify how well the artefact performs regarding three different parties involved with its use—namely, the Managing Partner, the Limited Partner and the Market Actors. The latter actor is considered since the artefact has been found to affect a variety of well-established procedures and parties that, being difficult to face individually, have been grouped in what can be defined as a macro-category named *Market Actors*. Thanks to identifying these actors and recognising which and how the individual concepts affect them, it is then possible to discuss their implications. Table 4 depicts the identified correlations between the actors impacted by the artefact and which principles most affect them the most. Three levels of impact have been adopted to give an idea about the relevance of such impact.

Correlation	Home buyers	Investors	Market actors
Dual-sided	■	■	■
Trust	■	■	■
Accessibility	■	■	■
Liquidity	■	■	■
Unicity	■	■	■
Link asset	■	■	■

Table 4. Correlation between principles and actors

■ high correlation
■ medium correlation
■ low correlation

Notably, the principle affecting the most actors has been identified as Liquidity and Accessibility. In these regards, the market actors have been recognised to be potentially impacted by the implication of the artefact if it had to be deployed on a large scale. However, it was also noticed how those actors could act as barriers to such adoption. Regarding potential home buyers, the possibility of becoming a managing partner has arguably a significant impact on the Accessibility of the market for them. Also, the implications of higher liquidity have been considered relevant for home seekers. However, it has been found that higher liquidity is not as crucial for investors (both retail and institutional). The unicity of the tokenised real estate property represented via NFT has been found mainly relevant for home seekers since the managing partner is the only actor to trade an NFT. Contrarily, investors would trade regular ERC20 tokens. Finally, granting an always available link between the price of real estate assets and the tokens (both fungible and non-fungible) has been found not relevant. Firstly, the market has been found not suited for short term

speculations, which could be argued to be the main driver of the high price fluctuation of NFTs seen in the market up to this point. Secondly, the real estate market does not currently provide tools to calculate the price 'on demand'. However, the solution has been found to impact the general prices of real estate properties potentially. Hence, its impact on the market actors cannot be marked as low.

6.9 Final round of informal interviews

Before proceeding with the discussion regarding the findings and the implications of the artefact, it is relevant to report feedback received from the informal interviewees regarding the final iteration of the artefact presented. As a reminder, the first two iterations of interviews can be found in the Appendix of this research. Compared to the previous rounds, which counted 21 interviewees, this last round counted only 16. The main modifications could be argued to be the introduction of the managing partner and the limited partner and the fact that residents are not obliged to acquire the property.

The last iteration of interviews can be declared to have been received positively from interviewees. Similarly to the previous iteration, several questions were asked in relation to the operational aspect of the artefact. Those, as previously declared, have not been considered to keep the focus of the research on solving the issues outlined by the research question. Such a question can be argued to have a broad scope than the detailed definition of all the aspects of the artefact. Significantly, it was interesting to notice how removing an APY from the investors was not considered an issue overall. The researcher considered this interesting as they were expecting more resistance towards this decision. However, gaining exposure to the real estate market was considered attractive by the interviewees without the need for an APY.

The main division point was found regarding the possibility of living in the property without becoming full owners. Some interviewees found it flexible and a viable alternative to rent. Others did not like the idea of living in a partially owned property since they would not perceive the property as their own. In these regards, the chart in Figure 21, depict how many of the interviewees have been found interested in the options presented by the artefact.

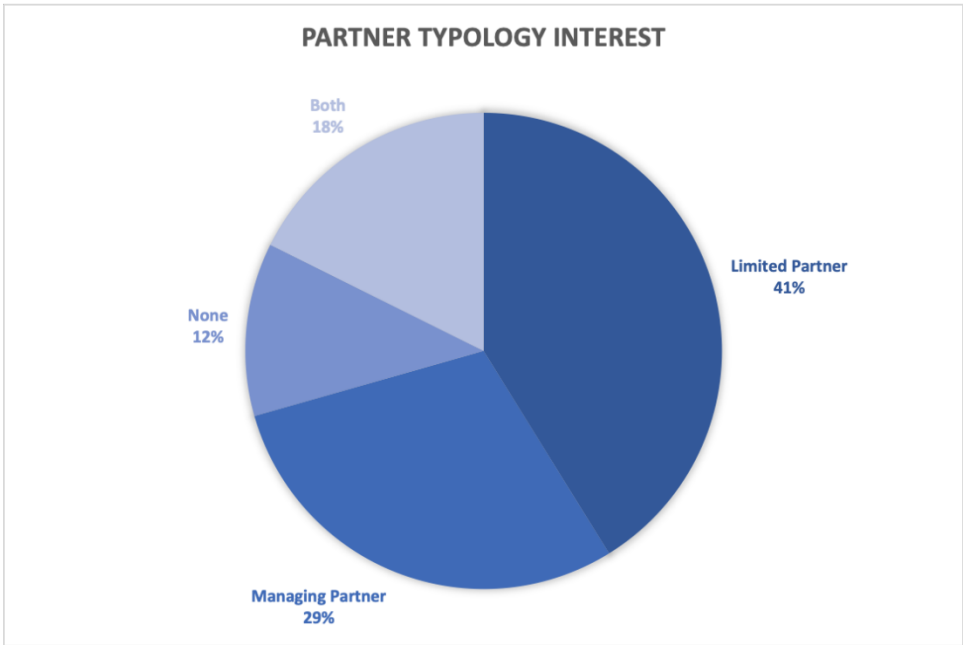

Figure 21. Interest in partner role (own creation)

7. Discussion

The last step suggested by the DSR methodology is the *Communication* step. This phase aims at communicating elements such as the relevance of the problem, the utility and novelty of the artefact and its effectiveness in the eye of the researchers and other relevant audiences such as practicing professionals (Peffers et al., 2007). Following the *Schema for a Design Science Research Study* offered by Hevner & Gregor (2013), the communication will be divided into two sections: discussion and conclusion (Hevner & Gregor, 2013). In regards to the discussion section, an interpretation of the results obtained in the evaluation phase is recommended. Notably, what the results mean and how they relate back to the objectives stated in the Introduction section (Hevner & Gregor, 2013). The methods adopted to communicate such information can include a summary of what was learned, limitations, practical significance, and areas requiring further work. (Hevner & Gregor, 2013). In general, the section should discuss the research contributions and the broad implications of the paper's results to research and practice.

Before proceeding it must be declared how for this section, the design principles will not be used as a thread to guide the reader through what will be analyzed. At the end of the evaluation phase, it has been possible to identify three main actors affected by the artefact: home buyers, investors and the market actors. Further, it has been possible to analyse which of the design concepts affects

the most each of the actors. Therefore, the discussion will move from the concepts to their impact of the different individuals involved in the artefact. Such a choice is considered relevant to leave the reader with a discussion about the underlying potential and limitations of the designed artifact to solve the problem identified on the area, which in turn guides answering the overarching RQ in this thesis.

7.1 Implications of the artefact for home seekers

The artefact analysis allowed to identify some benefits concerning young adults looking to buy a property. The presence of a managing partner can be argued to introduce a novel aspect in the real estate market that currently is not offered. Specifically, Andersen recognised the need to find more parties involved in the housing market to allow new actors to join it with reasonable exposure and risk mitigation. In this regard, the interviews with Stub, Lodhal and Harmsen allowed noting how the focus of companies working in fractionalised real estate is currently on large investment projects or merely seen as an investment vehicle for retail investors looking to diversify their investment portfolio. In this regard, the artefact is believed to offer a new opportunity for home buyers. Significantly, owning a share of a property instead of its entirety would increase accessibility for individuals who struggle with coming up with the down-payment. This feature could potentially enable home seekers to afford better and more pricey properties since they would not have to face the entire cost alone.

On a more general note, it could be argued that currently, the housing market offers limited options that, with some levels of simplification, can be narrowed down to either buying or renting. Both options present drawbacks. The former, beyond the already discussed issues connected with becoming an owner, also present a high switching cost. This is a particularly relevant element in modern society since people are arguably moving more often than before. In this regard, Andersen, after citing the higher rate of moving, mentioned his expectations regarding switching cost in real estate by saying '*[…] if you don't think that you will live in the in the next coming home for at least five, probably 10 years, I would just advise you to rent.*' (Personal Communication). This timeframe can be argued to be quite relevant and problematic for some individuals, especially when the only alternative possible is renting. Therefore, the design concept proposed could offer a new, and arguably never seen, alternative to renting a real estate property. Instead of paying rent,

a home seeker could acquire the *Managing Partner NFT* and acquire the rights to live in a property. Compared to the currently available options, two main benefits can be identified.

On the one hand, the issues concerning the switching cost related to buying a property would be dramatically reduced. Indeed, the *Managing Partner NFT* is born to be a tradeable asset, and it can be argued to be a relatively liquid asset in the real estate market. Notably, since it represents a fraction of a property, it is significantly more affordable than the entire asset. Due to the lower cost barrier to acquiring this NFT compared to a whole property, it could be argued that it could offer a viable solution for the problem of the switching cost. Further, since the *Managing Partner NFT* is sold when the managing partner moves out, the initial investment would be taken back. This element differs from renting a property since the tenant never recovers all the capital spent on paying rent. Such a difference could make the solution very suitable for individuals that do not want to be bound to a property for a timespan of 5-10 years but, at the same time, do not want to rent a property for such a long time.

Secondly, since the *Managing Partner NFT* grants the right to live in the property, the only requirement needed from a potential managing partner would be having enough liquidity to acquire the asset. If such liquidity would not be available, regular channels could be used to require a loan. In this case, both the required down-payment and monthly expenses would be dramatically lower than the ones needed to acquire the whole property. After acquiring the *Managing Partner NFT*, in one way or the other, the managing partner can live in the property and benefit from less fixed monthly costs than compared to regular rent. Furthermore, the NFT can be sold on the market, and the initial investment can be returned. A crucial benefit of this solution is that it would allow users of the system to potentially save enough capital to then buy an apartment with the traditional methods if they wish to. This idea was often mentioned during the last round of informal interviews.

Furthermore, the increased housing affordability could become even more relevant if a solution like the one proposed by the artefact could see hundreds of units in the secondary market. In this case, it could be argued that the *Managing Partner NFT* could become a viable alternative to the binary choice of either buying or renting, currently available. Indeed, as for now, the artefact here presented implies that a managing partner finds a property and then goes through the founding and fractionalisation processes illustrated. Thus, several stages and actors are involved in the process,

and, as previously depicted, there is no safety that enough limited partners will be found. However, suppose several managing partners would go through such a process during the years to come. In that case, at one point in the future, it could be assumed that the process would be easier and faster since a new managing partner could simply acquire the *Managing Partner NFT* from a managing partner that, for whatever reason, wants to move out of the property. In this case, the multistep process described by this research would be reduced to a mere transaction between two parties, with the limited partners not required to take any action. Figure 22 offers a reminder regarding how the process would like. It could be argued that the hypothetical secondary market of *Managing Partner NFTs* could be a huge catalyst for more extensive use of the solution. Indeed, the process would be more straightforward and less intimidating for less tech-savvy users, which, as a reminder, have been assumed to be the first to use the artefact. Also, witnessing that another person lived in the property using the solution could help mitigate skepticism towards the solution, which was noted in the informal interviews.

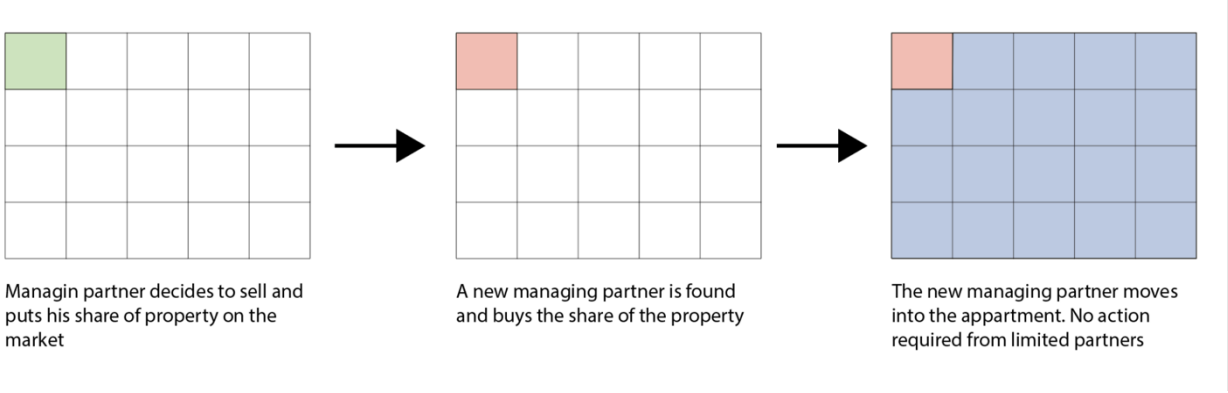

Figure 22. Managing Partner NFT - selling process (own creation)

7.2 Implications of the artefact for investors

Although the solution offered by the artefact is focused on testing the ability of NFTs to provide more affordable housing buying opportunities, the designed artefact relies heavily on the availability of enough limited partners to finance the managing partner. Consequently, it could be argued that the implications of the artefact on this category of partners are equally relevant. During the evaluation phase, it has been possible to compare the artefact to the solution currently available to investors. Notably, it is believed that the artefact offers investors an alternative to REITs and current fractional solutions, potentially offering more advantages.

Over the past ten years, REITs has offered great returns at smaller risk levels than other investment vehicles (Personal Communication, Nadim Stub). REITs allow private investors to get exposure to a costly asset class such as real estate without requiring vast liquidity. However, when investing in REITs, the investor is not becoming a fractional owner of a property but rather an asset that creates dividends through leasing and rent income. At the same time, investing with REITs leaves the investor with a smaller amount of liberty on portfolio decisions since fund managers decide where to invest, also requiring a fee for their services (Personal Communication, Jonas Lodahl). In these regards, the artefact offers more liberty since a limited partner keen to invest in multiple properties using the proposed solution could easily fund the acquisition of multiple properties and diversify its portfolio. It must be noted that previous research showed that retail investors do not necessarily possess the knowledge necessary to efficiently and safely individuate good investment opportunities (Smith et al., 2019). Therefore, the lack of expertise in real estate investing may be a drawback for less experienced retail investors. However, despite the higher risk involved, having more control over which assets to buy could be a valuable feature for some individuals. The trim control private investors have over what has been bought or sold does not affect only REITs but also a solution like the one offered by The Many.

An alternative currently available on the market is offered by tokenizing real estate in the form of security tokens like in the solution offered by Digishares. In comparison to REITs, security tokens allow investors to personally decide the properties they want to invest in as they do not present a central actor deciding the investment direction is not present (Personal communication, Jonas Lodahl, 2022) (Liu et al., 2020). The main issue identified during the analysis section regarding security tokens is in them requiring an SPV to be offered to customers. Similarly to REITS, investors would not own a fraction of the properties they invest in but instead shares representing the property in the form of tokens. The proposed artefact, contrarily to both the option previously discussed, could enable investors to own a fraction of the property, especially if the property deed could be transferable via NFTs. In this case, the *Limited Partners NFT* fraction would represent the property, and, consequently, its fractions would do the same. Despite this is not possible yet, this has been found to be one of the main empowering possibilities offered by the adoption of NFTs for allowing real estate investments (Personal communication, Jonas Lodahl, 2022).

Another aspect where the artefact differs from current investing solutions such as Digishares and The Many lies in its intrinsic liquidity. Currently, companies offering tokenized real estate properties or fractionalized investments need to create legal entities in states where the legislation in these regards is clear, acquire the property via those companies and then offer their shares. Consequently, the resulting market is fragmented since users have to interact with multiple companies to invest in different properties. Referring to the exit opportunities provided by current offerings, during the interview with Hemsen, it was possible to learn how The Many decided to move from offering open funds to closed ones. The implications are that investors will not be able to exit the investment for a period predicted to be ten years. This could be a liability considering that one of the most anticipated benefits of tokenizing real estate is increased asset liquidity (Smith et al., 2019). Further, having a market spread in different SPVs or funds potentially implies that customers have to go through multiple KYC procedures since the companies may have different legal and verification processes requirements to fulfil (Personal communication, Jonas Lodahl, 2022). This could arguably increase the sensation of a fragmented market for users. Hence, none of the offerings offers a unique marketplace listing all the properties. In this regard, the artefact offers what could be argued to be a more smooth solution, being it based on Ethereum. Notably, if a parallel with current NFTs marketplaces could be drawn, the artefact users would trade different properties on the same platform, avoiding the issue of a fragmented market, which previous researchers also mentioned (Smith et al., 2019). It must be specified that also in the case of the artefact, each fractionalized *Limited Partner NFT* will have its liquidity pool, as the real estate property backs the value of tokens. However, since the resulting tokens could be listed on the same DEX or CEX it would be possible to trade them without problems regarding multiple KYC procedures or multiple marketplaces, as depicted previously. Lodahl mentioned the possibility of having digital wallets connected with a real ID instead of containing only a public address. This would help streamline the tokenization process since users would not need to do KYC processes for every platform they interact with (Personal communication, Jonas Lodahl, 2022).

Regarding liquidity, similarly to what was depicted for managing partners, reduced barriers could be imagined over time for limited partners. Indeed, the platform's first users would be the ones with the most risk tolerance since the solution would be new. Contrarily, new limited partners

could simply acquire tokens on a decentralised exchange and not be involved with the process of funding the property.

Another possibility offered by a hypothetical decentralised marketplace is the fall of geographical barriers. Investing in properties in foreign countries could be argued to be difficult at the moment, even only from an informational point of view. Knowing the foreign housing market dynamics may be difficult without a network in the targeted nation. Consequently, the possibility of having a more open market could be an opportunity to see capital injected in the real estate market currently inaccessible to retail investors. Further, DeFi and DAOs can be argued to control investments in a decentralised manner without the need for a third party. The DAOs introduced in the literature review section manage hundreds of millions of dollars among parties that do not know each other. It could be argued that such a possibility does not exist yet in the real estate market, and the artefact, if developed in a decentralised manner, could enable this possibility. Notably, as depicted in the design concept phase, decisions regarding the future of a tokenised property could be held via a voting system empowered by a smart contract, further affirming the decentralised nature of the decision-making possibilities. Further, DAOs are featured by social channels empowering global communication. Therefore, a DAO where investors could meet and discuss possible investment opportunities in foreign countries could help mitigate the information barrier previously mentioned. This also connects to one of the barriers mentioned by Stub in the analysis phase. He mentioned that opening investing opportunities to more retail investors is difficult due to governance barriers. It could be argued that blockchain empowered solutions like DAOs could offer the possibility of solving such management issues thanks to decentralised governance.

Finally, it must be reminded that the artefact allows any investor to participate in the process. Therefore, also institutions could become limited partners. In this case, it could be argued that possible drawbacks related to the artefact, such as the possibility of a limited partner not possessing the knowledge required to invest safely, would be reduced. Indeed, institutional investors can be, theoretically, assumed to possess knowledge ensuring the feasibility of the investments. Regarding the involvement of institutional investors, the interviewees mentioned that interest from institutional investors could be foreseen since real estate has proven to be a safe asset class to invest in (Personal Communication, Mads Hamsen, 2022). In this regard, Chaplin et al. (1997)

mentioned how institutional investors always seek new ways of investing and diversifying (Chaplin et al.,1997). Such a possibility opens stimulating possibilities in terms of how institutions could play a role in fast-forwarding the applicability of the solution offered by the artefact. Indeed, if managing partners would find institutional investors financing their properties, they could achieve two things. On one hand, since institutional investors have more buying power than retail investors, some limitations like the possibility of not finding enough limited partners could be limited. On the other hand, having institutional investors involved could help managing partners better trust the solution in comparison to stagers on a blockchain network. However, it must be noted that during the informal interviews, several interviewees have expressed concerns related to having a significant portion of the properties held by institutional investors. The main apprehension is that if institutions own many properties, they could increase the overall price of the asset class. In this regard, Andersen mentioned that such a possibility would hurt institutions rather than help them. However, this seems a concern that could become a reality in the distant future whether enough properties would be offered with the artefact's method to affect the real estate market prices in general.

7.3 Implications of the artefact for the real estate market

The final significant implications identified during the analysis are related to the real estate market and the current procedures characterizing it.

The first market-related implication concerns the nature of the artefact and the current characteristic of the market. It could be argued that the artefact and real estate tokenization empower transactions among users without the need for some of the third parties currently required. In the case of the artefact, this is especially true when considering simple transactions of tokens among parties rather than the funding process. In such a scenario, several stakeholders holding power in the industry could be negatively impacted. In this regard, according to Stub, despite blockchain bringing positive change within the industry, its real-life applicability can depend on these stakeholders since they would arguably have too many downsides from the wide adoption of the usage of the technology (Personal communication, Nadim Stub, 2022). This seems to confirm what previous researchers identified by recognizing several actors that are likely to be highly impacted by the widespread adoption of blockchain empowered solutions in real estate.

More specifically, large institutional investors, which can count favourable economy of scale at the moment; debt servicers; major intermediaries such as brokers; law firms that charge transactions on real estate transactions (Smith et al., 2019). Hence, it could be argued that if benefits have been identified for potential managing and limited partner, the same cannot be declared for the actors that currently act as a third party.

Another aspect identified regarding the current methods applied within the real estate market is the inadequate IT structure. During the evaluation of the artefact, it was indeed recognized that certain data and IT system structures within the real estate industry are not up to date in terms of flexibility and trust in data usage and storage. Notably, Stub mentioned the low amount of confidence or trust in the available data. The main reason behind this lies in the old methods adopted to update the land registry, which have been argued to be prone to human error (Personal Communication, Nadim Stub, 2022). Although this aspect could be easily regarded as a barrier, it can also be considered an opportunity. Indeed, as highlighted during this research, having properties represented on a blockchain could present several benefits. Notably, the designed artefact could offer a way for other industry stakeholders to recognize the value of adopting a more digital approach to handling property data. As discussed in the analysis section, the metadata inheritably coded within NFTs during their creation could offer a novel way of digitally registering property data. Consequently, especially considering the declarations of Andersen, who said that the Danish Knowledge Centre for Housing Economics is actively looking for solutions to improve housing affordability, the possibility of a pilot project from the government could be argued not to be hugely remote. Potentially, and very speculatively, this could be the start of a digital registry on a blockchain which could be further extended. As Stub pointed out, registering data of new buildings is effortless. So, a secondary market where *Managing Partner NFTs* and *Limited Partner NFTs* are tradeable and registered on a hypothetical digital land registry could help the creation of such a register. Further, should the real estate business start adopting blockchain on a larger scale, the designed artefact could have higher chances of success, as trust in using the technology would also increase. However, the feasibility of such complicity remains hard to predict, especially considering the high numbers of stakeholders being negatively impacted by the usage of blockchain mentioned before.

Finally, some speculation can be done regarding the effects of fractionalization and tokenization of properties on the overall market. During the research, some insight was attained regarding the potential effects of a more liquid and accessible real estate market on the properties' value. Notably, during the interview with Andersen, it was discussed how one of the critical issues currently affecting the real estate market in Copenhagen is the pace of newcomers in town, which real estate supply cannot meet. Notably, Andersen mentioned how the population is expected to rise by 10.000 per year and how the supply to satisfy such a demand is not available. Further, he mentioned how building more buildings would not allow meeting the demand. However, a fascinating fact regarding the Copenhagen house market was mentioned. Notably, he declared how only 10% of the condominium in Copenhagen can be bought freely and are not belonging to cooperative housing or private rentals. This aspect is considered interesting because it allows seeing a dual-sided problem. On the one hand, there is difficulty saving enough capital to cover the required down-payment. On the other hand, there is an unbalanced offer between buying and renting opportunities. Therefore, it could be interesting to see whether the artefact proposed in this research could help balance this ratio. Notably, it could be easier for rental properties owners to sell their properties thanks to lowering the down payment price barrier. This could help the market to become faster.

However, unless more research is conducted, these are simple speculations. Nevertheless, the researchers considered the main idea behind such speculation to depict the potential impact of the artefact on the housing market in Copenhagen. However, as other interviewees (Lodahl, Stub and Hamsen) mentioned, to be considered accurate and believable, any speculation regarding the impact of a more liquid market requires further research. Due to the vast socio-economic implications linked with it, this type of research would require immense resources. As Lodahl said, '*you could write 10 papers only on this*' (Personal Communication, Jonas Lodahl, 2022).

7.4 Main barriers for the artefact application

The evaluation of the artefact also allowed to identify some barriers affecting the real-world applicability of the proposed solution. Due to the broad nature of such barriers, the researchers did not consider possible addressing or solving them in a further iteration of the design process. Therefore, the decision was to report them in this section.

The legal compliance of the artefact has been declaratively considered one of the assumptions in the design creation phase. Despite such an assumption, the recurrency of legislative related topics during the evaluation phase convinced the researchers to mention them in the discussion section. Especially since this part of the research also discusses the overall feasibility of the intended artefact and not only the two phases covered in the evaluation section. From a legal standpoint, the main issue identified is related to the property deed. More specifically, it cannot be transferred yet on a blockchain. Consequently, offering a legally compliant solution that uses NFTs is not possible yet. In the case of the artefact in question, legal viability could be even more complex since the solution has both investors and a resident living in the property. However, as mentioned in the evaluation section, the artefact could offer a solution to whoever would trust the underlying technology and the other investors enough to use it. Due to the high economic cost of real estate property, such an ideal user may prove hard to find. However, having real estate title deeds added to a smart contract has been recognized to offer much positive change for real estate potentially. Notably, lowered entry barriers and increased liquidity (Personal communication, Jonas Lodahl, 2022). A solution to such complex legal issues could be offered by digital wallets connected with the real identity of their users, in what Lodahl defined as self-sovereign IDs in the digital ecosystem. Such solutions are in their infancy today but could help ensure compliance in using the designed artefact (Personal communication, Jonas Lodahl, 2022).

About the primary offering of the artefact, the fractionalization of real estate, previous research suspected a lack of interest from investors and a general doubt regarding their ability to effectively and safely use such a solution if that was available (Smith et al., 2019; Liu et al., 2020). Therefore, the artefact could be argued to need to demonstrate its attractiveness to potential users. It must be noted how the previous solution mentioned neither offered a solution like the one here presented, nor they used NFTs. However, the sample of informal interviews allowed perceiving a general understanding of the solution's potential and interest in it. Notably, the results depicted in Figure 21 show how many interviewees showed interest in the solution.

From a technical point of view, although it has been declared that the artefact does not support thousands of transactions, some issues of the Ethereum network must be pointed out. Notably, the scalability issues and the high transactional costs. For a managing partner, the cost of a transaction fee on the Ethereum network may not be relevant, but this could be relevant for limited partners.

Ethereum transactions average from 50 to 150$ when interacting with smart contracts and from 30 to 50$ when transferring tokens. Further, the deployment of smart contracts is quite expensive. Johal also mentioned this in the primary data collection. Paradoxically, the high cost of the Ethereum network is the reason why the researchers used the Ropsten network in the demonstration phase rather than the main network. Therefore, this could be a barrier to adoption. It is true that few transactions are initially predicted for the artefact. However, since the solution claims to solve some of the costs associated with acquiring real estate property, the transactional costs on the Ethereum network can be considered an added cost. Other blockchains can be adopted with lower transaction costs. However, such a choice could potentially decrease the decentralization of the solution since Ethereum is among the most decentralized networks. This is what can be defined as the *Decentralization Dilemma* (ReturnValues Academy website, 2022). However, the solution this dilemma exceeds the purpose of this paper. It could be argued that some barriers inherited from blockchain are also present. However, since the artefact has been created assuming that its users are early adopters, they have not been considered. Therefore, the inherited barriers related to blockchain will not be considered. In relation to the technology-related barriers, it could be argued that also some barriers inherited from blockchain itself are present. Example of such barriers could be related to the diffusion of novel technologies, trust in its offerings, etcetera. However, the artefact has been created with the assumption that its users are early adopter and ok with the risks associated to using the artefact. Therefore, the inherited barriers related to blockchain will not be considered.

Finally, it is relevant to cite an element distinctive of the Danish house market. Regarding structural challenges related to proposing innovation on the financing of properties, a few specific elements related to Denmark could also act as barriers. For one, Andersen mentioned that the large trust in the mortgage system could be a barrier in Denmark, as he claims that it is probably the best mortgage system in the world. So, the system could be hard to change due to the perceived effectiveness of the current system (Personal Communication, Marc Lund Andersen, 2021). This thought was also confirmed by Hamsen, who expressed doubts regarding the possibility of improving the Danish financial system (Personal Communication, Mads Hamsen, 2021).

It could be argued that some of the concerns here described are similar to the ones reported by previous literature or to the ones identified by the interviewees (Smith et al.,; Vogel, 2019).

Notably, the legislative barriers are the main obstacle to possible fractionalisation in a decentralised manner. However, due to the high regulations in the real estate market, overcoming such challenges without the help of legislators may be difficult. Indeed, for the artefact presented to go through the next demonstration stage, a real-life application could be a viable next step. In that way, it will be possible to prove how both Limited and Managing Partners can potentially adopt the artefact. However, currently, this seems like a remote option.

7.5 Limitations and Further research

Having evaluated and discussed the design principles and immediate implications for the users of the designed artefact with the help of interviews of professionals, we now turn to stress the immediate limitations impacting its attainable practicality in the real world. A single iteration of the artefact has been evaluated employing interviews with experts. Thus, the evaluation, discussion and limitations would be advised for subsequent design iterations, following the design science principles.

The overarching limitation impacting the designed artefact's feasibility and success relates to **legal implications**. The housing market and the investment world is both under heavy regulation, which means that most factors verifying the possible success of the solution proposed in this paper rely on being legally compliant. As already mentioned in previous chapters, legislative barriers are currently holding back any possible implementation of the artefact in the real world. During our interviews with experts working with the housing market or real estate investing, regulation and compliance issues were a talking point.

Other than legal implications for the actual transaction, additional legal and compliance issues also exist. Certain elements have been identified, such as *the possibility for the managing partner to finance his NFT with a traditional mortgage* and *the direct contractual obligations* (between the managing and limited partners). **The contractual obligations** could include renovations and other work done to the property that increases its value and damages that could deteriorate the value. Circumstances related to this point was mentioned several times during our informal sample interviews collecting initial thoughts from possible users. Most notably, circumstances around the maintenance levels, renovation and improvement costs were brought up as matters of worry for the potential users. Since this relates to circumstances after the actual transaction has taken place,

it has been deemed to be outside the scope of this paper. Nonetheless, it is seen as a detrimental next step for evaluating the possible success of the artefact.

For the managing partner to acquire the property, investigating **the possibility of financing his/her NFT with a traditional mortgage** is another prominent point. This aspect has been deemed out of scope for this paper. However, it remains crucial to cover in future iterations of the artefact and compare this to the potential for adding DeFi elements to allow the managing partner to finance their NFT.

The broad field of **investing** is vast, so the focus has been on simplified immediate implications of investing for this paper. In effect, this means that more technical investing calculations are not included, going into depths with the taxation of investment assets and risk & return calculations and similar. In order to further evaluate the future potential of the artefact, these components would have to be explored. However, everything related to whether an investment is feasible has many variables that need to be assessed. Therefore, as this thesis only scratches the surface on direct characteristics related to investing in assets around real estate, further research should investigate the artefact's investment rationale and diversification potential.

Furthermore, a direct following by the rationale to invest using the artefact is also **willingness for potential users to utilise the solution**. Before creating the artefact, our preliminary informal sample interviews consisted of a small sample of potential users. The informal interviews were conducted with people living in Copenhagen or individuals financially exposed to the Copenhagen housing market. Consequently, our research revolved around the Copenhagen housing market, indicating that the small user data collected can vary considerably to other geographical and social contexts. Thus, future iterations of the artefact should be incentivised to investigate how great demand exists within the potential user groups. Also, this continuation should include characteristics such as ownership revolving around the asset for managing partners and factors following the previously mentioned contractual obligations between managing and limited partners. Doing this will also help evaluate the total potential size of the solution user base. As the proposed artefact is dual-sided, this will likely entail much research into two-sided market potential. Since the user base will also be adopting new technology such as NFTs, further iterations of the artefact also warrant research into **technology adoption**. This will help identify what user segments are likely to adopt the solution at its initial usage growth.

Further, the artefact is based on the NFTs solutions currently available. Notably, the fractionalization process of the *Limited Partner NFT* is based on a decentralized protocol that is not born to deal with real estate properties. Therefore, with coding knowledge that the researcher of the paper does not possess, it would also be possible to develop a new fractionalization function better suited and with more functions related to the operational life cycle of a real estate property. Since this paper aimed to study the current possibilities of adopting NFTs to make property acquisition an easier process, adopting what is presently available and usable seemed the best option. However, the creation of a new smart contract with fractionalization functions created ad-hoc for this application could help solve some issues related to the operability and security of the artefact.

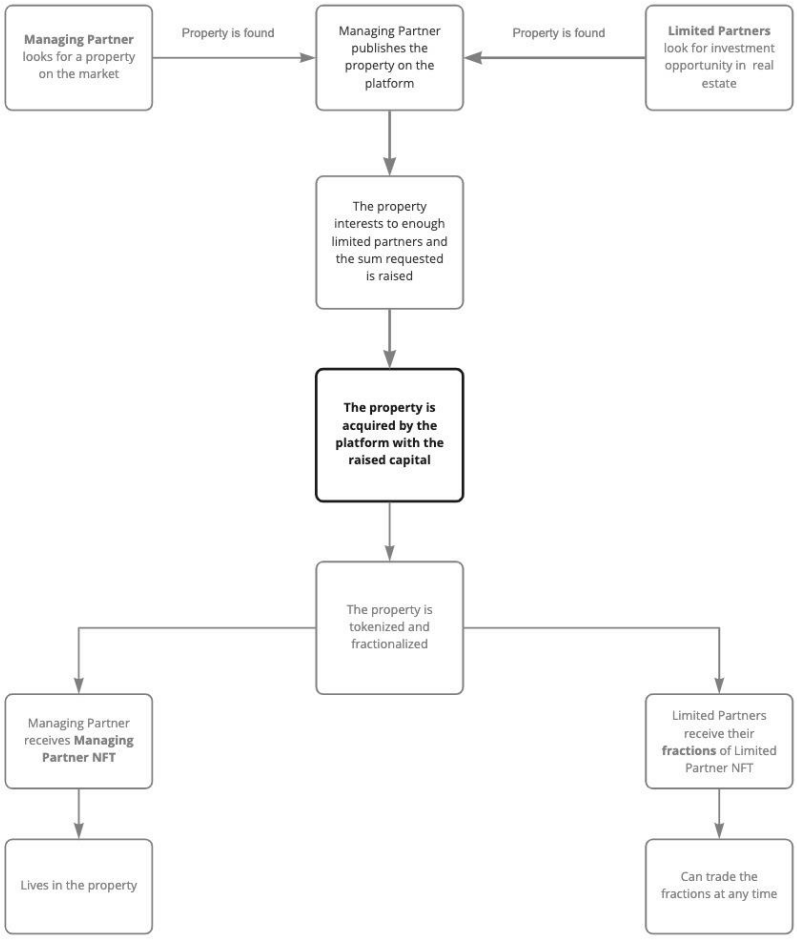

Figure 23. Property acquisition step (own creation)

The artefact demonstration has covered only the steps related to creating the NFTs because they were the steps more related to the scope of this research. However, another point in the whole

design concept that could be declared challenging to achieve in reality is the property's crowdfunding. Figure 23 offers a reminder of the process. Notably, the issues could be related to how such crowdfunding would be considered from the Danish legal system. If the overall concept is considered valid, this is something that further researchers should consider. Another limitation connected with the funding phase is the current inability to use cryptocurrencies in the process. In the artefact presented, the limited partners go through KYC and use fiat money to invest. However, by looking at the vast amount of users that nowadays adopt crypto solutions, it could be argued that such an option is potentially limiting. Especially since the artefact potentially does not know any geographical barriers. Bank transfers and taxation across nations and continents can be costly and complex. Paradoxically, such struggles are what Bitcoin offered to solve from its birth, a decentralised payment system not locked by geopolitical barriers (Nakamoto, 2008). Therefore, it could be argued that the artefact could drastically increase its reach if allowing payment in cryptocurrencies such as Ethereum and Bitcoin would be possible. Considering the potential benefits of such a possibility, further research should be conducted on this topic.

Another important element to consider is also that the artefact demonstration and analysis has been limited to the steps of the process that can be considered either 'testable' (intended as it was possible to demonstrate this phase in the spatial limits of this paper) or 'novel' (intended as there are no currently similar applications available). However, if the whole conceptual design had to be considered, the artefact could empower more actions. The analysis has been focused on proving the validity of using NFTs to make the real estate market more accessible. However, an aspect that was not considered since the artefact demonstration did not cover that phase is the potential of using DeFi landing protocols and liquidity pools to guarantee novel sources of income from real estate. For example, users could use their fractions, stake them and earn returns. This is particularly relevant if the liquidity of an asset is an issue. As seen in the case of The Many, having a central authority taking care of all transactions requires massive liquidity. Studying DeFi, showed how liquidity pools potentially allow overcoming the issue. So, staking returns could be provided to keep the market liquid. Further research could be conducted to verify the potential of this option and the market interest in its regard.

It is crucial to note that the authors of this thesis are fully aware that numerous different variables influence whether or not a retail investor makes a specific investment. Many of these variables are

not dealt with in this paper, such as taxation principles, concrete calculations of expected returns, and many others. In order to further evaluate the potential effectiveness of the artefact proposed, thorough research into these investment rationalities would need to be conducted. The main rationale has been that the paper's primary purpose has been to explore whether NFTs and blockchain technology can make the property market more available for homebuyers – especially first-time buyers.

8. Conclusion

The main goal of this paper has been to develop an artifact that can facilitate using NFTs and blockchain technology for transacting real estate and whether this can aid in making it more accessible for young people to become homeowners. The immediate implications and views related to the potential users have been considered to evaluate further and discuss the designed artefact. Furthermore, a general aspect of the implications on the real estate industry is included, as it has been found to carry significant importance. This leaves us with more insight to answer the following main research question:

How can NFTs and Blockchain technology allow better access to the real estate market for young adults?

The artefact proposed a new way to buy and live in a property currently unavailable in Denmark. Notably, the conceptual design presents a duality offered by the *Managing Partner(s)*, who lives in the property, and *Limited Partner(s)*, who invest in the property. Such a duality has also impacted the introduction of two NFTs representing the property, the *Managing Partner NFT* and the *Limited Partner NFT*. This was found relevant since previous efforts to make real estate investing more widespread and attractive have not included the residents of the property in their offering. Furthermore, the current market offerings in Copenhagen for a place to live revolves around buying or renting. It has been seen throughout this thesis that renting does not directly facilitate wealth accumulation, while owning has high entry barriers and switching costs associated. These drawbacks could potentially be limited by using the proposed artefact. As we spoke to potential users of the final artefact iteration presenting it, they also saw the solution as a great way to enter the real estate market as investors. However, they also recognized potential benefits in using the artefact to buy a *Managing Partner NFT* and becoming homeowners.

Regarding the benefit offered from NFTs compared to fungible tokens, it must be noted that the artefact favour the trade of NFTs when it comes to the *Managing Partner NFT*. Contrarily, the fractions treaded by limited partners are fungible tokens. Therefore, it was found that the main benefits of NFTs for the real estate market are bonded to property deeds or living rights. Oppositely, using NFTs as a mere fraction was found not to offer tangible advantages compared to fungible tokens.

Following the investigation into the implications for future young first-time homeowners using the artefact, the duality of the solution also warrants taking some investor circumstances into account. This is due to the limited partner, who buys an NFT as a representation of fractional ownership of the property. Therefore, we have also gained insights into possible answers to the sub-research question of this paper.

How can a solution utilizing NFTs and Blockchain technology for real estate transactions add value for both home buyers and investors?

The main benefits of using NFTs for real estate investing were found in increased liquidity, lower entry barriers, and higher accessibility to the asset class. Remarkably, the two-sided market empowered by the artefact could remove the need for a third party. Further, some drawbacks of current offerings like REITs or fractional real estate could be mitigated. Notably, higher control over the investment and the fractional ownership of a property rather than a legal entity. The potential to increase market liquidity was also found, as investors would not need to go through various third parties to sell. This would be particularly significant if the artefact would be widely adopted and new limited and managing partners could avoid the funding process but merely trade tokens.

The designed artefact has also been recognized to potentially bring significant change to the real estate industry. During our research, it was confirmed that many stakeholders within the industry would be negatively impacted by blockchain adoption. However, blockchain technology diffusion within the industry could also bring positive change, particularly regarding data quality. Potentially, the artefact could be adopted as a pilot project to link NFTs' metadata to a digital land registry. Such a topic is considered worthy of future investigation by future researchers.

However, many legal implications must be solved for NFTs to be widely adopted in the real estate market. Even without being in the scope of this research, the current legal barriers were mentioned during the data collection. Further, the artefact's design was based on a sample of interviews considered too small to provide statistical validity. Hence, further testing would be required. Finally, not all the steps of the proposed artefact have been demonstrated. Therefore, to test the feasibility of the whole process, further research could be conducted. These limitations could be less crucial whether the parties using the artefact would know each other. Indeed, it would be possible to use the proposed process to create a non-legally compliant real-life adoption of the artefact, similarly to what Bitcoin did when it was first born. However, the users' risk tolerance should be high due to the limited guarantees offered.

Bibliography

Analytics, Dune. (2022). *Dune Analytics website.* Retrieved from https://dune.xyz/rchen8/opensea

Andersen, M. L. (2020). *Brug af forsikringer baseret på boligprisindeks til dækning af boligejeres tab ved boligprisfald.* Boligøkonomisk Videncenter. Retrieved 11 12, 2021, from https://www.bvc.dk/media/1813/brug-af-forsikringer-baseret-paa-boligprisindeks-til-daekning-af-boligejeres-tab-ved-boligprisfald.pdf

Andrew, M., & Glenn, M. (2003). Public and private real estate in a mixed-asset portfolio. *Journal of Real Estate Portfolio Management, 9(3)*, pp. 193-203.

Andrews, D., Sánchez, A., & Johansson, Å. (2011). *Housing markets and structural policies in OECD countries.*

Arundel, R. (2017, 02 06). Equity Inequity: Housing Wealth Inequality, Inter. *Housing, Theory and Society*, p. 26.

Arundel, R., & Doling, J. (2017). The end of mass homeownership? Changes in labour markets and housing tenure opportunities across Europe. *Journal of Housing and the Built Environment, 32(4)*, pp. 649-672.

Baum, A. (2020). *Tokenization - The Future of Real Estate Investment?* Intelligence LTD.

Beck, R. (2018). Beyond Bitcoin: The Rise of Blockchain World.

Behrens, A. (2021, 03 02). *NFT Mania: February Trading Volume Just Topped All of 2020*. Retrieved from decrypt: https://decrypt.co/59968/nft-mania-february-trading-volume-just-topped-all-2020

Bez, M., Fornari, G., & Vardanega, T. (2019). The scalability challenge of ethereum: An initial quantitative analysis. *IEEE International Conference on Service-Oriented System Engineering (SOSE)*, pp. 167-176.

Block, R. L. (2011). *Investing in REITs: Real Estate Investment Trusts.* John Wiley & Sons.

Boligøkonomisk Videncenter Website. (2021). Retrieved from www.BVC.dk/om-oskontakt

Bored Ape website. (2022). Retrieved from https://boredapeyachtclub.com/#/home

Braun, V., & Clarke, V. (2018). Using thematic analysis in counselling and psychotherapy research: A critical reflection. In *Counselling and psychotherapy research* (pp. 107-110).

BVC Website. (2022). Retrieved from https://www.bvc.dk/

Chaplin, A., Tracy, J., Chan, S., & Freeman, C. (1997). *Housing partnerships: A new approach to a market at a crossroads.* Mit Press.

Chayka, K. (2021, 07 30). *Why bored ape avatars are taking over twitter*. Retrieved from newyorker: https://www.newyorker.com/culture/infinite-scroll/why-bored-ape-avatars-are-taking-over-twitter

Chiuri, M. C., & Jappelli, T. (2003). Financial market imperfections and home ownership: A comparative study. *European economic review, 47(5)*, pp. 857-875.

Coingecko website. (2022, 2022). Retrieved from https://www.coingecko.com/en/coins/banana

Copeland, T. (2012, 03 11). *Beeple NFT Artwork Sells for $69.3 Million in Christie's Auction*. Retrieved from decrypt: https://decrypt.co/60971/beeples-nft-artwork-sells-for-60-3-million-in-christies-auction

Copeland, T., & More, S. (2021, 06 25). *Jay-Z puts a CryptoPunk NFT as his Twitter profile picture*. Retrieved from theblockcrypto: https://www.theblockcrypto.com/post/109655/jay-z-puts-a-cryptopunk-nft-as-his-twitter-profile-picture

Dain, A., Hays, D., Yorke, B., & Rosenberg, H. (2020). *DeFi Adoption 2020: A Definitive Guide to Entering the Industry.* Cointelegraph Consulting.

Davis, M. A., Ghent, A. C., & Gregory, J. M. (2021). *The Work-from-home technology boon and its consequences.* National Bureau of Economic Research, Cambridge.

De Filippi, P., & McMullen, G. (2018, 06). Governance of Blockhain Systems - Governance of and by Distributed Infrastructure. *Blockchain Research Institute*, p. 40.

Dean, S. (2021, 03 11). *$69 million for digital art? The NFT craze explained.* Retrieved from LATimes: https://www.latimes.com/business/technology/story/2021-03-11/nft-explainer-crypto-trading-collectible

DEAS Website. (2022). Retrieved from https://deas.dk/

Deloitte. (2018). *Komparativ analyse af boligfinansiering i udvalgte lande.* Deloitte. Retrieved 10 5, 2021, from https://forenetkredit.dk/wp-content/uploads/2018/12/DELOITTE-KOMPARATIV-ANALYSE_FINAL_DEC2018.pdf

Denzin, N. K. (2001). The reflexive interview and a performative social science. In *Qualitative research, 1(1), 23-46.*

Digishares Website. (2022). Retrieved from https://digishares.io/

DuPont, Q. (2017). Experiments in algorithmic governance: A history and ethnography of "The DAO," a failed decentralized autonomous organization. *Bitcoin and beyond*, pp. 157-177.

Elkjaer, B., & Simpson, B. (2011). Pragmatism: A lived and living philosophy. What can it offer to contemporary organization theory? In *Philosophy and organization theory.* Emerald Group Publishing Limited.

Elton, E. J., & Gruber, M. J. (1997). Modern Portfolio Theory, 1950 to date. *Journal of banking & finance, 21(11-12)*, pp. 1743-1759.

Ethereum. (2021, 12 3). *Ethereum Website 2*. Retrieved from ERC-20 Token Standard: https://ethereum.org/en/developers/docs/standards/tokens/erc-20/

Ethereum. (2021, 12 2). *Ethereum Website 3*. Retrieved from ERC-721 Non-fungible token standard: https://ethereum.org/en/developers/docs/standards/tokens/erc-721/

Ethereum. (2022). *Ethereum website 1.* Retrieved from https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/

Ethereum. (2022). *Ethereum Website 4*. Retrieved from Non-fungible tokens (NFT): https://ethereum.org/en/nft/#nfts-and-defi

Ethereum. (2022). *Ethereum Website 5*. Retrieved from https://ethereum.org/en/dao/

Ethereum Website 6. (2021, 04 22). Retrieved from HOW TO WRITE & DEPLOY AN NFT (PART 1/3 OF NFT TUTORIAL SERIES): https://ethereum.org/en/developers/tutorials/how-to-write-and-deploy-an-nft/

Etherscan website 1. (2022). Retrieved from Contract creation: https://ropsten.etherscan.io/address/0x50F2D7dc98f1dF6eEdC759801046aF05CBb70787

Etherscan website 2. (2022). Retrieved from Contract address: https://ropsten.etherscan.io/tx/0x27ebfd08f4919918cbe221489d83bfadec2ba84cc5feb3e85b0af67e091254bd

Etherscan website 3. (2022). Retrieved from https://ropsten.etherscan.io/tx/0xc335e7345a69292a9372aaac977cd119b44cb275c14522b3efee519dfbd1f2e6

Etherscan website 4. (2022). Retrieved from https://ropsten.etherscan.io/address/0x50f2d7dc98f1df6eedc759801046af05cbb70787

Etherscan website 5. (2022). Retrieved from https://etherscan.io/address/0x85Aa7f78BdB2DE8F3e0c0010d99AD5853fFcfC63

Etherscan website 6. (2022). Retrieved from https://etherscan.io/address/0x85Aa7f78BdB2DE8F3e0c0010d99AD5853fFcfC63#writeContract

Euromoney website. (2022). Retrieved from https://www.euromoney.com/learning/blockchain-explained/how-transactions-get-into-the-blockchain

Eurostat. (2020). *Is housing affordable?* Eurostat. Retrieved from https://ec.europa.eu/eurostat/cache/digpub/housing/bloc-2b.html?lang=en

Finck, M. (2018). *Blockchain Regulation and Governance in Europe.* Cambridge University Press.

Forrest, R., & Hirayama, Y. (2015). The financialisation of the social project: Embedded liberalism, neoliberalism and home ownership. *Urban Studies*, pp. 233-244.

Fractional website. (2022). Retrieved from https://fractional.art/

Frankenfield, J. (2021). *What is a 51% Attack?* Retrieved from Investopedia: https://www.investopedia.com/terms/1/51-attack.asp

Geroni, D. (2021, 09 01). *Understanding the Attributes of Non-Fungible Tokens (NFTs)*. Retrieved from 101blockchains: https://101blockchains.com/nft-attributes/

Gogel, D. (2021). *DeFi Beyond the Hype - The Emerging World of Decentralized Finance.* Wharton Blockchain and Digital Asset Project.

Governatori, G., Idelberger, F., Milosevic, Z., & Riveret, R. (2018). *On legal contracts, imperative and declarative smart contracts, and blockchain systems.*

Greenspan, G. (2017). *The Blockchain Immutability Myth.* Retrieved from Coindesk: https://www.coindesk.com/markets/2017/05/09/the-blockchain-immutability-myth/

Gupta, M. (2020). *Blockchain for dummies, 3rd IBM Limited Edition.* John Wiley & Sons.

Gutter Cat Gang Dao Website. (2022). Retrieved from https://www.gcgdao.info/

Hackl, C. (2021, 06 01). *What are DAOs and why you should pay attention*. Retrieved from Forbes: https://www.forbes.com/sites/cathyhackl/2021/06/01/what-are-daos-and-why-you-should-pay-attention/?sh=1a0feed27305

Hassan, S., & De Filippi, P. (2021, 04 20). Decentralized Autonomous Organization. p. 10.

Heap, I. (2017, 06 05). *Blockchain Could Help Musicians Make Money Again.* Retrieved from Harvard Business Review: https://hbr.org/2017/06/blockchain-could-help-musicians-make-money-again

Hedera. (2021). *What is a non-fungible token (NFT)?* Retrieved from Hedera Website: https://hedera.com/learning/what-is-a-non-fungible-token-nft

Hetland, S. T., Hviid, S. J., Pedersen, J., & Schmith, A. M. (2021). *Robustheden på boligmarkedet bør styrkes.* Nationalbanken. Nationalbanken. Retrieved from https://www.nationalbanken.dk/da/publikationer/Documents/2021/06/ANALYSE_Nr.%2016%20-%20Robustheden%20p%C3%A5%20boligmarkedet%20b%C3%B8r%20styrkes.pdf

Hevner, A. R., & Gregor, S. (2013, 6). Positioning and presenting design science research for maximum impact. *MIS Quarterly Vol. 37 No. 2, pp. 337-355*.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004, 3). DESIGN SCIENCE IN INFORMATION. *MIS Quarterly Vol. 28 No. 1, pp. 75-105*.

Karayaneva, N. (2021, 4 8). *Forbes.* Retrieved from https://www.forbes.com/sites/nataliakarayaneva/2021/04/08/nfts-work-for-digital-art-they-also-work-perfectly-for-real-estate/?sh=1031fc743f33

Kastrenakes, J. (2021, 03 11). *CryptoPunks NFTs sell at Christie's for $16.9 million*. Retrieved from theverge: https://www.theverge.com/2021/5/11/22430254/cryptopunks-christies-sale-larva-labs

Kelemen, M. L., & Rumens, N. (2008). *An introduction to critical management research.* Sage.

Kvale, S., & Brinkmann, S. (2018). *Doing Interviews.* Sage.

Lama, S. (2022, 02 9). *NFT Renting — How do Lenders and Borrowers Benefit From IQ Protocol?* Retrieved from beincrypto: https://beincrypto.com/nft-renting-how-do-lenders-and-borrowers-benefit-from-iq-protocol/

Laurence, T. (2019). *Blockchain for dummies.* John Wiley & Sons. Retrieved 09 04, 2021

Liu, N., Duncan, R., & Chapman, A. (2020). *A critical review of distributed ledger technology and its applications in real estate.* RICS Research Trust.

Lunde, J. (2012). Impacts on Wealth and Debt of Changes in the Danish Financial Framework Over a Housing Cycle. In *Challenges of the Housing Economy: An International Perspective, First Edition.* John Wiley & Sons, Ltd.

Majer, A. (2019). *Nun-Fungible Tokens - Transofmring the Worlds of Assets, Gaming, and Collectibles.* Blockchain Research Institute .

Makerdao website. (2022). Retrieved from https://makerdao.com/da/

Markowitz, H. (1952, 3). Portfolio Selection. *The Journal of Finance*, p. 15.

Markowitz, H. M. (1991). Foundations of portfolio theory. *The journal of finance, 46(2)*, pp. 469-477.

Meebits DAO Website. (2022). Retrieved from https://www.meebitsdao.world/

Metamask website. (2022). Retrieved from https://metamask.io/

Moore, G. A., & McKenna, R. (1999). *Crossing the chasm.*

Møller, M. H. (2021). *Boligmarkedet, danskernes forventninger 3. kvartal 2021.* Boligøkonomisk Videnceter.

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved from https://bitcoin.org/bitcoin.pdf

Opensea Website. (2022). Retrieved from Metadata Standards, How to add rich metadata to your ERC721 or ERC1155 NFTs: https://docs.opensea.io/docs/metadata-standards

Orcutt, M. (2018, 04 25). *How secure is blockchain really?* Retrieved from technologyreview: https://www.technologyreview.com/2018/04/25/143246/how-secure-is-blockchain-really/

Pawczuk, L., Walker, R., & Tanco, C. C. (2021). *Deloitte's 2021 Global - A new age of digital assets.*

Peaster, W. M. (2021, 08 24). *How to fractionalize NFTs.* Retrieved from banklesshq: https://newsletter.banklesshq.com/p/how-to-fractionalize-nfts?utm_source=url&s=r

Peffers, K., Tuunanen, T., Ruthenberger, M. A., & Chatterjee, S. (2007). A Design Science Research Methodology for Information System Research. *Journal of Management Information Systems, 24:3, 45-77*. Retrieved 10 17, 2021, from https://doi.org/10.2753/MIS0742-1222240302

PleasrDAO Website. (2022). Retrieved from https://pleasr.org/

Popescu, A.-D. (2021). Non-Fungible Tokens (NFT) - Innovation beyond the craze. *In 5th International Conference on Innovation in Business, Economics and Marketing Research.*

Pries-Heje, J., Lee, J., & Baskerville, R. (2011). Theorizing in Design Science Research. In *Lecture Notes in Computer Science LNCS(6629), 1-16.* Retrieved from https://rucforsk.ruc.dk/ws/files/34394180/Lee_et_al_2011_Theorizing_in_Design_Science_Research.pdf

Quiroz-Gutierrez, M. (2022, 01 25). *The next major trend in NFTs is to rent them out, and crypto landlords are making a killing*. Retrieved from https://fortune.com/2022/01/24/nft-rental-axie-infinity-crypto-pay-to-earn-video-game/

Ravi, R. (2021, 12 15). *What is a DAO and How Does It Relate to NFTs?* Retrieved from https://nftevening.com/what-is-a-dao-and-how-does-it-relate-to-nfts/

Rawat, A. S. (2021, 10 04). *What is a Non-Fungible Token (NFT)? Features & Benefits*. Retrieved from analyticsstep: https://www.analyticssteps.com/blogs/what-non-fungible-token-nft-features-benefits

Realkreditrådet. (2016). *Den klassiske danske realkreditmodel.* Ane Arnth Jensen. Retrieved 10 12, 2021, from https://finansdanmark.dk/media/37418/den-danske-realkreditmodel.pdf

ReturnValues Academy website. (2022). Retrieved from http://www.returnvalues.academy/blockchain/basic/trilemma/?fbclid=IwAR2LEKdfQgb-99qghc3-phpQJbGIIzDu05ql2valAt2dxcrvr2FvAeEGc2U

Riley, S. F., Ru, H. Y., & Feng, Q. (2013). The user cost of low-income homeownership. *Journal of Regional Analysis and Policy, 43(1100-2016-90119)*, pp. 123-137.

Rubenstein, M. (2002). *Markowitz's "Portfolio Selection": A Fifty-Year Retrospective.* The Journal of Finance Jun., 2002, Vol. 57, No. 3 (Jun., 2002), pp. 1041-1045.

Saleh, F. (2021). Blockchain without waste: Proof-of-stake. *The Review of financial studies, 34(3*, pp. 1156-1190.

Saunders, M. N., Lewis, P., & Thornhill, A. (2019). *Research methods for business students, eight edition.* Pearson Education Limited.

Schweifer, J. (2020). *Asset-Backed Tokens.* coinmarketcap. Retrieved from https://coinmarketcap.com/alexandria/glossary/asset-backed-tokens

Schär, F. (2021). *Decentralized Finance: On blockchain-and smart contract-based financial markets.* St Louis Review.

Seffinga, J., Lyndon, L., & Bachmann, A. (2017). *The Blockchain (R)evolution – The Swiss Perspective White paper.* Deloitte. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/innovation/ch-en-innovation-blockchain-revolution.pdf

Shawdagor, J. (2021, 10). *What are Fractionalized NFTs?* Retrieved from cryptovantage: https://www.cryptovantage.com/non-fungible-tokens/what-are-fractionalized-nfts/

Sherman, E. (2021, 05 30). *After The Hype: The Future For NFTs*. Retrieved from Forbes: https://www.forbes.com/sites/zengernews/2021/05/30/after-the-hype-the-future-for-nfts/?sh=19b1971b2146

Smith, J., Vora, M., Benedetti, H., Yoshida, K., & Vogel, Z. (2019). *Tokenized Securities & Commercial Real Estate.* MIT Digital Currency Initiative.

Spry, A., Pappu, R., & Cornwell, B. T. (2011, 05 31). Celebrity endorsement, brand credibility and brand equity. *European Journal of Marketing*.

Stefanoski, D., Sahin, O., Banusch, B., Fuchs, S., Andermatt, S., & Quertramp, A. (2020). *Tokenization of Assets - Decentralized Finance (De-Fi).* Ernst & Young LTD.

Suddaby, R. (2006). From the editors: What grounded theory is not. In *Academy of management journal 49.4.*

Swinkels, L. (2022). *Empirical evidence on the ownership and liquidity of real estate tokens.*

Szabo, N. (2017). *Winning strategies for Smart contracts.* Blockchain research institute.

Sørvoll, J., & Bengtsson, B. (2020). Mechanisms of solidarity in collaborative housing- the case of co-operative housing in Denmark 1980-2017. *Housing, Theory and Society*, pp. 65-81.

Tapscott, A. (2021). *The Rise of Defi and the Reinvention of Financial Services.* Blockchain Research Institute.

Tapscott, D. (2020). *Toward a Universal Digital Wallet - A means of Managing payments, Data, and Identity.* BLOCKCHAIN RESEARCH INSTITUTE.

Tapscott, D., & Tapscott, A. (2017, 03 22). *Blockchain Could Help Artists Profit More from Their Creative Works*. Retrieved from Harvard Business Review: https://hbr.org/2017/03/blockchain-could-help-artists-profit-more-from-their-creative-works

Tapscott, D., & Tapscott, A. (2018). *Blockchain Revolution: How the Technology Behind Bitcoin and Other Cryptocurrencies Is Changing The World.* Penguin Publishing Group.

The Many website. (2022). Retrieved from https://the-many.com/dk

Vauplane, H. d. (2018, 09 22). *The debate on the fungibility of Bitcoin.* Retrieved from Medium: https://medium.com/@maitrehub/the-debate-on-the-fungibility-of-bitcoin-bbcd101581c9

Verhallen, T. M., & Robben, H. S. (1994, 06). Scarcity and preference: An experiment on unavailability and product evaluation. *Journal of Economic Psychology*, pp. 315-331.

Whitehead, C., & Williams, P. (2017). Changes in the regulation and control of mortgage markets and access to owner-occupation among younger households. In *OECD Social Employment and Migration Working Paper,.* Paris.

Woo, G., & Thiel, S. (2020). *Fractionalizing the Future of Asset Ownership, Securely.* NASDAQ. Retrieved from https://www.nasdaq.com/articles/fractionalizing-the-future-of-asset-ownership-securely-2020-12-01

Wu, W. Y., Lu, H. Y., Wu, Y. Y., & Fu, C. S. (2012). The effects of product scarcity and consumers' need for uniqueness on purchase intention. *International journal of consumer studies, 36(3)*, pp. 263-274.

Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2018). *Blockchain Technology Overview.* U.S. Department of Commerce.