POLITECNICO
MILANO 1863

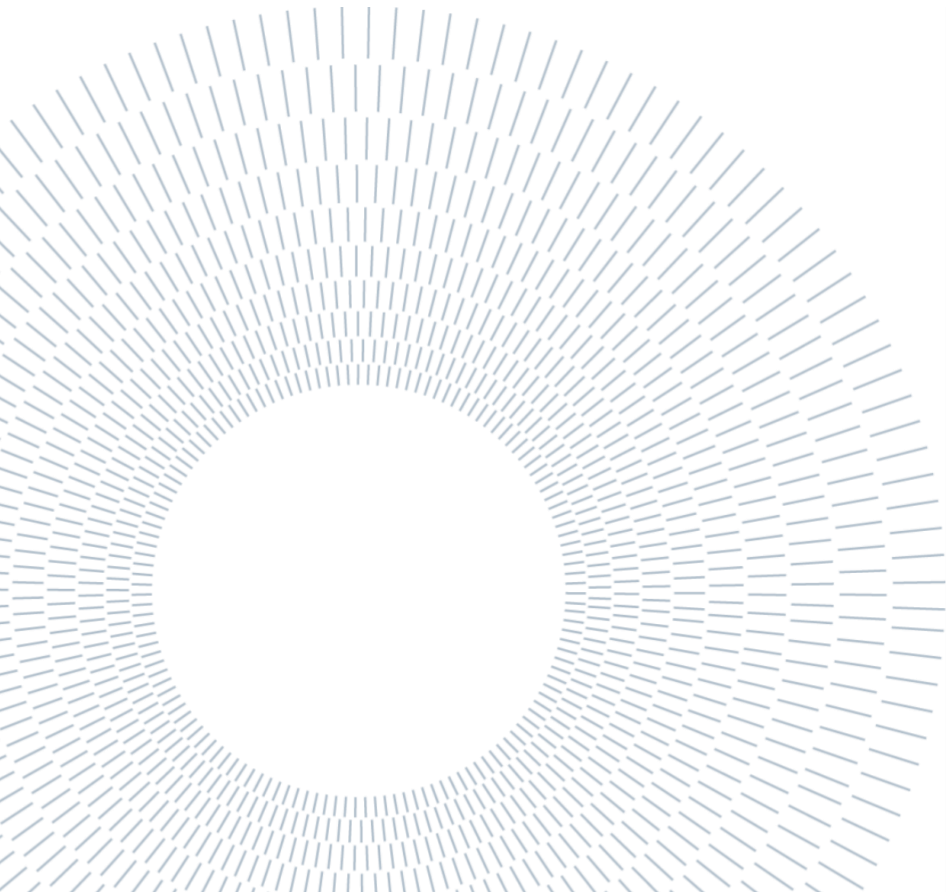
SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Exploring the Potential of Liquidity Pools in the Non-Fungible Tokens (NFTs) Market: an In-Depth Analysis and Management Model

MASTER OF SCIENCE THESIS IN
MANAGEMENT ENGINEERING

Author: **Michele Maria Capitanio**

Student ID:	969818
Advisor:	Alessandro Perego
Co-advisor:	Valeria Portale, Giacomo Vella, Davide Ghezzi
Academic Year:	2021-22



Abstract

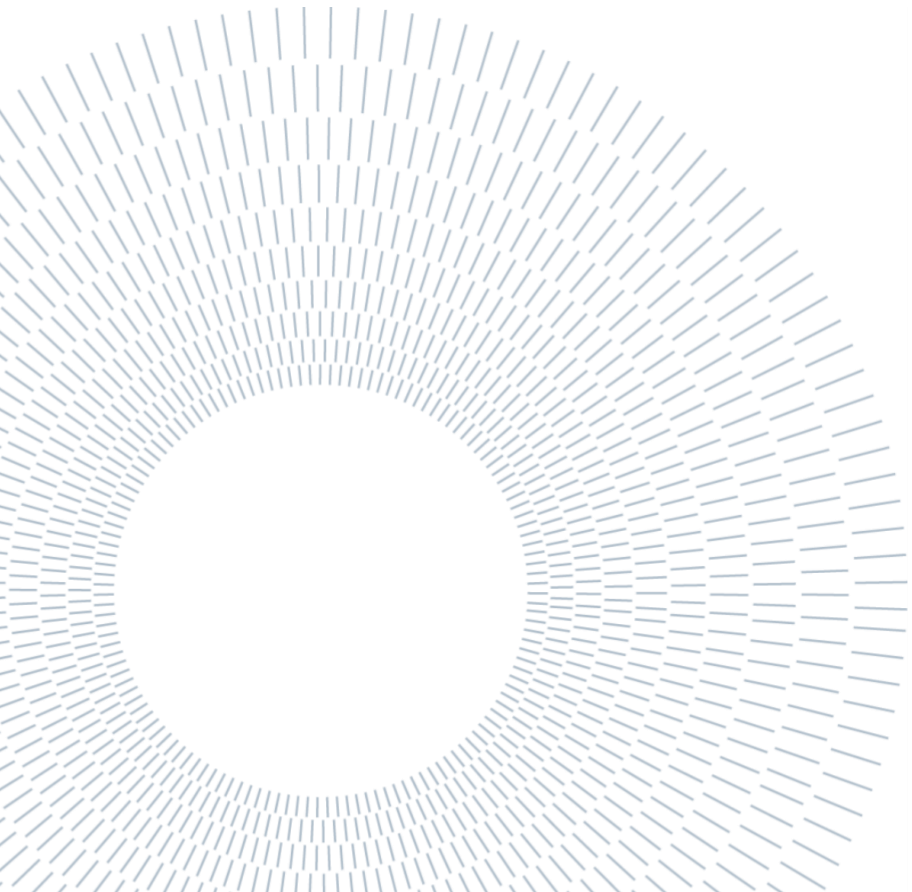
Non-fungible tokens (NFTs) are unique digital assets stored on a blockchain that are often associated with digital media like images or music. These tokens are traded on marketplaces, often with cryptocurrency, and are encoded within smart contracts. In 2021, the NFT market gained widespread attention due to record-breaking sales. However, the NFT market - which mainly adopts auctions and bid-ask as exchange mechanisms - suffers from several challenges, including illiquidity and pricing inefficiency, presence of wash trading. This thesis aims to explore the potential of liquidity pools in addressing these problems and presents a comprehensive analysis of the NFT secondary market. The study conducts a census of innovative projects that have introduced the Automated Market Maker (AMM) mechanism for NFT trading. Each project was analyzed and surveyed through a purpose-built framework to provide a comprehensive overview and examine how different liquidity pool constructions or pricing mechanisms adopted by these projects impact these issues. In addition to the analysis, the thesis proposes a management and trading model based on the internship experience at AerariumChain, a blockchain startup that uses NFTs derived from 3D scanning of works to support the preservation of cultural and artistic heritage. The proposed solution demonstrates the potential of liquidity pools in improving liquidity, decentralization and market efficiency for certain categories of NFTs. Overall, this thesis offers valuable insights into the secondary NFT market, contributes to existing literature, and provides a reliable framework for future implementations.

Key-words: Blockchain, NFT AMM, Secondary Market, AerariumChain.

Abstract in lingua italiana

I token non fungibili (NFT) sono asset digitali unici memorizzati su una blockchain, spesso associati a media digitali come immagini o musica. Questi token vengono scambiati sui marketplace, spesso con criptovalute, e sono codificati all'interno di Smart Contract. L'attenzione del pubblico per gli NFT è esplosa nel 2021, quando il loro mercato ha registrato vendite record. Tuttavia, il mercato NFT - che adotta principalmente il modello delle aste e di vendita tra gli utenti come meccanismi di scambio - presenta diversi problemi, tra cui l'illiquidità del mercato, l'inefficienza dei prezzi e la presenza di wash trading. Questa tesi si propone di esplorare il potenziale dei pool di liquidità nell'affrontare questi problemi e presenta un'analisi completa del mercato secondario degli NFT. Lo studio conduce un censimento dei progetti innovativi che hanno introdotto il meccanismo dell'Automated Market Maker (AMM) per il trading di NFT. Ogni progetto è stato analizzato e censito attraverso un framework appositamente costruito per fornire una panoramica completa. Si è esaminato come le diverse tipologie di pool di liquidità e i diversi meccanismi di prezzo, adottati dai progetti analizzati, incidano su alcune criticità. Oltre all'analisi, la tesi propone un modello di gestione e di trading basato sull'esperienza di stage presso AerariumChain, una startup blockchain che utilizza NFT derivati dalla scansione 3D di opere per supportare la conservazione del patrimonio culturale e artistico. La soluzione proposta dimostra il potenziale dei liquidity pool nel migliorare la liquidità, la decentralizzazione e l'efficienza del mercato per alcune categorie di NFT. Nel complesso, questa tesi offre preziose intuizioni sul mercato secondario degli NFT, contribuisce alla letteratura esistente e fornisce un quadro affidabile per le future implementazioni.

Parole chiave: Blockchain, NFT AMM, Secondary Market, AerariumChain.



Contents

Abstract ..... **i**
Abstract in lingua italiana ..... **iii**
Contents ..... **v**
Executive Summary **7**
Introduction **19**
1 Literature review **21**
1.1 General overview 21
1.1.1 NFT definition 23
1.1.2 History 23
1.1.3 NFT Attributes 25
1.1.4 Categories of NFTs 26
1.2 NFT Market 30
1.2.1 Different actors interacting with NFT 30
1.2.2 How are NFTs usually bought 32
1.2.3 Main Marketplaces 33
1.2.4 Current exchange mechanism 35
1.3 Criticisms of NFTs actual exchange mechanism 37
1.4 Revolutionizing NFT trading: introduction to NFT AMM 44
1.5 Gaps found in literature 45
1.5.1 Master thesis objective 45
1.5.2 Research Question 46
2 Research Methodology **47**
2.1 Introduction 47
2.1.1 Choice of variables 48
2.1.2 Projects picking 49

2.1.3 Selection of tool to collect data 50
2.2 Variables description 52
3 Findings 65
3.1 General information 66
3.2 Liquidity pool: 69
3.3 Key features: 75
3.4 Economics 77
3.5 Performance 80
3.6 Problem solved 81
4 AerariumChain 91
4.1 Company description 91
4.2 Project objective 92
4.3 Previously defined feature 93
4.3.1 Algorand 93
4.3.2 NFTMicro™ description 94
4.3.3 Primary market 97
4.4 Achieving Liquidity: AEC Solution 98
4.4.1 Advantages 113
4.4.2 Limits 113
4.4.3 Future development & follow up 114
5 Conclusion 117
Bibliography 121
List of Figures 129
List of Tables 131

Executive Summary

Introduction

The emergence of blockchain technology has opened new possibilities for innovative applications, one of which is the creation and exchange of non-fungible tokens (NFTs). NFTs are unique digital assets that represent ownership of a specific object, such as digital art or music. Their popularity has surged in recent years, with NFT trading reaching an astounding $17.6 billion in 2021, marking an increase of over 21.000% from the previous year's total. This master thesis delves into the NFT secondary market, providing a detailed analysis of its main characteristics, the current state of the art and its inefficiencies in the literature chapter. The primary objective of this research is to explore the potential impact of liquidity pools on the secondary NFT market and how they can be utilized to create a more efficient and effective market for buying and selling NFTs. The methodology and analysis of several NFT projects are presented respectively in the second and third chapters, focusing on their main characteristics and the problems they aim to solve, as highlighted by the literature. In addition to this analysis, the thesis includes a practical component, presenting a model for managing and trading NFTs through liquidity pools. The model was developed during a curricular internship at AerariumChain, a blockchain startup that supports the conservation of cultural and artistic heritage through an NFT service.

Literature & Research Question

This step is extremely important, as it forms the basis for the fruitful development of the entire thesis. The analysis begins by introducing NFTs and then delving into the secondary market of NFTs. Specifically, the state of the art and the inefficiencies of the current dominant auction and bid/ask system are highlighted, including the presence of wash trading activities, high royalties of centralized systems, low democratization, illiquidity, price inefficiency, and the inability to sell instantaneously. While the literature identifies the major critical issues, empirical studies are scarce, and there is a lack of research that surveys and analyzes current projects attempting to solve these critical issues and the mechanisms they aim to

adopt. Therefore, this research addresses the literature gap by providing a comprehensive overview of the new NFT market managed through an Automated Market Maker (AMM). It presents the main characteristics of each project and identifies the impact of certain characteristics on the problems identified by the literature. The research question is:

RQ: *Can the liquidity pool be used as a method to improve the trading of NFTs in the secondary market?*

Research Methodology

The chapter on research methodology outlines the process used to select variables, projects and data collection tools. It also provides a detailed explanation of the analyzed variables and their possible values.

To ensure consistency across all projects, 41 variables were selected that could be applied to all projects. These variables have been grouped into six macro-areas of analysis. The second choice was to select which NFT AMM projects to use as input for the analysis. The method used involved searching for keywords such as "NFT AMM", "NFT liquidity pool", "NFT DEX" and "NFT liquidity". Initially, 132 top accounts were discovered through the aforementioned research. However, further analysis was needed to eliminate fake accounts, those belonging to moderators or community managers, and those that did not use a liquidity pool as a method of trading NFTs. In the end, the final database consisted of 41 projects that met the established criteria.

The third decision concerns the selection of tool to collect data. Sources include: whitepapers, mediums, funding information websites including Traxcn and Crunchbase, NFT market monitoring websites including Dune, Cryptoslam, DappRadar, TIEXO, and finally social media platforms such as Twitter, Telegram and Discord. It has been decided to use the same sources to ensure uniformity of data and cross-referenced data from multiple sources to ensure accuracy as some websites have different ways of tracking data. The methodology chapter ends with the description of the 41 variables analyzed and the description of the possible measures they can adopt.

Findings

The chapter presents the most significant results of the empirical research conducted on AMM NFT protocols. The research is divided into six sections, the first five of

which provide an overview of the general information, liquidity pool, key features, economics and performance of the protocols. The last section attempts to answer research questions by examining the problems solved by the protocols.

General information:

The first section highlights the significant interest in the emerging market of NFT AMMs. The growing trend towards the creation of new projects is a positive indication of the sector's potential, despite still being in its early stages and immature. Figure I shows the ownership of projects based on their foundation year and current status. Although Sudoswap - the first decentralized NFT AMM - has generated interest in NFT sector in August 2022, there are NFT AMM projects dating back to 2020 or 2021. These projects may have initially started as fractional NFTs, and only later transitioned to liquidity pools due to the benefits offered by Sudoswap.

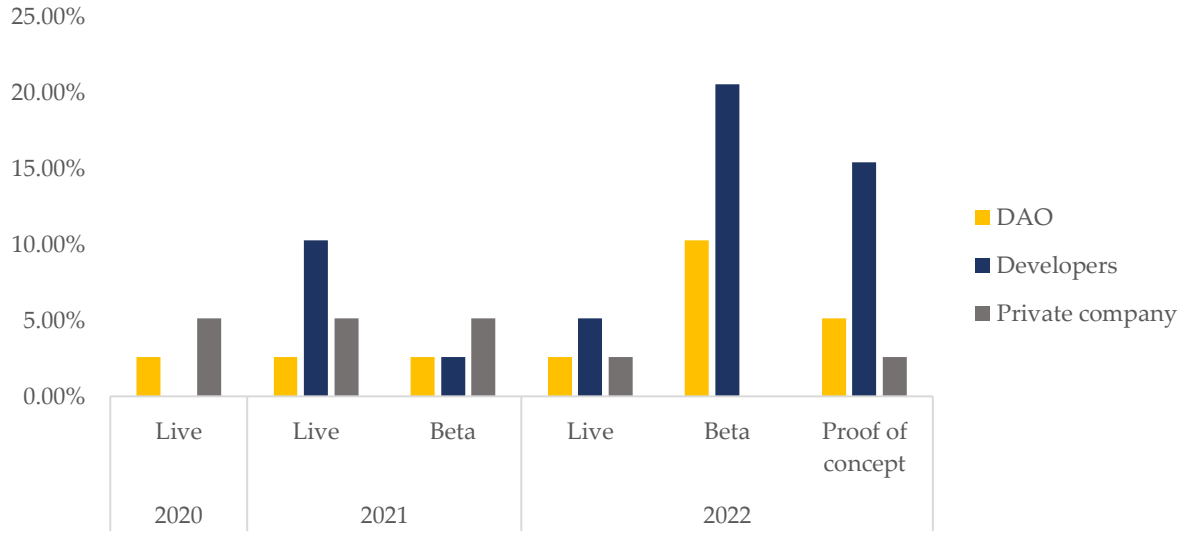


Figure I: Ownership and Status distribution over the year (basis: 40 cases)

It's worth noting that the proof-of-concept projects mentioned in this report were all created in 2022, which suggests that the time to create a beta version is at most one year. Additionally, all the projects created in 2020 are currently live, indicating that the maximum time it takes to create an NFT AMM project is two years. These findings suggest that the development of NFT AMM projects is relatively quick, which is promising for the growth of this market.

Liquidity pool & Price mechanism:

The following section is central to the analysis because the presence or absence of the liquidity pool mechanism used for NFT trading was the primary criterion for

selecting the projects analyzed, as explained before. The section shows in the first part of the analysis how the liquidity pools analyzed are constructed and in the second part what pricing mechanisms are adopted.

In terms of liquidity pool construction, 52% of liquidity pools are manually constructed by the liquidity provider. The remaining 48% are divided equally between protocols that build liquidity pools through a fully automated process and hybrid models. Liquidity pools tend to be constructed with a pair of assets (89%), while only 11% of the protocols employed multi-asset LPs - meaning more than two assets – due to the complexity of applying this model to NFTs. In addition, exactly half of the projects examined have the smart contract forked or built on top of another project. Among the projects where smart contracts were most widely used, Sudoswap (44%) and Uniswap (19%) stand out. These data are significant because they demonstrate both the importance and relevance of Sudoswap in the NFT AMM sector and how Uniswap remains the reference model for protocols building a smart contract for a liquidity pool. Only 24% of the projects implemented the ability to trade between a pair composed of both sides of NFT, as it is difficult to implement and challenging to ensure that the counter value of the two traded assets is equal.

The pricing mechanism adopted by the projects analyzed is crucial. It should be emphasized that a project can adopt more than one price mechanism, for this reason the percentage sum in Figure II is not equal to 100%. Most projects use linear and exponential bonding curves (51% and 49%, respectively), while 27% of projects use other types of bonding curves. Interestingly, 19 % of the projects analyzed - while proposing a different exchange model from traditional auctions - include auctions in their exchange models probably to avoid standing out too much from the market.

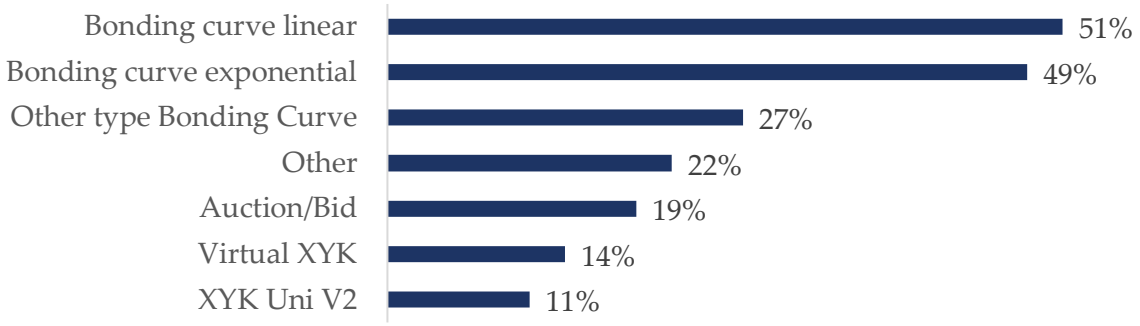


Figure II: Distribution of the price mechanisms by the analyzed projects (*basis: 37 cases*)

The constant product model is the least used due to its difficulty in implementation, with only 14% of projects using it virtually. Finally, only 11% of projects use the model proposed by Uniswap for exchanging non-fungible tokens.

Key Features:

This section examines additional features of NFT projects beyond the liquidity pool swap mechanism that is mandatory, including *fractional process*, *multichain*, *loan*, *staking*, and *audit*. Most projects analyzed lack these features, which is not surprising as they were primarily designed to address specific problems using the liquidity pool mechanism. Fractionation is available in only 27% of projects, while 30% support smart contracts on multiple blockchains, and just 22% allow NFTs to be used as collateral for loans, likely due to the difficulty of valuing NFTs accurately. Despite the importance of auditing for security and trust, only 39% of smart contracts are audited, possibly due to the high cost of the service and limited funding for proof of concept projects. The analysis also examined the prevalence of these features by project stage, revealing a higher prevalence of review and fractionation in proof-of-concept projects. The data also show that proof-of-concept projects focus primarily on liquidity pool characteristics with virtually none of these characteristics being presented. This finding is in line with the purpose of fledgling projects, which is to address the problems highlighted in the literature.

Economics:

The main finding in this section concerns the protocol fee, which is a key factor in the business model of a liquidity pool-based protocol. The average fees collected by the liquidity provider differed according to the fee construction mechanism. Specifically, 37% of the projects imposed a fixed value, 29% allow the liquidity pool creator to set fees arbitrarily within a set range while instead 34% give the liquidity pool creator complete freedom to set the fee they prefer. The fee that the protocol takes on average is highest in already live projects (1,8%) and decreases significantly in beta projects (1,1%) before halving at proof of concept projects (0,9%). Finally, only a small percentage of protocols have integrated credit/debit card payments (11%) and only 26% offer incentives to liquidity providers with tokens to increase returns in order to attract new users and increase the protocol adoption.

Problem solved:

Among the analyses presented in this chapter, this section is particularly informative as it not only examines the problems solved but also how they relate to the key characteristics highlighted earlier. Figure III shows the percentage of problems reported by analyzed projects they aim to solve. The results suggest that the most significant problems are the inability to sell NFT instantly (89%) and illiquidity (86%), followed by centralization (61%). Transparency in price discovery and the ability to use NFT as collateral (44%) are also important. High royalties and wash

trading are less prioritized issues, with only 25% of projects analyzed addressing the latter.

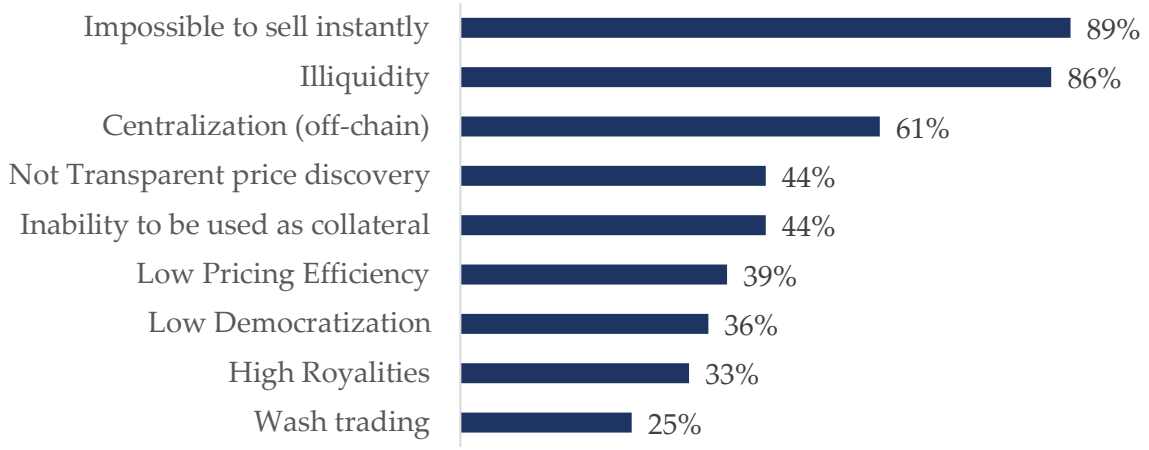


Figure III: Distribution of the problems solved by projects (*basis: 36 cases*)

The key step in this analysis is summarized in Table I, where are highlight the strengths and weaknesses of each pricing method in relation to each specific problem analyzed. These data are obtained by cross-referencing the variables from the *pricing mechanism* and the *solved problems*. It was necessary to normalize the data given the significant difference between projects adopting different pricing mechanisms. The procedure is shown in Table 3.4 in the *findings chapter*. The result of this calculation is reported in Table I, where each cell represents the percentage contribution of the pricing method to the solution of a specific problem. The last column shows the same total values described in price mechanism paragraph, and the last row shows the total sum indicating the pricing method that best attempts to solve the problems seen in Figure III. The analysis reveals that the constant product method introduced by *Uniswap V2* is the most effective pricing method, contributing 82% to overall performance. The second method falls under the *Other* measure (73%). This category includes all those projects that use innovative and singular pricing methods, and thus do not fall into the other categories. Among the most interesting projects that fall into this category are Quantix [1] and Solvent [2]. Both protocols - in different ways - facilitate the division of NFT into equal parts that can be bought and sold by multiple owners, increasing liquidity and democratization. As for pricing based on *bonding curves* they tend to be similar as performance standing between 62%-63%. Finally, the model of *auctions* and offers between individual users is the one with the lowest percentage. This exchange model was kept in the analysis because the projects analyzed included it probably to avoid a total disruption with the traditional method. None of the projects analyzed used only this pricing method because as described in the *project picking* section only those projects that used the liquidity pool

were included in the analysis. However, only those projects that have declared that they want to solve fewer problems than others have adopted this pricing method. This is due to the difficulty in matching three important factors when using this pricing method, namely: finding the right buyer, agreeing on value, and timing, as described in the literature chapter.

1,1	BC linear	BC exponential	Other BC	Virtual XYK	XYK Uni V2	Auction/Bid	Other	% Tot prob. solved
Wash trading	2%	2%	4%	3%	7%	4%	4%	**25%**
High Royalties	11%	11%	2%	9%	0%	0%	0%	**33%**
Centralization	12%	13%	9%	6%	8%	4%	9%	**61%**
Illiquidity	11%	11%	12%	15%	11%	11%	15%	**86%**
Inability to be used as collateral	3%	3%	7%	3%	13%	8%	8%	**44%**
Low Democratization	2%	2%	5%	3%	14%	4%	7%	**36%**
Low Pricing Efficiency	4%	3%	5%	5%	7%	6%	9%	**39%**
Not Transparent price discovery	4%	4%	5%	8%	10%	4%	9%	**44%**
Impossible to sell instantly	15%	15%	12%	13%	12%	9%	12%	**89%**
% tot of problems solved by pricing	**63%**	**62%**	**62%**	**65%**	**82%**	**50%**	**73%**	

Table I: % distribution price mechanism on solved problem normalized by lines (*basis:36 cases)*

AerariumChain

The chapter focuses on the solution implemented during the curricular internship in AerariumChain and is divided into two parts. The first part introduces the company, the project, the characteristics of the fractional NFTmicro™ of AerariumChain and the choices already made by the company, including the functioning of the primary market. The second part presents the management proposal of the NFTmicro™ secondary market - developed during the internship months - considering the previous analysis. AerariumChain is an Italian startup that aims to preserve cultural and artistic heritage worldwide. The project mainly provides three services: care, fund and show. Between October 2022 and April 2023, the project focused on managing the NFTmicro™ secondary market by designing, simulating, and defining an optimal methodology for trading on this market. The ultimate objective was to identify a model that aligns with the business model and goals of NFTMicro™. These last ones are obtained through 3D scanning of artworks which are subsequently notarized in the Algorand blockchain. Through the sale of these, the Museum is financed for maintenance and restoration activities.

AerariumChain's solution involves the use of liquidity pools and key decisions have been made to obtain liquidity. The following are reported:

- The first decision was made regarding the primary and secondary markets as trading mechanisms. It was determined that the primary market would be closed once a liquidity pool was created for a single collection to simplify the model and avoid creating two different prices of the same asset at the same time, thus enabling the possibility of arbitrage.
- The second decision concerns whether or not to activate the liquidity pool for all works for sale on the primary. In fact some artworks are worth more than one million euros others are worth a few thousand. The works were classified into 5 tiers based on their value, and a minimum threshold was established for the value of the artworks. Only artworks falling under Tier 4 or 5 - with a minimum value of 1 million - would have a liquidity pool created for the secondary market. This decision aimed to avoid creating small pools with little liquidity.
- Another major decision concerns the minimum amount of initial liquidity required in the liquidity pool for the activation of the NFT secondary market. An inverse method to simulate a purchase on traditional DEXs was used to evaluate the impact price and the reserve ratio of the two assets was used to calculate the price before and after the swap. A minimum liquidity of 25.000 USDC and the counterparty in NFTmicro was established to reach the secondary market which guarantees a price impact that falls within the range of 1-3% for an average swap on a DEX in a stable-coin pair and which allowed a purchase of $1500 with a maximum discount of 10%. Figure IV shows the impact price against a $146 swap across different pool sizes.

The chapter proceeds to discuss whether to develop the smart contract for the liquidity pool internally or to collaborate with third-party. It was decided to collaborate with Pact - the dex with the most liquidity on Algorand - to build the liquidity pool. Most of the projects analyzed chose to build their liquidity pool in asset pair mode, and AerariumChain's solution follows this model. The company will use a stablecoin and NFTMicro as assets pair to provide stability and simplicity. The project will implement Uniswap V2's XYK constant product as its pricing mechanism because in the findings chapter it was found to be the one that solves multiple problems and improves transparency and price discovery. The solution includes a dual-sided LP instead of single-sided LP, allowing both buy and sell transactions, and a 1:1 relationship between the liquidity pool and NFTMicro Tier 4-5. The liquidity poos will be built automatically.

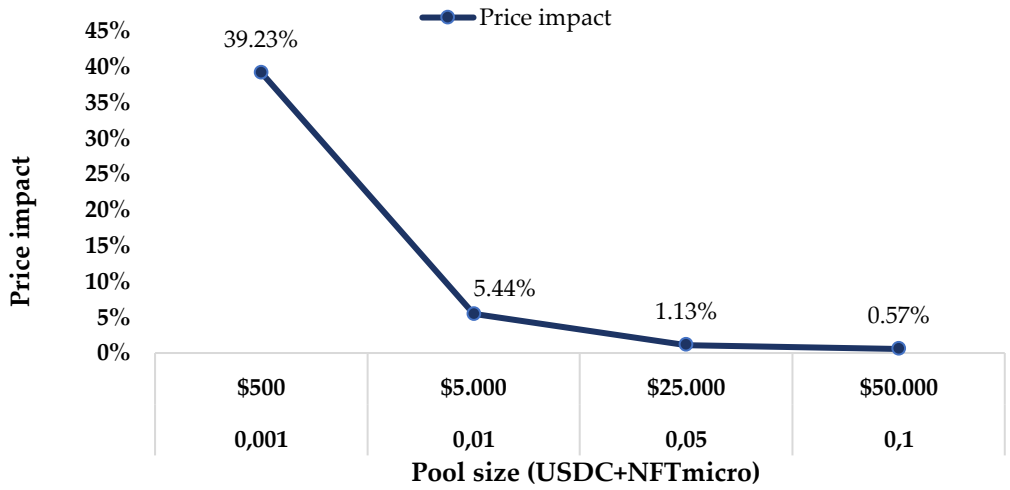
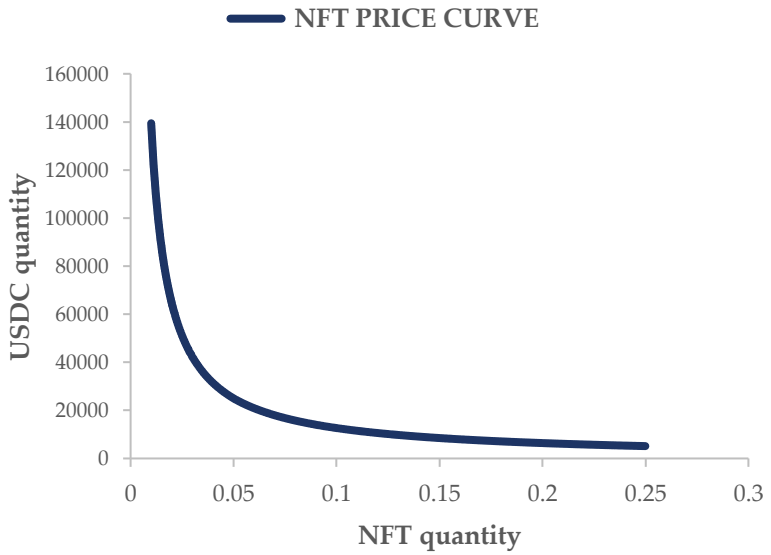


Figure IV: Price impact of 146$ sell order in different pool sizes

Regarding the AerariumChain price curve, this was generated by combining two simulations to illustrate how NFTmicro prices will fluctuate based on buying and selling activity. Initially, a liquidity pool was established with 0,050000 NFTmicro and $25.000, with the value of a single NFT set at $0,5. Next, 2273 transactions were simulated where 0,0000880 NFTmicro was sold to the liquidity pool, worth approximately $46 at the start. In the second simulation, 2533 transactions were carried out where NFTs worth $46 were bought from the liquidity pool. Combining the 4906 points of the transactions resulted in the price curve - shown in Figure V - assuming that the value of stablecoin is indeed stable against the dollar.



FigureV: Representation of the price curve obtained by simulating 4906 transactions. USDC assumed stable at $1

It was chosen to simulate the change in the price curve with purchases of $46 since it was the average amount traded by a user on Pact. The X axis represents the amount of NFTmicro in the liquidity pool, with the maximum sellable being 0.25 per artwork, while the Y axis represents the amount of USDC, which can exceed the indicated value.

In order to provide a comprehensive solution for the NFTMicro™ secondary market, the chapter not only covered the solution for Tier 4-5 works but also outlined the solution for Tier 1-2-3 works. Figure VI is an illustration of the solution of AerariumChain secondary market and it also show the commission percentage that the startup earns on each exchange.

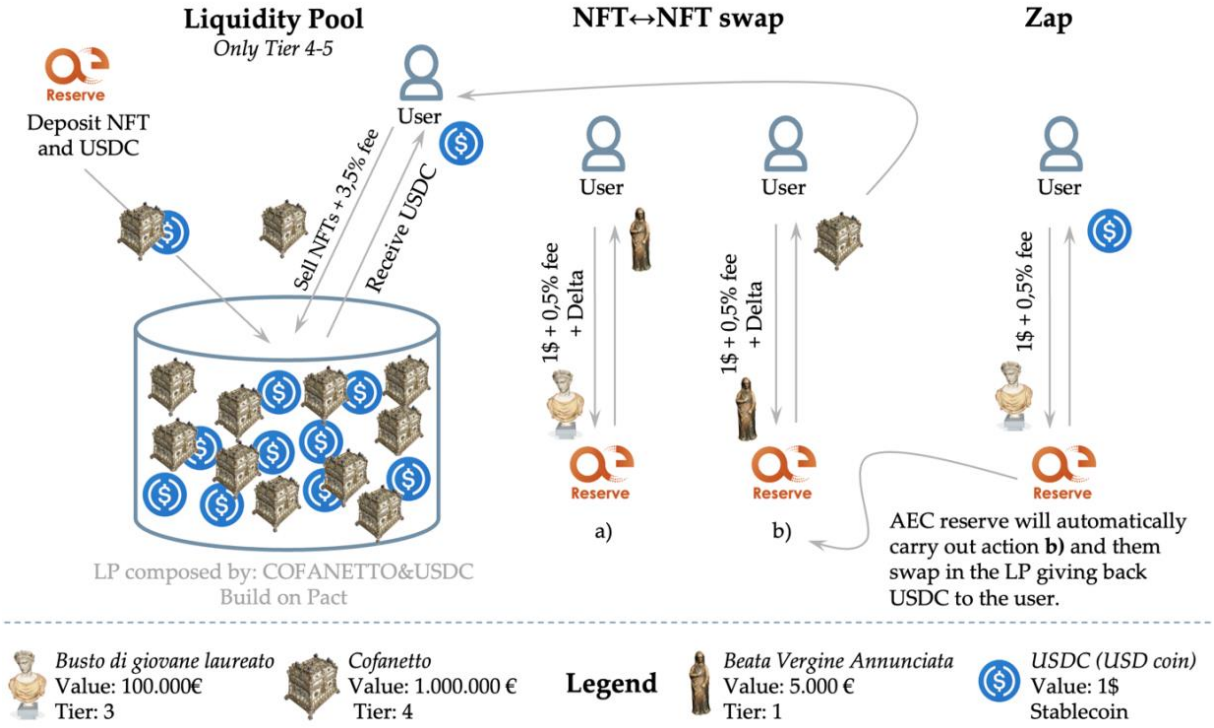


Figure VI: Secondary market representation of AerariumChain

This solution design includes two different functionalities to enable the liquidity provision for Tier 1-3 NFTs despite not reaching the threshold level described above. Firstly, the NFT-NFT exchange service, which allows users to exchange their NFTs to obtain other NFTs or sell them for USDC by exchanging them for Tier 4 or 5 artworks. This solution provides an easy and cost-effective way for users to access liquidity in the secondary market. Secondly, the ZAP service is designed to provide users with the option to exchange their NFTs for USDC in one step. However, it is a more expensive option compared to the NFT-NFT exchange service.

Conclusion

This thesis offers a comprehensive empirical analysis of an aspect that has been neglected in the literature on the topic of the NFT secondary market, and provides the design of a proposed solution developed during the internship at AerariumChain. The main benefit of this research is the establishment of a reliable framework that can be used as a baseline for future implementations, as well as a solid design for the startup mentioned earlier.

An attempt was made to answer the research question by presenting the main characteristics of each project that identified the problems highlighted and developed a mechanism for trading NFTs through the liquidity pool. The analysis revealed the potential of this market. The results show that most of the projects use linear and exponential bonding curves, while the Uniswap V2 constant product model is the least used. However, in the solved problems section, the analysis also revealed that it is precisely the least-used pricing model that turns out to be the most effective in solving some problems. Precisely for this reason, the solution proposed by AerariumChain uses the Uniswap V2 model for the secondary market and introduced an essential innovation, which is the differentiation of the type of exchange model according to the value of the artwork and also. It also presents a model to make decisions and simulate the impact price, calculate the minimum amount of liquidity to ensure a stable market and took into account the disparity of different NFTs.

Given the analysis carried out and the internship experience, and considering that not all NFTs need a very liquid secondary market, it is believed that the best trading model for the secondary market of NFTs strongly depends on two main factors: the category of NFT and its value. It is hypothesized that for all those rare and high-value NFTs, the best model is the most popular one, namely auctions and direct transactions. The liquidity pool model would fit these types of NFTs only in the event that a decision is made to fractionalize them by making their value very accessible and the market more democratic, which is exactly the case for AerariumChain. The liquidity pool model also works well for all collections where the value of the NFT does not vary too much between one NFT and another, thus being able to trade two NFTs from the same collection at the same price.

However, this paper is subject to four main limitations. First, the low number of existing NFT AMM projects reduces the robustness and consistency of the results obtained. In addition, almost all of the projects analyzed are initial pilot projects that have not yet reached full implementation, which limits the conclusions that can be drawn. As more and more projects move from the proof of concept phase to the live

phase, it will be interesting to explore their performance. The second limitation concerns the lack of tools available to test the effectiveness of the proposed solutions. While the projects analyzed aimed to address inefficiencies in the current trading mechanism in the NFT secondary market, no tool was designed to verify an improvement objectively and numerically in metrics. The third limitation pertains to the AerariumChain solution, as its implementation and validation in the market could not be carried out. Finally, the last limitation relates to the fact that the liquidity pool mechanism was applied to a specific category of NFTs, and the analysis lacks a framework that compares on different axes the category of NFT, the value of NFT, and the best exchange type.

Nevertheless, these limitations may offer insights for future studies. Firstly, it is recommended to expand the set of applications to complement and/or modify the current framework over time and to survey new projects that will arise in this area in the future. Secondly, it is suggested to develop or use tools to verify whether the problem analyzed is affected differently by the liquidity pool mechanism and whether it leads to an improvement. Finally, an interesting analysis would be to survey all the exchange mechanisms used with the different pricing methodologies and analyze in detail the value of each NFT and the price difference between NFTs in the same collection and try to create a dashboard categorizing the best exchange model according to the type of NFT.

Overall, this research provides a solid foundation for future studies in the field of NFT marketplaces and their potential solutions. The proposed solution design can serve as a starting point for further research and development in this rapidly evolving and exciting field.

Introduction

The rise of blockchain technology has unlocked new opportunities for innovative applications, one of which is the creation and trading of non-fungible tokens (NFTs). NFTs are unique digital assets that represent ownership of a specific object, such as digital art or music. Their popularity has recently increased, with NFT trading reaching $17.6 billion in 2021. Despite the cryptocurrency market crash, the total volume of NFTs traded in 2022 is almost equal to that of the year previous [3]. If 2021 marked the moment NFTs emerged into the public consciousness, 2022 was the time for exploration, as new initiatives and applications emerged to test just how transformative the technology could be. From the emergence of new profile picture collections (PFPs) to attempted excursions into experiences in fashion, music, entertainment, gaming, and the metaverse, these new concepts and trials have seen many successes and setbacks. In fact – in 2022 - major brands and companies have started playing with NFTs to engage and grow their customer base. Some big names entered the NFT market including Starbucks, Instagram, Nike and Reddit, as well as luxury brands such as Burberry, Gucci, Louis Vuitton, Dolce & Gabbana [4]. Leading brands are starting to recognize that they need to create NFT strategies to stay competitive. Despite the growing interest and popularity of non-fungible tokens (NFTs), some studies have begun to analyze some inefficiencies of current trading methods of main marketplaces such as lack of instant sale, wash trading, illiquidity and market centralization.

This master thesis delves into the NFT secondary market, providing a detailed analysis of its main features, the current state of the art and its inefficiencies in the literature chapter. The main objective of this research is to explore the potential impact of liquidity pools on the secondary NFT market and how they can be used to create a more efficient and effective market for buying and selling NFTs. The methodology and analysis of different NFT projects are presented in the second and third chapters respectively, focusing on their main features and the problems they aim to solve, as evidenced by the literature. In addition to this analysis, the thesis includes a practical component, presenting a model for managing and trading NFTs via liquidity pools. The model was developed during a curricular internship at

AerariumChain, a blockchain startup that supports the conservation of cultural and artistic heritage through an NFT service.

Overall, this thesis offers an in-depth analysis of the NFT secondary market, contributing valuable information to the existing literature. It also features a new management and trading model that showcases the potential of liquidity pools to enhance the market by increasing its liquidity, decentralization and efficiency.

1 Literature review

In recent years, the world of non-fungible tokens (NFTs) has captured the attention of many, offering a new way to interact with digital assets. As the NFT market has grown and evolved, it is important to understand its core attributes and potential applications. This chapter aims to provide readers with a review of the literature on NFTs, delving into the main features, the different categories and their history.

In addition to exploring the technical and historical aspects of NFTs, this chapter will also examine their current state of the market, highlighting which are the main marketplaces where NFTs are currently bought and sold, and which are the most widely used exchange mechanisms. Finally, analyzing criticisms of the current exchange mechanism, the chapter will introduce the concept of automated market maker (AMM) of NFTs as a potential alternative mechanism.

Gaps in the existing literature will be illustrated and opportunities for future investigation in this rapidly evolving field will be highlighted. The ultimate goal of the chapter is to provide readers with a solid knowledge base on NFTs, enabling them to address the more advanced topics explored later in this thesis. By the end of this chapter, the reader will have a clear understanding of what NFTs are, their key attributes, and the current state of the NFT market.

1.1 General overview

To understand the technology behind NFTs, it is important to examine the blockchain. The blockchain is a distributed database that serves as an irreversible and incorruptible public repository of information. It allows unrelated parties to reach consensus on a transaction or event without the need for a supervisor, making it a highly secure way to transfer assets. [5].

The blockchain was first introduced in 2008 by Satoshi Nakamoto Whitepaper Bitcoin [6]. In it, a new financial system was outlined that could handle payments without the involvement of a financial intermediary. This was made possible by a

consensus mechanism, which allows all nodes on the blockchain to reach a democratic agreement [6]. To validate a transaction, the consensus mechanism is used to allow miners - computational nodes that create new cryptocurrencies and verify transactions on the blockchain - to vote on the validity of the transaction [6]. If a majority of miners believe a transaction is valid, it is processed. Hash functions are an important part of the blockchain. A hash function is a cryptographic function that transforms an arbitrary-length message into a fixed-length output. The output of a hash function is called a hash and is used to identify transactions in the blockchain. It has three properties:

- *Non-invertibility*: This is a non-reversible mathematical function that takes an input and transforms it into an output. The message cannot be retrieved from the hash value.
- *Consistency*: Two or more messages cannot have the same hash. This ensures that two account transactions cannot collide.
- *Fixed hash length*: Regardless of the data size, this function returns the same hash length.

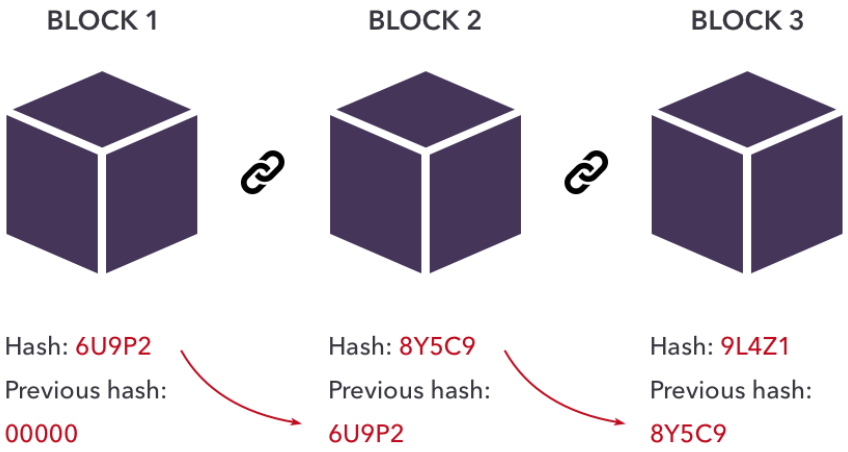


Figure 1.1: blockchain: a block of information plus chain of hash identifier. Source: Blockchain 101

The name of the blockchain comes from the chaining of hashes that occurs when a transaction is recorded in the distributed ledger. Each transaction is assigned a unique hash and the hash of the previous block is included in the calculation of the new one. This creates an immutable record of transactions that can be traced back to their origin as simplified in Figure 1.1.

The ability to securely verify the integrity of transactions and track ownership changes all the way back to the genesis of the blockchain is a key feature of NFTs. This system not only validates transactions, but also gives the blockchain its fundamental properties, which are reflected in NFTs. By tracking the entire path of

every object exchanged in the blockchain, it becomes possible to define the unique owner and creator of every asset exchanged within the blockchain system. This makes the system essential for NFTs and is a key factor in maintaining their value and authenticity.

1.1.1 NFT definition

Combining and extending the definitions of Bal and Ner [7], Regner [8] and Leech [9], it has been defined a non-fungible token (NFT) as a unique, indivisible, irreplaceable and verifiable token that represents a given asset, be it digital, or physical, on a blockchain [10]. NFTs can be thought of as digital certificates of ownership encoded as smart contracts. Due to the transparency of the blockchain, NFTs provide an indisputable confirmation of the current and historical ownership of the asset, potentially reducing information asymmetries and information acquisition costs for marketplace participants. Most NFTs are encoded on the Ethereum blockchain. However, NFTs exist on other blockchains. [11]

1.1.2 History

In 2012-2013, Colored Coins were born, a denomination of a cryptocurrency - often Bitcoin - that is repurposed by marking it with metadata [12]. Through the utilization of Colored Coins, users were capable of symbolizing a variety of diverse assets, including property, subscriptions, and digital collectibles. The valuation of these Colored Coins was established through mutual agreement regarding the number of coins that equated to a particular value. In 2014, a peer-to-peer financial platform named Counterparty was established. Subsequently, in 2015, Spells of Genesis, a game, integrated blockchain technology for in-game assets. In 2016, Counterparty collaborated with a trading card game called Force of Will to introduce its cards to the blockchain. In addition, a viral internet phenomenon known as Rare Pepe emerged within the space. By 2017, Rare Pepes and other memes had begun to be traded on the Ethereum blockchain [13], [14]. In their current format, NFTs were implemented in 2017, when Dieter Shirley, a contributor to the Ethereum source code repository and founder of the digital collectibles game CryptoKitties, introduced the ERC-721 smart contract standard, which allowed for the creation of a new type of Ethereum tokens [15]. In 2017, NFTs started to attract more extensive attention and interest, largely driven by two projects: CryptoPunks and CryptoKitties. CryptoPunks is a set of procedurally generated - i.e., automated by a computer program - highly pixelated portraits that blend art with collectibles. CryptoPunks portraits were initially given away for free, with early resales ranging from $1 to $30 and more recently individual portraits reselling for upward of $1 million [16].

CryptoKitties is a game based on purchasing, collecting, breeding, and selling unique digital creatures inspired by cats [17]. Both CryptoPunks and CryptoKitties use the Ethereum blockchain to digitally store, preserve, and authenticate ownership. Both CryptoPunks and CryptoKitties use the Ethereum blockchain for digitally storing, preserving, and authenticating ownership. These projects helped initiate the digital art movement and provided a way of monetizing digital content through NFTs. A prominent example illustrating how NFTs aid artists in monetizing their work is Everydays: The First 5000 Days, which is a digital artwork. The piece is a virtual mosaic comprising 5,000 images by artist Beeple that sold at auction for more than $69 million [18].

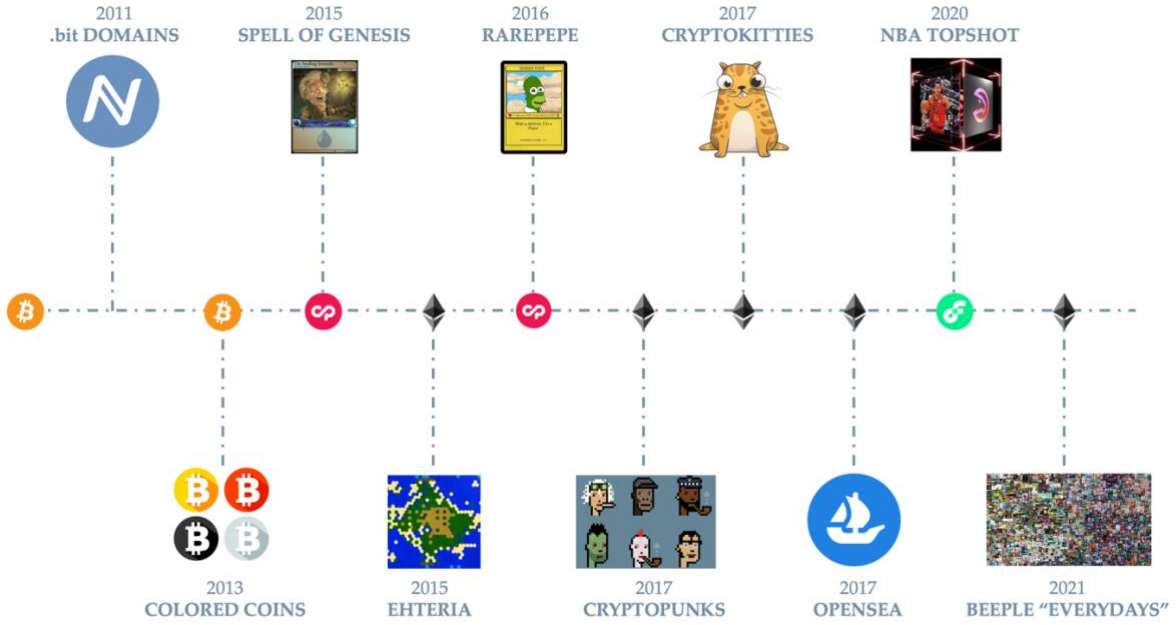


Figure 1.2: NFT Timeline - History of NFTs designed by Ownest

In early 2021, NFTs have exploded in popularity. This phenomenon was due to a confluence of factors including a lucrative market for cryptocurrency – for example Bitcoin, Ethereum and the DEFI sector – repeated waves of speculative stock market moves and the emergence of COVID-19. Existing studies have found that cryptocurrency market liquidity has increased significantly following the OMS's identification of a worldwide pandemic [19]. At the same time, investors have flocked to various cryptocurrency markets, including NFTs, due to the significant decline in global market interest rates [20]. Significantly, the lockdown measures implemented during the pandemic have increased digital engagement and further stimulated the growth of NFTs [21]. These conditions have amalgamated to boost the NFT market. In sports, CryptoKitties developer Dapper Labs launched NBA Top

Shot, with a surge in popularity in 2021 [22]. Generally, in 2021, NFT sales increased drastically. According to the study developed in collaboration between the NFT data company Nonfungible and BNP Paribas-owned research business L'Atelier, NFTs trading reached $17.6 billion in 2021, leading to a staggering 21,000% increase from 2020's total of $82 million [23].

As for 2022 Dapp Radar reports that the trading volume increased by 0,41% compared to 2021 [3]. Despite the collapse of cryptocurrencies and the failure of Celsius, Terra Luna, FTX and other market difficulties, the NFT sector has not affected by a decline. Indeed, the number of unique traders increased by 876,89% over the previous year, reaching 10.6 million [3]. The blue-chip NFT collections remained the most traded collections even in 2022. Even in 2022 Opensea has not lost its dominance and it still represented 73,1% of the entire organic NFT trading volume[3]. Going forward, an article published by Verified Market Research (VMR) shows that the NFT market will have a total market capitalization of $231 billion in 2030 with a growth rate of 33,7% over the next eight years [24].

1.1.3 NFT Attributes

Having reviewed the literature related to the definition and history of NFTs, the analysis now examines the attributes of NFTs, those intrinsic characteristics that give value to this asset. In many different documents, NFT attributes are declared, and this is a comprehensive overview of those deemed most important. The attributes come from various sources including Popescu [25] Wang [26] Ali, Mujtaba [27]. Five are identified: indivisibility, uniqueness, authenticity, transparency and portability:

- *Indivisibility*: One of the main characteristics of non-fungible tokens is indivisibility. It is not possible to divide an NFT into smaller tokens, and a whole token must be purchased to own it [28]. NFTs are designed to be indivisible by default in order to serve their utility. However - with the advent of Fractional - people began to fractionalize NFTs to make them more affordable and democratic. Fractional ownership is another concept and in part is an improvement of NFTs and should not be confused as a denial of attribute. In fact, while it is not possible to split an NFT into several tokens, it is possible to represent an asset in the form of several NFTs.
- *Uniqueness*: NFTs are unique by definition due to their non-fungibility characteristic. Uniqueness is one of the prominent NFTs attributes which establish their value [28].
- *Authenticity*: Through the blockchain structure it is always possible to know who the creator of the NFT is. Non-fungible tokens also provide

representation for real-world assets, and it is important to have genuine NFTs. The blockchain is by nature immutable and this allows to trace information - which cannot be manipulated - such as the creator of an NFT or its ownership history [29].

- *Transparency* is a crucial aspect of NFTs that stems from the underlying blockchain technology, as elaborated in the authenticity attribute. The complete history of each NFT, including all past owners and transactions, is accessible to all via blockchain platforms. This transparency is highly advantageous for buyers in determining the market value of an NFT.
- *Portability*: NFTs are portable and easily accessible. Like cryptocurrencies, NFTs can be stored in a digital wallet, allowing the owner to bring the NFT anywhere and still maintain access to it from devices like your phone or personal computer. This is a fundamental advantage compared to traditional physical assets that you need to carry, store, or deliver. For instance, sending a physical artwork to a new owner in a different country involves dealing with shipping, which can introduce risks such as damage or loss. NFTs, on the other hand, can be transferred with a click of a button, throwing out the need for any logistics to take care of.

Among the authors mentioned above have also included other characteristics - different from each other - perhaps giving them different names. These include: *ownership, rarity, atomicity, tradability, and verifiability*, which are essentially just variations of the five attributes discussed earlier. Although the names differ, the underlying concepts remain consistent.

1.1.4 Categories of NFTs

The development of the blockchain infrastructure and the growing technological innovation in the domain of NFTs favor their applications in different sectors. There are currently many different types of NFTs, each with different scope and characteristics. Just as many have done before to divide NFTs into categories, an attempt was made to make a distinction that was as broad as possible. The different classifications of Geroni [28] and Popescu [25] were considered and reports from major companies such as Market Decipher [30], Non.Fungible.com [31] and Rejolut.com [32] were consulted. These reports helped identify 10 distinct categories:

1. ***Collectibles***: Collections of NFTs. Individual NFTs are usually associated with a larger collection, an aspect that makes NFTs similar to collectibles and art. Collections of NFTs are often formalized through a smart contract on the

blockchain-that is, a piece of software code-that is linked to each NFT within the collection [33]. In most cases, collections share some common characteristics. Collections can be very diverse in nature, from sets of collectible cards to selections of artistic masterpieces, to virtual spaces of online games [34]. The most famous collections are the Bored Ape Yacht Club and the Cryptopunks and CryptoKitties. There is often an overlap between various categories and collectibles, leading to disagreements on how to classify certain collections. For example, NBA Top Shot may be considered a collectible by some, while others might classify it as a game. In general, data from Non-Fungible.com is reported, which shows that collections are the most significant category with a total of 6 billion traded volume [31].

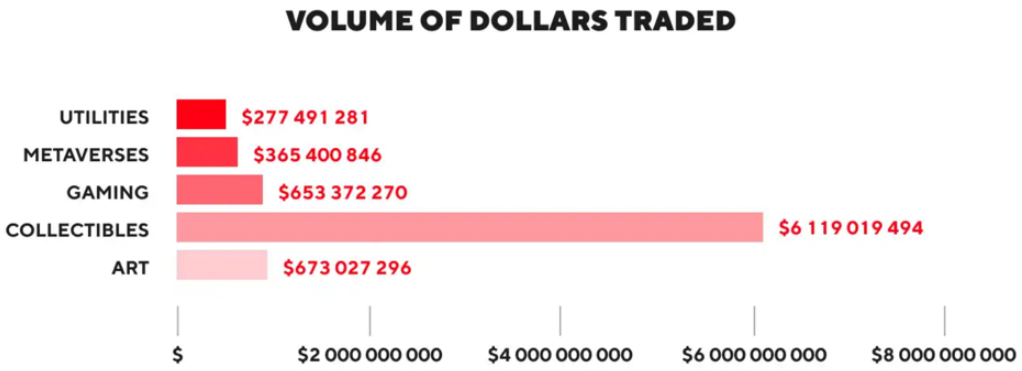


Figure 1.3: Volume per type. Source: Non-Fungible.com Report NFT market 2022

2. ***Art:*** The art industry is one of the most suitable sectors for NFT applications. Many digital artists have started to coin NFTs to monetize their work. At the same time, traditional art institutions have also initiated the first applications of NFTs. NFTs can be associated with tangible or intangible works of art. The most significant example is Beeples' "5000 Everyday," auctioned by Christie's for $69.3 million. This category includes all digitally created native works, created from physical works, works created by artificial intelligence, 3D artworks. However, these are mainly digital artworks with a public certificate of authenticity and ownership issued by the digital ledger on which they are stored. An interesting statistic regarding this category is reported by Market Decipher, which shows that the average sale price of NFT art was $15 in 2022 and only a small fraction of NFTs hovered near or above a price range of $1500. Only 10% of all NFT market participants accounted for 85% of all transactions [30].
3. ***Gaming NFTs***: The common types of NFTs in the gaming domain mostly focus on gaming objects. NFTs have sparked deep interest among game

developers. They can offer ownership register functionality for in-game items, thereby driving the growth of in-game economies [28]. More importantly, NFTs in the gaming industry focus on introducing various benefits to gamers. One of the most relevant examples is Sorare. It was also decided to include the aforementioned collection, NBA Top Shot, and all those GameFi projects that are NFT-based play-to-earn (P2E) games in this category. As shown in Figure 1.3 they represent $653.372.270 traded volume.

4. ***Metaverse***: Metaverse is a collective virtual shared space that enables all kinds of digital activities. In general, it covers a number of techniques such as augmented reality and the Internet to establish the virtual world. Participants in these blockchain-based alternate realities can have many types of use cases such as enjoying games, trading goods and virtual properties. This category includes those NFTs which - if purchased - guarantee ownership of virtual land.[32]
5. ***Utility***: Utility NFTs are a type that provide their owners with a specific utility or function. They are designed to serve a practical purpose within a particular ecosystem or platform. An example of NFT utilities are access tickets or passes to a particular event or experience. For example, a music festival may issue NFTs that grant the owner entry to the event while providing additional benefits such as backstage access or discounts on merchandise. Utility NFTs can also be used to grant access to exclusive content or functionality within a platform. For example, a social media platform may issue NFTs that grant the owner access to premium features such as ad-free browsing, exclusive content, or early access to new features. Another are governance NFTs that allow only those who own certain tokens to participate in votes [3], [30].
6. ***Avatars and PFP***: The NFT ecosystem is now dominated by non-fungible tokens (NFTs) with a profile photo (PFP). Since their remarkable popularity in 2021, the value of these generative avatar initiatives has only grown as the NFT ecosystem has evolved. A PFP NFT is, in essence, a digital token or artwork designed to be displayed as a person's social network profile picture. Many of the world's most popular NFT collections, such as Bored Apes and Doodles, are PFPs. PFPs are at the intersection of generative art and collectibles. They are similar to trading cards in that they are often sold in large quantities - around 10.000 - and have varying degrees of rarity, making them collectible. However, PFPs are also generative. They are created using a simple plug-and-play method in which users enter numerous traits, such as body type, head shape, background color, and so on, into an application, which then randomly assembles a large number of NFTs. Most PFP NFT

designs only show the head and shoulders of the avatar, which makes them naturally correspond to the two-dimensional online social interactions we are all familiar with today. This is why they can function as a unique profile picture or pseudonym identified on many sites that everyone use to communicate on the internet[3], [31].

7. ***Music***: The global music industry generated nearly $62 billion in sales last year, according to Statista. Music has been a fungible commodity for decades, being recorded and distributed on record, cassette, CD and digitally. However, musicians and DJs have lately been selling their work as NFTs, earning some of them millions of dollars in a matter of hours. Musicians typically pocket only a fraction of the money their music generates due to cutbacks to streaming platforms and record labels. When it comes to NFTs, musicians can keep around 100% of the money which is why so many musicians are turning to this method. The American rock band Kings of Leon may have been the first to release an album as NFT. Kings of Leon made nearly $2 million off their new album after putting the NFT on sale [32].
8. ***Fashion***: Wearables in virtual fashion are the new emerging trend in the fashion and beauty industries. They also describe the link between what a user possesses in both the virtual and physical worlds, as they refer to their user's avatar which can be dressed in virtual universes or metaverses. For example, Nike and NFT Cryptokicks are a good example of an NFT wearable. Digital accessories such as bags, hats, shirts, etc. they can be used for clothing purposes. But best of all, NFT wearables can be found under digitally native brands like DressX or The Fabricant, which use augmented reality to dress users. Today's NFT wearables are the direct inspiration of high fashion and luxury. Additionally, NFTs can be used to produce one-of-a-kind, one-of-a-kind designs. This would allow fashion designers to create truly original and unique creations. Similarly, a designer's intellectual property could be safeguarded through NFTs. They can also be used to track the history of garments. Customers would then be able to identify the manufacturer and source of their clothes. Making sure that the resources come from ethical sources would also be beneficial. This would create a transparent clothing supply chain, which is something that many people value very much [28], [32].
9. ***Domain names***: The NFT market has made it possible for users to register and sell domain names. People can create a detour around having to pay a third-party company for the management of your domain name by acquiring one on the NFT market. There are exclusive rights on the name ownership meaning you don’t need the middleman. Unstoppable Domains and

Ethereum Name Service (ENS) are prime examples of Domain Name NFTs. ENS can help translate long and complex user addresses into a flexible and user-friendly experience with easier onboarding [28].

10. ***Miscellanea***: Miscellaneous NFTs do not fall into any particular category or classification. Unlike other NFTs designed specifically for a particular purpose or function, Miscellaneous NFTs are often created as one-of-a-kind digital assets that are intended to be collectible or purely aesthetic in nature. These types of NFTs can take many different forms, ranging from digital artwork to unique virtual objects within game environments or blockchain-based virtual worlds. These NFTs come in various forms, including digital artwork, rare virtual items in gaming environments, and even social media posts like tweets, blogs, and Instagram posts. Some NFT Miscellaneous may be designed to be purely decorative or ornamental, while others may serve a more practical function within a particular ecosystem or platform.

After the first paragraph *general overview* where the general coordinates of NFTs were given by introducing them with definition, their history, main characteristics and possible categories it is intended to analyze in the next paragraph the current state of the art.

1.2 NFT Market

The purpose of this paragraph is to describe not only the market and fields of application, but also to explain the different interaction points that people can perform using NFTs. The first distinction that affects the object of the research is that between the primary market and the secondary market of NFTs. The aim is to provide a comprehensive overview of the main players, showing the difference between primary and secondary market and the current trading mechanisms by focusing on the secondary market.

1.2.1 Different actors interacting with NFT

The first sub-section analyzes the various actors that make up the NFT ecosystem and how they interact with NFTs. From content creators to buyers and external entities, each plays a crucial role in the world of NFTs. Below, these roles are explored:

- ***User***: The NFT ecosystem consists of three main categories of users: *content creators, sellers, and buyers* [35]:

- *Creator:* Content creators are the individuals who produce the original digital content that forms the basis of NFTs. They can be artists, musicians, filmmakers, or any other type of creative professional. Their work is what gives value to the NFT and they are usually the ones who coin and sell the NFTs.
- *Sellers*: are the individuals or entities that offer NFTs for sale on various marketplaces or platforms. They may be the creators themselves or third-party sellers who are focused on selling NFTs. Sellers often play a crucial role in promoting and marketing NFTs to potential buyers.
- *Buyers* are end users who purchase NFTs as a form of investment or to enrich their collections. They may be collectors, investors, or simply fans of a particular type of digital content. Buyers are the driving force behind the demand for NFTs, and their willingness to pay a premium for unique and rare digital goods is what makes the market possible. If a buyer buys an NFT, he or she obtains the role of *holder/owner*.

- ***Marketplace***: An NFT marketplace is a platform where people can buy, sell, and trade non-fungible tokens (NFTs) [36]. These marketplaces typically consist of a user-friendly web interface and a set of smart contracts that interact with the blockchain to manage NFT ownership and transactions. Users interact with the web application, which in turn sends transactions to the smart contracts on their behalf. *Users* can engage in a variety of activities on NFT marketplaces, including creating new NFTs, listing NFTs for sale, browsing available NFTs, and bidding on or making offers for NFTs listed by other sellers. Once a transaction is completed, the NFTM transfers ownership of the NFT from the seller's account to the buyer's account. All transactions are recorded on-chain or off-chain, depending on the marketplace's protocol [35].
- ***External entities***: External entities play a crucial role in the NFT ecosystem. They provide the infrastructure necessary for the system to function seamlessly. These entities are external to both NFTMs and the blockchain. For instance, creators store their artwork on web servers or storage services like Amazon S3 or IPFS. When *buyers* buy NFTs, they can display it on websites or digital frames made specifically for NFTs, like a photo album. The websites and NFTMs fetch tokens from the blockchain and the corresponding artwork from hosting services [35].

1.2.2 How are NFTs usually bought

To purchase an NFT, the buyer needs to have a cryptocurrency to complete the transaction. As there are numerous cryptocurrencies available, it is essential to choose the appropriate one depending on the seller and NFT network. The first step is to create a digital wallet to store the currency, with popular wallet like MetaMask. The next step is to fund the wallet with dollars or euros and purchase the required currency for the NFT network, with Ethereum being the most common. Once the buyer has obtained the necessary currency, they can purchase an NFT through auctions or fixed prices, depending on the object and market type. It is worth noting that there are two markets for NFTs, the primary market, where the NFT is initially minted, and the secondary market. In particular:

- ***Primary market***: The primary market for NFTs can be described as the market where NFTs are purchased directly from the *creator* by a collector or investor after the creator lists their NFT for sale. New NFT collections are listed, and it offers collectors the opportunity to become the very first buyer of an NFT. This process is known as *minting* [37] Specifically, the creator can set up a smart contract to deploy the NFTs directly to the public. In this setup, buyers *mint* NFTs from the smart contract by sending a pre-specified cryptocurrency amount - i.e., the mint price - to the smart contract. The smart contract then creates the NFT and sends it to the purchaser's wallet [33].
- ***Secondary market***: The secondary market refers to all those sales made after the initial sale. The volume of secondary sales can indicate the level of interest in a project and can also provide insight into the liquidity of a project. High secondary sales volumes imply an active trading environment, while low volumes may suggest a lack of interest or limited availability of assets for sale. In the NFT space, the secondary market represents a significant opportunity for earning income.

Despite many projects focusing on primary sales, those that plan ahead can benefit from perpetual income. In fact, according to nonfungible.com, secondary sales have far exceeded primary sales in the past year. Although sales slowed during the bear market, secondary markets remained strong and accounted for more buyers and money spent [31]. Also in this case VMR [24] shows how the majority of NFT trades take place on the secondary market which represents 80% of the total trading volume.

1.2.3 Main Marketplaces

In the paragraph *different actors interacting with NFTs* it was seen how marketplaces are essential players in this market. In the previous paragraph which explained the difference between the *primary and secondary market*, it was highlighted how the current market is traded on marketplaces. For this reason - due to their importance - this paragraph will focus on marketplaces by analyzing the main ones and the current state of the market. It is important to note that this paragraph has undergone changes since the beginning of the thesis work in September 2022, due to the rapid changes in the NFT market. In particular, the data has been updated to April 1, 2023, using the Nansen.io platform [38].

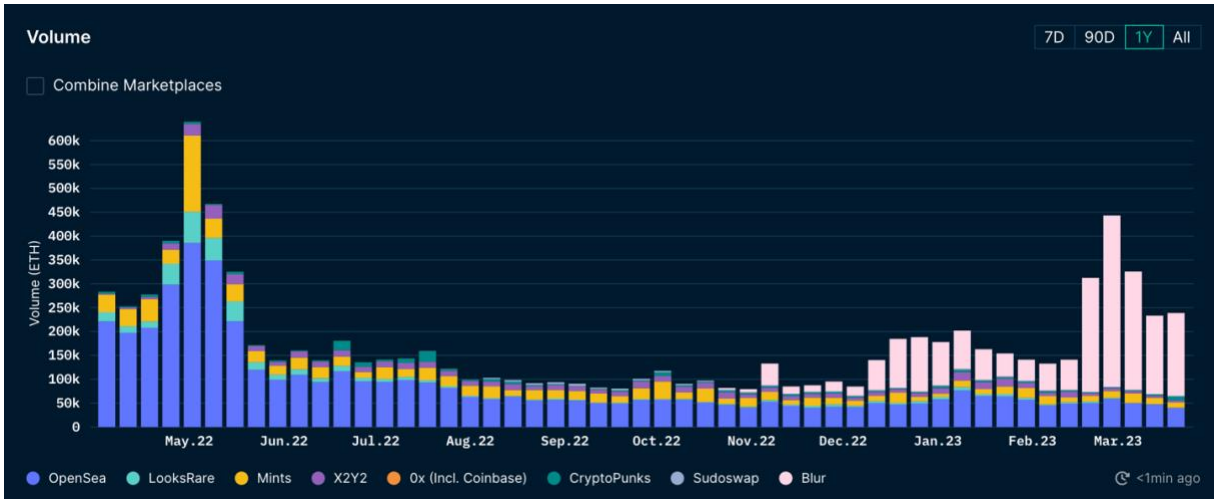


Figure 1.4: Trading Volume of NFTs on ETH across Multiple Marketplaces from April 2022 – April 2023. Source: Nansen.io [38]

Initially, OpenSea was the dominant player in the NFT market, with significant funding and a goal of becoming the "Amazon of NFTs". OpenSea raised $23 million in Series A funding, followed by a $100 million raise in Series B funding, which brought the company's valuation to $1.5 billion [39]. In June, OpenSea reported sales of almost $150 million [40]. However, in October 2022, Blur emerged as a new player in the market and within six months had become the industry leader, surpassing OpenSea in sales volume. According to Nanesn.io [38], a platform that provides market data, Figure 1.4 illustrates the volume traded on various marketplaces over the past year, with Blur dominating the market in the last month.

Blur literally changed the NF market after the project launched 12% of its BLUR tokens to NFT traders on 14 February. It accounted for more than 70% of daily NFT trading volume on Ethereum for each day since the airdrop, prompting OpenSea to

cut commissions [38]. Blur was launched with zero commission trading, something other marketplaces such as SudoSwap also do. It was also given an airdrop of its native token - $BLUR - to traders on the platform. One of Blur's great strengths is the fact that it is not only a marketplace, but also an aggregator. An NFT aggregator basically works to consolidate NFT prices from different marketplaces and platforms in one place. For example, users can see and interact with NFTs listed on Opensea, X2Y2, and LooksRare all on the same page. Blur has this functionality, which makes it a very versatile tool that can be used not only by beginners but also by advanced traders. The main contributor to Blur's new supremacy was Art Gobblers, who saw about 75% of his trading take place on Blur. Interestingly, Art Gobblers is backed by the Paradigm fund, which is also a major investor in Blur [41]. One of the main reasons for Blur's volume is its zero commission and optional royalty listing structure. Traders have the option of zero royalties by default, and the platform takes no commission; compared to OpenSea's 2.5% commission. The absence of commissions, especially for high value assets, makes a big difference.

As seen in Figure 1.4 Blur and OpenSea are currently dominating the market, however it was decided to report the top 10 NFT Marketplaces in a table, specifying for each the blockchain on which they are available, the number of traders on the platform and the average price of the 'NFT. The data was taken from Dapp Radar [3]. Projects were ranked in order of trading volume over the past 30 days and the data was collected on 1 April 2023. For this reason, this table represents the top 10 trading volume marketplaces for March 2023. This metric was chosen - and not the annual one - because it is a constantly changing market and in a few months - as has been seen - the structure of the market can completely change.

#	Name	Chain	Volume	Traders	NFT avg.price
1	Blur	ETH	$ 1,48 B	97.625	$ 1.470
2	OpenSea	ETH, BSC, Sol, Polyg, Avax	$ 383,5 M	279.208	$ 95,8
3	X2Y2	ETH	$ 37,65 M	11.749	$ 2.002
4	CryptoPunks	ETH	$ 31,66 M	235	$ 122.260
5	Immutable X Marketplace	Immutable X	$ 26,08 M	28.314	$ 46,6
6	JPG store	Cardano	$ 6,49 M	19.577	$ 101,1
7	ThetaDrop	Theta	$ 5,29 M	2.846	$ 224,4
8	Axie Marketplace	ETH, Ronin	$ 2,7 M	33.900	$ 6,5
9	Looksrare	ETH	$ 2,29 M	1.769	$ 875,3
10	NBA Top Shot	Flow	$ 2,06 M	14.296	$ 11,8

Table 1.1: Top 10 NFT Marketplace by volume exchanged. Source: Dapp Radar

The Table 1.1 reveals that while Blur has surpassed OpenSea in terms of volume in March 2023, but it has a smaller number of traders. OpenSea is still the platform most used by users (279.208). However, the average price of an NFT traded on Blur is significantly higher than on OpenSea, which is $ 100. It is noteworthy that other marketplaces have considerably lower numbers than the first two cited, with X2Y2 ranking third and having only one-tenth of the volume of OpenSea. This suggests that the NFT market is currently concentrated in a few marketplaces, with only very few marketplaces attracting the majority of volumes. The top two marketplaces analyzed incubate the highest volumes.

Regarding other marketplaces, a study by Aliyev examined 100 NFT marketplaces and found that - with some exceptions - they have similar characteristics, and the majority of NFTs are traded through auctions. This study leads to the next paragraph, which will present the most commonly used trading methods in the current secondary market of NFTs [42].

1.2.4 Current exchange mechanism

As previously discussed, the NFT market is currently concentrated in a few major marketplaces, with auctions being the most commonly used trading method according to various studies. Additionally, there are fixed-price sales and offer-based sales, each with distinct features and benefits. In the following section, the most commonly used trading methods in the NFT secondary market will be examined, with a focus on their key features and use cases. In particular:

1. ***Fixed price***: a seller can put his NFTs up for sale on the marketplace by setting a fixed price and creating an ad without any type of auction. It is the most used method for example by OpenSea. If the buyer decides to buy, he will see a button like *buy now* and the transfer of ownership will take place. The sale announcement tends to have an arbitrary deadline which can vary from a few hours to over seven days in which the asset remains on sale. If the NFT is not sold, the owner will have to reset a fixed price and try to see if anyone is willing to buy.
2. ***Negotiation or Bid/Ask model***: The NFT may be for sale, or it may not. The potential buyer wishing to purchase the NFT can make an offer to the owner. If the owner is satisfied with the offer and accepts it, the transaction takes place, otherwise the NFT owner can refuse the offer or send the offer back asking for more. Two interesting graphs from Nansen.io show how in the last two years the average percentage of acceptances of these offers has been

around 6-7%. This value has increased since June to around 10% and has had a further increase in the last two months, even reaching above 25%.

3. ***Auction***: The non-fungible token industry has various types of auction mechanisms [43] for buying and selling NFTs. The vast majority of single-item (NFT) auctions currently take place off-chain generally on centralized web platforms, such as OpenSea. The entire auction takes place on this centralized platform, including the choice of auction format design and the bidding process. Once the auction is complete, the NFT is transferred to the winner and the winner is charged accordingly. These final settlements are usually the only transactions that happen on-chain. A comparative advantage of off-chain auctions is that they minimize the number of on-chain transactions and thus minimize transaction fees [44]. The most type of auction used are:
    - *English auction*: also known as an ascending price auction, this is the most common type of auction used in the NFT industry. In an English auction, the NFT price increases over time and the highest bidder at the end of the auction wins the NFT.
    - *Dutch auction*: in a Dutch auction, the price of the NFT starts high and decreases over time until a buyer is found. The first buyer to bid at the current price wins the NFT [45].
    - *Secret bid auction*, in which buyers submit a bid without knowing the other bids until the end of the auction. Secret bid auction: In a secret bid auction, buyers send in their bids privately and the highest bid wins the NFT. This type of auction is used when the NFT is unique or rare and the seller wants to avoid a bidding war that could drive up the price.
    - *Continuous double auction* involves two ongoing auctions, one for buyers and the other for sellers, and transactions occur when the two auctions meet in the middle.
    - *The reserve auction* is a type of auction in which the seller sets a minimum price, also called the reserve price, below which the item cannot be sold. The reserve price is usually not communicated to bidders and acts as a protection for the seller, ensuring that he or she receives a minimum price for his or her item. If the highest bid at the end of the auction does not reach the reserve price, the item is not sold, and the seller can put it back up for auction or try to sell it by other means. The reserve auction is commonly used in the sale of high-value NFTs, where the seller wants to ensure that they receive a minimum price for their asset.

- *Batch auctions* are a mechanism used by some marketplaces in which bidders deposit a certain amount of ETH into a smart contract during the bidding phase. Once the bidding phase is over, the smart contract assigns each bidder a fractional token with a value based on their bid. Users can exchange these fractional tokens and redeem them for NFT items [46].

Auctions are commonly used in the NFT industry, each with its own rules and procedures to ensure transparent transactions. Auctions are seen as a suitable mechanism for art as conventional ways of setting prices are inappropriate for unique objects [47]. However, there are cons that should be taken into account such as the *afternoon effect* where final prices decrease during an auction relative to estimates, and the *burning effect* where remaining unsold at auction has a negative effect on subsequent sales prices [48]. In the next paragraph, the current inefficiencies of these mechanisms will be analyzed in detail.

1.3 Criticisms of NFTs actual exchange mechanism

The current exchange methods analyzed are very valid for some types of NFTs, for example very rare ones and for single pieces [47], but they are less suitable for all fractional NFTs or for other types of NFTs. Even very expensive NFTs are often difficult to sell at their initial price in a reasonable period of time. This happens because it is difficult to match three important factors:

- *Finding the right buyer*: In an emerging market that is yet to gain widespread acceptance, the process of identifying a suitable buyer for an asset can be complex. To qualify as the *right buyer*, the individual must not only express a willingness to purchase the asset, but also possess the necessary financial resources to do so. Although numerous individuals may express interest in procuring a Bored Ape, or any high-value NFT for that matter, the unavailability of 75 Ethereum to facilitate such a transaction severely limits the pool of eligible buyers, exacerbating the inherent illiquidity of the NFT market [49].
- *Agreeing on value*: Creating a mutual agreement on the value of the asset is imperative for successful transactions. However, this is also the stage where the majority of purchases fall. Sometimes a buyer may demonstrate a strong desire to buy the asset and as a result, may offer a price that exceeds the true value. Similarly, a seller may express a desire to sell the good and may agree to a price lower than the initial expectations. However, both users find

themselves in one case paying more than expected and in the other receiving less than they should [49].

- *Timing*: Due to the extreme volatility of the NFT market, collectors often focus on timing their purchases to capitalize on favorable market conditions. The value of a project can fluctuate dramatically in a matter of hours, with negative news causing the value to drop sharply. As a result, collectors may choose to wait for favorable market conditions. Furthermore, even if a right buyer is identified and an *agreed value* is established, market conditions – in the NFT market – can dissuade the buyer from completing the transaction.

Based on the aforementioned factors, the existing NFT trading models have been scrutinized in the literature and have been found to create various challenges and obstacles. One of the major problems is the lack of mechanisms that facilitate the *instantly sale* of NFTs, which often leaves the user owning NFTs that he or she cannot sell. This highlights the first issue identified by the literature. To provide a more coherent and lucid review, other critical concerns will be presented and categorized.

Illiquidity:

The previous paragraph show that the actual NFT Marketplace model or NFT floor, has enabled buyers and sellers to connect, providing a source of liquidity for the entire market. However, the price formation process for NFTs is based on bid and ask prices set arbitrarily between two parties, leading to NFTs becoming fewer liquid assets than stocks or cryptocurrencies. The value of NFTs is determined by their rarity or attractiveness, and the use of various valuation methods, including emotional pricing, has widened the spread between bid and ask prices for most NFTs on the market today [50]. According to literature, the NFT market is widely regarded as illiquid [51]. Although the launch of Blur has improved the situation by aggregating supply and demand from different marketplaces, the lack of price standardization and limited demand for certain NFT types tied to specific blockchain platforms exacerbate the problem [49]. Additionally, high market volatility and fluctuations in NFT prices have made buyers and sellers hesitant to enter into transactions due to uncertainty about future market conditions, further contributing to illiquidity [52]. A study done by Blockchain Research measured the volume of transactions at any given time and observed that most NFT products often have good liquidity when first issued. Some even sell out within hours of a shopping spree. However, transaction volumes inevitably decrease over time and many NFT products even end up with zero interest from the buyer [53]. The study also showed how the average number of traders for a single NFT is less than 1 – indicating that the NFT market is, to an extent, dominated by a small number of investors making

bulk trades [53]. Danu Finance [54] has carried an analysis study on the top 20 most traded PFP collections on OpenSea including only transactions directly happening on OpenSea until September 2021. Kristof [55] extensively covered it showing how the NFT market presents a low liquidity environment and high price volatility with long holding times potentially to sell near fair valuation prices. It is shown in Figure 1.5

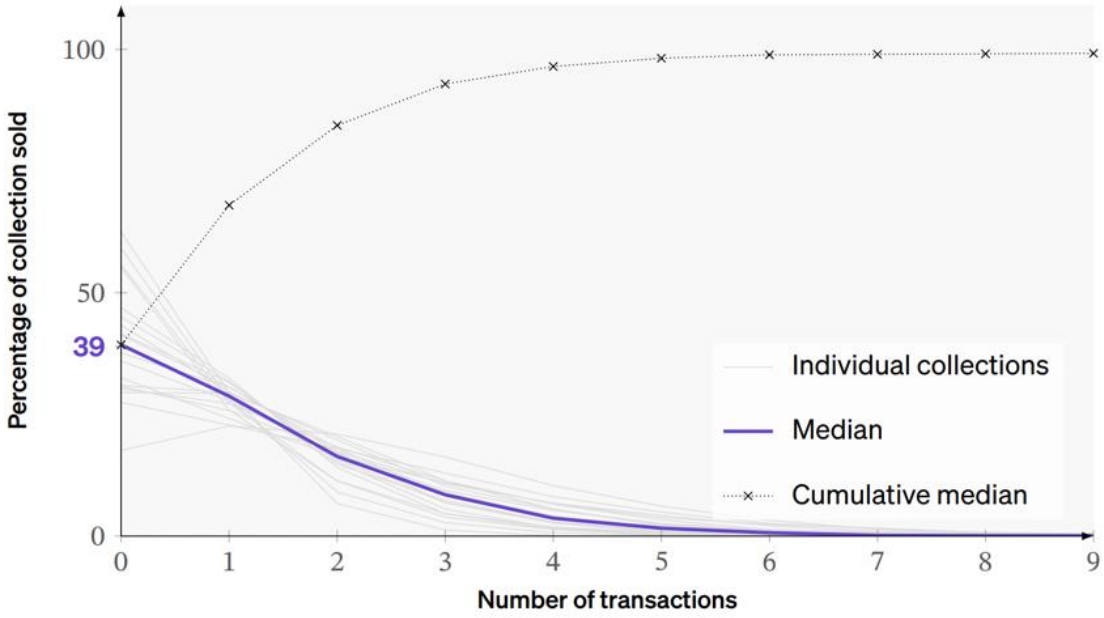


Figure 1.5: Pareto chart of the fraction sold of collection, and their median, against the number of transactions for the twenty most traded profile picture (PFP) – based collection on OpenSea. Source: DanuFinance [54]

Despite the growth in trading volume, NFTs remain significantly illiquid. For example, analysis of NFT collections on OpenSea shows that 39,3% of NFTs were never sold after minting and 92,2% were only sold three times or less [55]. Note that only 0,07% of all assets are sold more than 10 times [34]. It is important to underline that the liquidity in these articles, in fact, is understood as the possibility of selling one's NFT after a short period of time, managing to obtain in exchange a value that is not excessively lower than when the NFT was purchased [56].

Wash trading

Wash trading is a well-known phenomenon in traditional financial markets and refers to the activity of repeatedly trading assets for the purpose of feeding mis-leading information to the market [57].

In the NFT sector, users engage in wash trading for two primary reasons: to earn platform rewards and to create an illusion of value or liquidity around an NFT. In the first case, some NFT marketplaces, such as X2Y2, which ranks third in trading

volume in Table 1.1, incentivize active users by providing returns in the form of protocol tokens based on their trading volume. Users exploit this system by generating artificially high trading volumes, which can easily mislead others seeking to analyze collections or NFT markets in terms of liquidity and volume. In the second scenario, a user may seek to inflate the value of a particular collection or NFT asset in order to deceive potential buyers[58]. This practice is motivated by the finding, as demonstrated by Watcher in a study analyzing the effects of wash trading on average prices, that subsequent sales after a detected wash trade result in an average price increase of 30,53% [57]. The prevalence of wash trading in the NFT market is a cause for concern, as it not only misleads investors but also undermines the credibility and stability of the NFT market as a whole. For this reason, Nansen [38] created a filter to check for wash trading activity in the NFT sector. In particular, the filter identifies these six types of activities:

- *Self-trades*: The buyer and seller of the sale have the same address.
- *Circular Trades*: Transactions where the same NFT was traded in a circle of any length and sold to the seller again on the same platform within a specified timeframe.
- *Same Funder*: NFT sale transactions where buyer and seller were funded by the same address, or one funded the other.
- *Flash Loans*: NFT sale transactions that include a flash loan.
- *Bounce Trades*: Transactions where any NFT was traded between the same buyer and seller for a premium price above floor multiple times on the same platform within a specified timeframe. Buyer-Seller relationship has to be flipped at least once
- *Multi-trade* Premiums: Transactions where the same NFT token was traded multiple times at a premium price above floor on the same platform within a specified timeframe.

Numerous studies have highlighted the prevalence of wash trading in the NFT sector, including research conducted by Wen [59] and Kalkavan [60], as well as various market data analysis tools such as Dune, CryptoSlam, Nansen.io, and Chainalysis. In particular, Chainalysis was the first to identify three major marketplaces that offered rewards to users based on transaction volume, namely Rarible with its $RARI token, LooksRare with $LOOKS, and X2Y2 with its $X2Y2 token, revealing that 110 addresses collectively earned $8,9 million in profits from this activity [61]. According to a Dune dashboard, wash trades typically represented less than 10% of NFT volume prior to 2022, but as the year progressed, the percentage of volume attributed to wash trades increased dramatically, reaching a

peak of over 80% in mid-January and remaining a significant proportion of the total volume throughout the year.

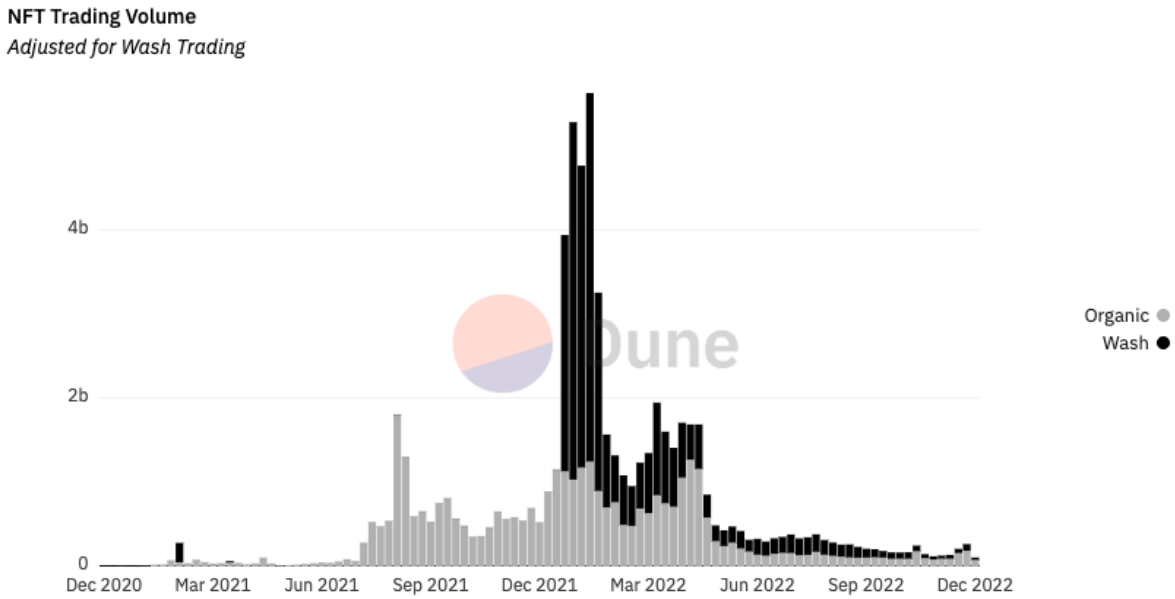


Figure 1.6: NFT trading volume on ETH. Source: Dune [62]

According to data analysis from Dune, LooksRare and X2Y2 are the biggest culprits, with 98% and 87% of their volumes respectively attributed to wash trading. The total wash trading volume on the market currently stands at a staggering $31,7 B, representing 42,41% of the total volume[62]. While Blur has overtaken OpenSea in terms of trading NFT volumes, Dune reports that 19,34% of these volumes are not organic, partly due to the lack of fees on the platform, which allows for exchanges between wallets belonging to the same person. However, some platforms are taking steps to address the issue by integrating filters from Nansen and Dune that show the wash trading percentage for each collection, thus providing potential buyers with more accurate information.

High Royalties:

NFT royalties have emerged as a popular feature that allows content creators to continue to profit from their work even after its initial sale. This creates a perpetual source of income for artists and encourages them to keep producing new content. To earn NFT royalties, the artist must coin the work, and the percentage of each sale paid in royalties is set in advance by the artist [63]. The percentage of each sale paid in royalties is set in advance by the artist. While there are no set requirements, the average royalty is close to 6%. While this may be beneficial to artists, some argue that the extra cost to buyers can reduce liquidity in the market[64]. Not all NFTs have

associated royalties, with only a small percentage on some marketplaces offering this feature. Of the marketplaces that were considered, it is reported that of the NFTs traded on Blur, only 8,7% fall into this category, while 98,3% on OpenSea. On LooksRare 64,7% and on X2Y2 56,5%. Among these, only SudoSwap has 0% royalties, favoring liquidity but penalizing the creator [65]. Sudoswap is a protocol that has great relevance in this research because - as will be explained in the *methodology chapter* - it is the first decentralized NFT AMM to be created. While royalties were initially a well-intentioned concept, their implementation may have inadvertently penalized the market, creating a 10% increase in the cost of an NFT for buyers [66]

Centralization:

The current state of NFT marketplaces is mostly centralized, such as OpenSea, which leads to off-chain exchanges to save on Ethereum gas fees. However, this centralized approach creates a significant problem in terms of security and verifiability during auctions. Most off-chain auctions require trust in a third-party platform, similar to traditional auctions with an auctioneer present, sacrificing security for convenience [44]. There are only a couple of current NFT marketplaces that offer on-chain auctions, including Foundation and SuperRare. Deepanshu Tripathi - founder of AssetMantle - points out that there is an additional problem coming from the fact that most of the existing marketplaces use centralized databases for the creation and storage of NFTs. While these platforms appear highly accessible and sustainable - which is also partly true - they have several shortcomings. For example, collectors who spend a lot to own NFTs usually don't become the true owners of these assets. In March 2021, Jonty Wareing looked into the matter further and found that most existing NFTs point to some Web2 URL or an IPFS hash, indicating centralized storage. For example, while Beeple's $69 million NFT is represented on Ethereum, the real picture resides in MakerPlace's private gateway[67].

Low Democratization:

Democratization is a crucial concept in the world of NFTs, as it allows for equal access to goods and opportunities. Unfortunately, the current dominant marketplace model of auctions tends to reward those who have greater financial resources. This is especially true for blue-chip NFTs, which are often too expensive for the average user to afford. This creates a significant barrier to entry, preventing many people from being able to participate in the market. In order to address this issue, there are a few emerging solutions that aim to split up NFTs into smaller pieces, making them more accessible to a wider range of users. By breaking down the high value of blue-chip

NFTs, these solutions aim to lower the entry barriers and make NFTs more usable for all [27].

Price

As seen in the *paragraph current exchange mechanism* Thompson in 2010 stated that auctions are seen as a suitable mechanism for art, in particular auctions are most suitable for unique objects [47]. However, in the NFT world it can happen that the same actor who has put his NFT up for sale through an auction, with another wallet raises the price in a fictitious way. For this reason, as regards the price determined by the models reported in the current paragraph on *current exchange mechanisms*, the literature identifies two main problems with the pricing models discussed in this section on trading mechanisms. First, there is a lack of *transparency in the price discovery* process. Second, these models are often *inefficient*, particularly for NFTs that are not rare or uncommon. Price discovery is essential in markets, as it determines the value of a commodity [68]. However, as seen in the *wash trading section*, some players manipulate prices in auctions, making it difficult for bidders to know how much to bid. In blockchain markets, where anonymity is prevalent, the seller may (and most likely will) be incentivized to maliciously affect the auction in order to enjoy maximum revenue. In particular what occurs is that the seller has more than one wallet address. In this way *the seller* can offer NFT with one address and with the others submit untruthful bids to artificially raise the price. The result then is a fictitious and manipulated price. In addition, when bidding on the chain, a gas supply race can occur in which bidders rush to have their bids included [44]. Dowling's early study of NFT pricing [69] showed that pricing is often inefficient and that auctions are not an optimal pricing model because they are not determined by supply and demand. Vitalik Buterin wrote about this phenomenon saying that this leads to bidders offering unsatisfactory prices [70] and repeatedly canceling old offers, resulting in low capital efficiency [71].

Inability to be used as collateral:

The last critical issue that the literature addresses concerns the need to use NFTs as collateral. Currently, most NFT marketplaces operate on an auction model, where buyers bid on a specific NFT, and the highest bidder wins the auction. However, this model does not allow staking LPs or earning passive income like a liquidity pool in the DeFi sector can. This is a potential limitation for NFT holders who want to make the most of their assets and earn a steady income from them. By giving NFT holders the ability to use their digital assets as collateral, they can access liquidity without having to sell their valuable assets[72].

In particular, Davies [73] identifies several potential benefits including greater access to liquidity, the ability to diversify by lending and borrowing NFTs generating potential additional income, greater decentralization and convenience. However, implementing an exchange model like this is not without its challenges, as it requires stability in the value of NFTs to serve as a guarantor for the counter value of the asset.

1.4 Revolutionizing NFT trading: introduction to NFT AMM

Having seen the main critical issues that the literature has identified with respect to current NFT exchange models, it is of interest in the research to show how the literature has begun to interrogate itself as a possible solution. In particular, two articles are reported. The first was published by Dreamer Club on September 22, 2022 on Mirror with the title, "*How NFT AMM Provide Liquidity to NFT*?" [74]. This article reports how the emergence of DeFi has started a revolution in the democratization of cryptocurrency finance. The freedom to create liquidity pools through AMM has greatly increased the liquidity of the ERC-20 token, so today it is possible to see a rich variety of transactions, loans, and leveraged transactions. On the other hand, with the explosion of NFT in the past two years, an NFT-based financialization infrastructure has begun to emerge. One such solution is called NFT AMM, which differs from the order book trading approach in that it primarily uses pools of liquidity to enable immediate and low-cost trading. The article reiterates what has just been observed which is that in the current market, even blue chip NFTs do not have much liquidity. It introduces the possibility of a method of trading NFTs through the liquidity pool, where anyone can add liquidity and earn a trading fee. The article reports on the NFT AMM projects available in the market today, which are SudoSwap, Granular, SeaCows, HerculeSap and Elisir. The second are two research reports by Wanxiang Blockchain. The first is number 158 which is called "*The Framework for NFT Financialization*" and proposes several mechanisms to improve the NFT auction mechanism and establish an NFT price index, which aims to improve NFT price discovery and transaction efficiency [53]. The second one is reporting number 232 also by Wanxiang Blockchain and is called "*NFT Liquidity Solutions and Regulation*" and shows how these solutions could include NFT liquidity pooling (LPP) and NFT fractionation (FP) mechanism. Despite the innovative aspects of these solutions, various obstacles are encountered during implementation [75]. It should be noted that this new approach applies to collection-based NFTs in which there are a number of heterogeneous NFTs within a collection. As argued by Oh,

Rosen, and Zhang [33] the largest fraction of NFT trading volume is concentrated in collections, so the model would be applicable to most of the NFT market. [55] As NFTs expand in the broader economy and gain more applications, the establishment of such a model will be crucial to further rationalize their asset value. Despite the challenges, the potential of NFTs as irreplaceable tokens is undeniable, and ongoing efforts to increase their liquidity and unlock their full potential appear to be promising.

1.5 Gaps found in literature

Despite the growing interest in and popularity of non-fungible tokens (NFTs), there are significant gaps in the literature when it comes to addressing the problems highlighted in the previous chapter of the NFT secondary market. There are several research that have analyzed the NFT market and the factors that influence NFT prices, however, little attention has been paid to the emerging market aimed at addressing these problems with only the articles mentioned in the last paragraph beginning to explore new solutions based on liquidity pools. In particular, there seems to be a lack of research that examines the most innovative protocols in the industry and questions the impact of liquidity pools on the NFT market, including factors affecting liquidity, the influence of liquidity on NFT pricing, and the potential risks and benefits of trading NFTs through liquidity pools. As the NFT market continues to evolve and mature, there is a growing need for research that addresses these gaps and provides a better understanding of the secondary market for NFTs traded through liquidity pools.

1.5.1 Master thesis objective

The aim of this thesis is to explore the impact of liquidity pools on the non-fungible token (NFT) secondary market. The study seeks to improve the understanding of the factors that affect liquidity, the influence of liquidity on NFT pricing, and the potential risks and rewards of trading NFTs through liquidity pools. To achieve this, the study employs a combination of qualitative and quantitative research methods, with the goal of filling gaps in the current literature regarding the emerging market for NFTs traded through liquidity pools. Moreover, this thesis has one main purpose:

- It aims to contribute to the literature by presenting a comprehensive overview of this new market by analyzing the key characteristics of each project and identifying the impact of certain characteristics on the issues identified in the literature.

Furthermore, considering the experience I had during the curricular internship period in AerariumChain from October 2022 to April 2023, and given the alignment of activities and purposes between the internship and the research carried out, this analysis was used by AerariumChain to design a management model for the NFT secondary market and implement a trading model for the same through liquidity pools. The model conceived during the months of internship at AerariumChain will be illustrated in Chapter 4.

1.5.2 Research Question

The research objectives and identified gaps in the literature resulted in the definition of the following research question:

RQ: Can the liquidity pool be used as a method to improve the trading of NFTs in the secondary market?

2 Research Methodology

2.1 Introduction

There are two types of research: primary research and secondary research. Each method of conducting market research falls into one of these categories and it is important to understand the difference between the two. The fundamental difference is that primary research is gathered first-hand while secondary research is built from pre-existing studies and frameworks. The primary search is often preferred if the purpose of the search is specific.

Given the novelty of the topic and the absence of an existing database regarding the specific subject, it was decided to use the primary research approach in order to gain more knowledge regarding the current state of the art of NFT AMM projects and to create a framework that describes and photographs the main characteristics of NFT marketplaces that use the Automated Market Maker as their exchange method. The further purpose of the research is to try to classify which problems, previously described, have been tried to be solved by implementing certain types of solutions.

Primary research can be conducted through various methods, but this type of research is often based on the principles of the scientific method. The most common primary market research methods are interviews, surveys, focus groups, observations and data analysis. Given the difficulty in contacting the developers - often anonymous - of the projects analyzed, it was decided to favor the approach of data analysis and observation conducted during the months of internship at AerariumChain by attending various conferences including: Blockchain Forum Italia, Decipher 2022 by Algorand, Blockchain & Web3: Time to Build, and CasaSanremo Invest 2023.

Before presenting the research results, it is necessary to show and explain the three choices that were made before starting the analysis, namely: the choice of variables, projects picking and the selection of the tools to collect data.

2.1.1 Choice of variables

This section aims to define the criterion for the choice of variables and which ones were taken into consideration. The first criterion for the definition of variables was to be able to have complete view of the NFT project by trying to identify the fundamental parameters intended to answer the research question. However, as mentioned above, the novelty of the research topic makes it difficult to investigate it and consequently to find some information. In addition, most of the analyzable projects are still in an embryonic phase where decisions and project structure can often easily change. For these reasons, it was decided as a second criterion not to consider certain variables because they would only be censurable for a few projects that had already been extensively developed. The third condition was to choose more variables that could be applied equally to all projects.

In particular - as illustrated in the Table 2.1 - six macro areas of analysis were identified with a total of 41 variables providing a snapshot of the field of NFT AMM protocols.

#	Categories	Variables	Measure						
1	General information	Name							
2		Blockchain Network	Ethereum	Solana	Algorand	Polygon	BSC	Near	L. Zero
3		Founding Date							
4		Ownership	Private company			Developers		DAO	
5		Capital Raised				$			
6		Notable Investor							
7		Categories				Type of NFT			
8		Status	Proof of concept			Beta		Live	
9		Live Since				Monthly Date			
10	Liquidity Pool	Token Format in the LP	ERC20	ASA69	SLP	ERC-1155	BEP-20	ERC721	
11		Forked/Build upon	1				0		
12		Protocol name	Name of the protocol forked						
13		Building method	Manual			Hybrid		Automatic	
14		Asset in a Pool	Asset 1-Asset 2						
15		Pair Asset in the Pool	Asset-pair Pools				Multi-asset pools		
16		Side	Single-side			Dual-side		Both	
17		Pool for collection	>1				=1		
18		Parameters	LP manual configuration			Hybrid		Follow protocol structure	
19		Direct NFT-NFT swaps	1			Other		0	
20		Pricing Mechanism	BC_Linear	BC_Exponential	OtherBC	VirtualXYK	uniV2	Auction/bid	Other
21	Key Features	Fractionation	1				0		
22		Multichain	1				0		
23		Loan	1				0		
24		Staking	No			Yes, the LP token		Yes, the NFTs	
25		Audit	1				0		
26		Other mechanism							
27	Economics	Token Name				Name of the Token			
28		Governance	1				0		
29		Protocol fee				%			
30		Swap fee	Selectable in a range			Selectable without range		Fixed value	

31		Cryptocurrencies Supported		
32		Credit Card/Debit Card	1	0
33		LP incentives	1	0
34	Performance	Total trading volume		
35		Total revenue		
36		Total number of User		
37		Total number of NFT		
38		Twitter follower		
39		Discord user		
40		Total Value Locked		
41	Problem Solved		Wash trading, Royalties, Centralization, Illiquidity, Low Democratization, Inability to use as collateral, Price discovery, Price efficiency, Instant sell	

Table 2.1: Variables framework representation

2.1.2 Projects picking

This phase involves the selection of projects to serve as input for the analysis.
The first consideration is that this market is extremely recent. The first NFT Automated Market Maker (AMM) protocol is SudoSwap [76], created by an anonymous developer - 0xmons - who launched the innovative project on 8 July 2022. The project immediately generated interest in the NFT world and emerged as the first truly decentralized alternative to what was an *OpenSea monopoly* in August 2022. Since that date, many protocols have emerged that have tried to imitate, copy or do better than this project. SudoSwap still remains the first comparison for any NFT AMM protocol. The NFTfi sector - Defi of NFTs - was born before the advent of SudoSwap, with Fractional.art introducing fractional NFTs, Arcade introducing lending/borrowing using NFTs and finally reNFT giving the possibility of renting.

In recent months, new projects were born from scratch and instead other projects that populated the NFTfi sector have converted their exchange method from auction to liquidity pool, such as NFTX which is a platform that was created to provide low-interest ERC20 loans to NFT collectors and mid this year introduced LPs.

One consideration that needs to be made is the method used to collect and retrieve data on AMM NFT projects. As there was no existing table or document containing the names of these projects, two sources were primarily utilized: Google and Twitter. The search criteria involved specific keywords such as "NFT AMM", "NFT liquidity pool", "NFT DEX", "NFT liquidity", and "NFTfi". This approach was taken to identify projects at an early stage, some of which may not have had a web page yet but maintained a Twitter presence.
Initially, 132 main accounts were discovered through the aforementioned search. However, further analysis was required to eliminate false accounts, those belonging to moderators or community managers, and those that did not present a liquidity

pool as a method of trading NFTs upon closer examination of the project. Ultimately, the final database consisted of 41 projects that met the established criteria.

Given the small number of protocols - less than fifty - it was decided to analyze them all. Although perhaps some protocols solved some of the problems previously highlighted in other methods, it was decided to only consider in the research those protocols that adopt the AMM model as a possibility for exchanging NFTs. Despite a thorough search comparing several sources, some projects may have been missed. Thus, there are more structured projects that were born well before Sudoswap as they allowed the possibility of lending/borrowing or splitting and that converted their exchange model after seeing Sudoswap's model in July. Clearly, these types of projects will turn out to have much higher metrics than purpose-built protocols such as NFT AMM.

2.1.3 Selection of tool to collect data

In this last section, the data collection tools of the primary research will be illustrated. Many of the fields defined during the construction of the framework investigate aspects that have not been explored by the literature or indexed by the databases, so they can only be filled by direct research. It was decided to use the same sources to ensure data uniformity. The following sources were used for the research:

Whitepapers

A cryptocurrency whitepaper enables projects to explain their products and goals to their audiences. Projects can freely choose what kind of information they want to provide, but whitepapers usually include an overview of the project's goals, tokenomics, products, features, and information about the team.
A whitepaper summarizes, in a single document, the important information related to a blockchain or cryptocurrency project. It's a popular way of explaining how a certain project works and what problems it's aiming to solve.
This document served as the main source at this stage of the research. However, the level of detail in a white paper varies from case to case and often some parameters are not specified in the document.

Blog / Medium

Medium is an open platform where readers find dynamic thinking, and where expert and undiscovered voices can share their writing on any topic.

In the cryptocurrency sector, it is customary for each project to have its own personal page on Medium, where it usually posts any new features, partners or general news about the project.

Websites for funding information

One of the hardest variables to find in this sector is that relating to capital raised and investors. It often happens because the platforms analyzed are created by anonymous developers and because sites with this type of complete and structured data are often paid. The three websites referred to most are:

- *Tracxn*: is a technology first platform that helps investors discover startups across the world and make better investment decisions.
- *Crunchbase*: is a firm providing business information about company from early-stage startups to the Fortune 1000. Their content includes investment and funding information, founding members and individuals in leadership positions, mergers and acquisitions, news, and industry trends.
- *Alphagrowth*: it is a cryptocurrency analysis site for traders and Web3 companies seeking insights into cryptocurrency analysis.

NFT marketplace tracking websites:

It has been referred to websites that track smart contracts and monitor the performance of the NFT world. Unfortunately, these sites often have different ways of tracking data resulting in different outputs. For this reason, it was decided to use multiple sources and cross-reference the data to ensure more accuracy. Specifically, reference was made to sites that guaranteed high data quality even with the basic, free version:

- *Dune*: it is a data platform widely used by crypto-asset investors and analysts to help them research individual projects, certain sectors and blockchain ecosystems. Using Dune, anyone can query data from the datasets and create visualizations with the query outputs. The platform currently supports data from Ethereum, Polygon, Optimism, Binance Smart Chain (BSC) and Solana.
- *Cryptoslam*: it is a NFT data aggregation platform designed to offer transparency for millions of NFT collectibles across multiple blockchains
- *TokenTerminal*: it is a platform that aggregates financial data on the leading blockchains and decentralized applications. The use of this platform was mainly for the tracking of the “revenue” variable

- *FlipsideCrypto*: it provides analytics and business intelligence to crypto organization like Dune. Compared to the latter, it supports the data of: Arbitrum, Avalanche, Near, Omsosis, ThorChain, Algorand.
- *Defillama*: provide data about DeFi projects. This site has been little used because it only tracks advanced projects, and many of the projects analyzed do not fall into this category as previously mentioned
- *DappRadar*: provides data and information about all the existing blockchain-based Dapps.
- *TIEXO:* it provides analytics to NFT marketplace for Solana blockchain

GitHub

GitHub is a distributed version-control platform where users can collaborate on or adopt open source code projects, fork code, share ideas and more.

Social

In the crypto sector, official Twitter profiles, Telegram, or the Discord channel can provide preview information that may be difficult to find elsewhere, although these sources may not be as reliable as others.

2.2 Variables description

This section will offer a technical explanation of the variables, their purpose of investigation, and the range of possible values. This is necessary in order to facilitate the discussion of the analyzed variables. The model consists of five macro areas, containing 40 variables, plus a category that examines the problem the project seeks to address in relation to the NFT secondary market. The variables analyzed are the following:

Name

It is indicating the name of the NFT protocol. In the event of a rebranding, the most recent name is reported.

Blockchain Network

It specifies the native blockchain on which the project is built. If the protocol is available on more than one blockchain, refer to the Multichain variable. Defillama tracks and considers more than 150 chains; these blockchains were referred to as possible values of this variable.

Founding Date

Denotes the year the project was founded.

Ownership

The ownership variable investigates who has the management and control of the application. Three options are considered:

- *Private company*: control and management of the application are in the hands of a single company. Sometimes the company may be part of a group or a larger company.
- *Developers*: In the crypto sector, many projects are first introduced by anonymous developers who identify a problem and attempt to solve it through their development efforts. These projects are typically announced through the Twitter channels of these developers, who typically use pseudonyms.
- *DAO (Decentralized Autonomous Organization)*: The network is built on a decentralized system of open-source codes, with control being equal among all individuals. This system utilizes smart contracts to automate all processes and internal mechanisms

Capital Raised

Amount of capital raised to develop the project expressed in dollars. Although this variable describes a measure that is often difficult to find, it was decided to keep it anyway because of its importance

Notable Investor

An investor is an individual or an organization that gives money to another person or organization hoping to see a future profit. In the case of multiple players, the lead investor is stated. It has often been difficult to find this figure due to the lack of regulation of this market and the projects that are often in the embryonic stage.

Categories

This variable identifies which type of NFT is being sold or otherwise traded via the protocol under investigation. In this case one value does not exclude another and often some values are only a subset of others. The types of NFTs have already been

analyzed in the literature chapter in the *Categories of NFTs* paragraph. They will therefore be briefly reported below.

- *Collectibles*: first type of NFT to be launched. They are the same physical collectibles, such as Pokemon cards or vintage toys in mint condition, but in digital form. The most famous are the Bored Ape Yacht Club and Cryptopunks.
- *Music*: It is possible to link music and media files to NFTs, thereby enabling an individual with true ownership claim to access the files
- *Gaming*: NFT-driven play-to-earn (P2E) games
- *Utility*: provide their owners with a specific utility or function. That are designed to serve a practical purpose. An example are ticket events, governance NFT and others.
- *PFPs*: Profile picture NFTs
- *Metaverse*: NFT related to metaverse, i.e., virtual lands.
- *Art*: These are mainly digital artworks with a public certificate of authenticity and ownership issued by the digital ledger on which they are stored. They may have been digitally created by artists, represent existing works of art such as paintings, be created by AI, and more.
- *Fashion*: Wearables in virtual fashion.
- *Domain Names*: Non-censorable domain ownership
- *Miscellanea*: This category includes anything and everything which has not been covered in the former categories. This includes tweets, blogs, Instagram posts and many others.

Status

The variable refers to the development stage of the underlying project to which the news relates to.

- *Proof of Concept (POC)*: it is used to validate an idea or concept, assess potential benefits, and determine feasibility. It can be presented in a document, whitepaper, presentation, or demo form, varying in detail and complexity.
- *Beta*: reference is made to the project launched in testnet. A testnet is a trial version of a blockchain network, which allows developers to test and experiment with new features and changes without any real value at risk.
- *Live*: the project is only considered "live" when the smart contract is running on the mainnet. The mainnet is the version of the blockchain that is live and publicly accessible, and where the transactions are recorded on the actual blockchain ledger

Live Since

It indicates the date when the project news was published online. To ensure data was consistent, the month of publication was used as the unit of measurement as it can be tracked more easily than the exact day.

Token Format in the LP

It indicates the standard of the token that is deposited and traded in the liquidity pool.

Forked/Build upon

The value of the variable will be 1 if the project copied the smart contract or constructed a liquidity pool on another protocol, and 0 in the opposite case.

Protocol name

This variable will only be filled in if the variable *"Forked/Build"* upon has output 1, otherwise it will be empty. In particular, this variable specifies the name of the protocol upon which the liquidity pool was built.

Building method

The liquidity pool construction method proposed by the protocol was taken into consideration, and for ease of analysis, the complexity of the projects was simplified into three possible outputs:

- *Manual*: In this case, the liquidity provider manually enters the initial liquidity and builds the liquidity pool by setting the criteria and parameters that they deem appropriate.
- *Automatic*: The liquidity pool is created through an automated process. In this case, the initial liquidity provider does not have to take any action but also loses the ability to make choices in the construction method.
- *Hybrid*: It is a model that combines both manual and automated processes. The user is required to take some actions manually, but the project also imposes choices or partially automates some processes.

Asset in a Pool

It specifies the amount of assets in the liquidity pool. Most traditional pools are 50/50 asset pairs.

- *Asset-pair pools*: liquidity pool formed by two assets
- *Multi-asset pools*: liquidity pool consisting of more than two assets

Pair Asset in the Pool

It further explains the components that contribute to the liquidity pool. Specifically, these components have been compiled as Asset 1↔Asset 2, to ensure that all cases of projects that have used innovative and unique methods are also included in the survey.

Side

Liquidity may be provided by a single or by dual side:

- *Single-side*: Liquidity pool where there is only the option to buy or sell the NFT. It is useful for those who act as liquidity providers because they are not subject to impermanent loss.
- *Dual-side*: Liquidity pool where there is the possibility of trading
- *Both*: Protocol with both exchange methods possible

Pool for collection

This variable is used to determine if the liquidity pool for a collection of NFTs, which may have similar characteristics or fractional NFTs of the same artwork, is singular or multiple. There could be also the case in which more collection are in one single pool in order to increase the liquidity

- *>1*: one collection can have more than one pool
- *=1*: one collection can only have one pool
- More collection are in one pool

Parameters

It precisely outlines the initial method of building the liquidity pool.

- *LP manual configuration*: the liquidity pool is created by the user who can decide: the assets to be deposited, the quantity, the initial price, the price curve and the swapping fees.
- *Hybrid*: No need to be actively set by liquidity provider manually, but it can be adjusted.
- *Follow protocol structure*: Follow the relevant structure as determined by the protocol. Usually in this case the liquidity pool is created automatically under certain conditions.

Direct NFT-NFT swaps

This variable can be assigned three values:

- *1*: ability to trade two NFTs by swapping into a liquidity pool directly, without using a router.
- *0*: the variable takes on this value if there is absolutely no possibility of directly exchanging two NFTs
- *Other*: other method of exchanging two NFTs in an LP than the indirect exchange

Pricing Mechanism

In a liquidity pool, the price mechanism refers to the method used to determine the price of an asset at any given time. The most common price mechanism used in liquidity pools is the constant product market maker (CPMM) model. Liquidity pools use different price mechanisms to determine the price of assets in the pool. This variable is key in understanding the differences between liquidity pools as it is the most impactful in the research. Specifically, under consideration were:

- *Bonding curve linear*: The linear curve performs an additive operation to update the price. The price of an NFT is increased by a flat amount - delta - every time an NFT is bought from the pool. Delta is assumed to be set properly by the LP to be the same precision of the pair's underlying token. The price behaves in the opposite way in the event of a sale
- *Bonding curve exponential*: The exponential curve performs a multiplicative operation. Delta is treated as a multiplier, or it is a percentage that is multiply every time an NFT in bought from the pool. To calculate the decrease, the percentage is usually converted into a decimal index - 25% would be 1.25 - and divide the price by this number.
- *Other Bonding Curve*: This price mechanism includes Bonding Curves that are not as common as Linear or Exponential. It was created to avoid a scattering of data and too many price curves. Included in this category are: sigmoid bonding curve, quadratic curve, sub-linear curve, polynomial curve, and others.
- *Virtual XYK*: It's a particular price curve invented by 0xacedia the 31 July 2022. It's like the xyk of Uniswap V2 but it's virtual. The X and Y are based on virtual amounts not actual amounts. This allows inventory to be decoupled from price/slippage. The user has the option of setting their X to 30 ETH and Y to 3 NFT, even if they only deposit 10 ETH and 1 NFT. In this way, the curve will be shifted as if there were 30 ETH and 3 NFT of liquidity, without the need for them to actually be there. Additionally, the user can adjust their specified ratio to further adjust the price. The user can set X equal to 20 ETH and Y equal to 3 NFTs in the liquidity pool, which would yield a price of 6.67

ETH/NFT. He/She can then deposit 10 ETH and 1 NFT, with a price of 10 ETH/NFT. This would cause the curve to move as if it had 20 ETH and 3 NFTs of liquidity. It should be kept in mind, however, that if virtual reserves do not match real reserves, it is possible for a pool to run out of liquidity if it is far enough ahead in the curve.

- *UNI V2 XYK*: Uniswap V2 Core - released by Hayden Adams in March 2020 [77] - is a revolutionary trading mechanism for DEXs. Being open source, it has been widely adopted by many protocols, and is a marked improvement on the proof-of-concept that was V1. In particular V2 introduced the addition of the ETH bridging capability which enabled two ERC20 tokens to be exchanged without the need of ETH as an exchange medium. This helps reduce transaction fees and the transaction count. Additionally, V2 also introduced a price oracle functionality which allows time-weighted average pricing based on the price of token pairs at each block. Lastly, flash swapping was also included, allowing users to "borrow" tokens from a Uniswap pool and pay back the borrowed funds at a specific interest rate all in one transaction. This enables more advanced transactions like arbitrage trading to be executed on a DeFi platform. This exchange method for NFTs is challenging as it requires trading a decimal for an integer unit.
- *Auction/Bid*: As indicated in the existing literature, the most common selling approach for NFTs is the English auction. This involves an opening price that increases with higher bids, and buyers can see all bids to decide whether or not to increase their bid. The buyer with the highest bid is the eventual winner. All other types of auctions have already been presented extensively from the literature in the *current exchange mechanism* paragraph. In order to understand user preferences, it is important to include alternative pricing approaches that do not use a liquidity pool. This will enable to analyze whether users will still opt for the most popular current exchange method, or they will prefer the AMM.
- *Other*: For all price curves that do not fit into the criteria of the above categories, this measure of the variable is referred to.

Fractionation

If it offers the ability to fractionalize the NFT within its platform or if the protocol has done so in advance, the variable will take a value of 1. Conversely, if this option is not available, the output will be 0, even if the NFT AMM utilizes fractional NFTs.

Multichain

This field investigates whether the smart contract of a Dapp is stored only on one blockchain protocol or on multiple ones. In an attempt to attract a larger pool of users, exploit the advantages of other protocols and improve scalability, some applications are landing on other blockchains apart from their original one. The parameter is set to 1 if the protocol is Multichain and to 0 if it is not.

Loan

This variable simply denotes the possibility of making an income by lending or borrowing an NFT. The value will still be 0 if there is a possibility of lending but not an NFT.

Staking

Staking is the process of holding and locking up a certain amount of cryptocurrency assets as collateral in order to participate in the validation of transactions on a proof-of-stake (PoS) blockchain network and receive rewards for doing so. This is a way of supporting the network security and earning rewards at the same time. In this case the NFTs staking allows the protocol to have capital tied up. Three options were considered:

- *Yes, the NFT*: This is the most interesting mechanism, namely the possibility of staking a token other than an ERC20, e.g., an ERC721.
- *Yes, the LP token*: It will assume this output if LP token - if it exists - can be locked, thus ensuring liquidity within the pool for a certain time. An early redeem option may be given in some cases with punishment mechanisms.
- *No*: There is neither the possibility of staking the NFT nor the LP token.

Audit

A smart contract audit is a security check done by cybersecurity professionals meant to ensure that the on-chain code behind a smart contract is devoid of bugs or security vulnerabilities. Although it is very important to obtain, it is often not reached because of the prohibitive cost of this 'revision', especially for newly born projects. This variable will follow the same pattern as the other variables and will obtain the value 1 if the smart contract is audited and 0 otherwise.

Other mechanism

Other key features is certainly the most heterogeneous variable, and it will be difficult to use it for a uniform analysis. Nevertheless, it is fundamental because it is the container for all those fundamental mechanisms that are unique to each protocol

and for which it would not have made sense to create variables on purpose. Some examples are: burn mechanism, sweep mode, limit buy/limit sell, NFT aggregator, trading view integration, launchpad, airdrop etc.

Token Name

The name of the protocol token is specified if there is one. Otherwise, this field remains empty.

Governance

Crypto governance refers to the system of decision-making and management in a decentralized blockchain network. In a crypto governance system, stakeholders, such as token holders or validators, have the power to make proposals, vote, and participate in the decision-making process that affects the future development and direction of the network. This is typically done through a voting system, or a consensus mechanism built into the network's protocol.

Protocol fee

This parameter represents the fees that the NFT AMM protocol earns directly, rather than the fees earned by liquidity providers. This fee can vary, and not all the projects charge all fees. With this parameter, the aim is to simplify the model by identifying the fees that the protocol earns, including fees for liquidity provision, withdrawal, listing, and others. The value of this parameter is expressed as a percentage, referencing the commission percentage declared by the project to support its business model.

Swap fee

Swap fees are charged for every asset swap transaction made within a liquidity pool. They are typically a percentage of the trading volume and are distributed to liquidity providers based on the amount of their LP tokens. Those who provide initial liquidity are rewarded by earning a portion of the fees collected within the liquidity pool based on the percentage of liquidity they provide. If there is only one liquidity provider, they would receive 100% of the fees. As the values of these fees can vary even within a single protocol, the aim is to provide a flexible output for this parameter. Rather than the percentage value itself. Indeed, guidance will be offered on how the liquidity pool creator can determine this value. Specifically, the parameter is divided into three categories:

- *Fixed value*: a fixed percentage imposed by the project, which cannot be changed by the liquidity provider.
- *Selectable within a range*: a percentage that can be chosen from a range of values selected by the project, for example, from 0% up to 15%.
- *Selectable without a range*: this refers to projects where the liquidity pool creator can choose any value they want to charge as a swap fee for anyone who uses the liquidity pool.

Cryptocurrencies Supported

The tokens that can be traded within the protocol are listed.

Credit Card/Debit Card

One of the mechanisms to achieve mass adoption is to facilitate the use of applications. With this variable the intent is to investigate whether the protocol allows the purchase of NFTs directly with a normal credit/debit card by relying on some existing on/off ramp services such as Moonpay, Transak, Ramp and others. Cleary is the output will be 1 it means that there is the possibility to buy NFT or load the wallet on the platform using credit cards directly.

LP incentives

Early adopters of a DeFi protocol are critical to its success, providing the necessary liquidity to drive positive growth. As such, it is essential to incentivize these individuals for their invaluable contributions to the platform in its early stages. By this is meant the variable LP incentives. The variable will assume the value of 1 if there are incentive mechanisms for liquidity providers and 0 if they are not present.

Performance category

These seven variables will be described in aggregate. It must be emphasized that these metrics are fundamental to the evaluation of a project because it is the final judgement of the user that rewards or does not reward a certain type of project. Although the *Performance* category of evaluation has less impact due to the majority of projects being in the early stages, it would be fascinating to see the change in metrics by taking another snapshot of this category - which includes the next seven variables - in a few months. The data was collected in January 2023 from the sources mentioned in the section *NFT marketplace tracking websites*. These metrics are often manipulable and difficult to be objective. In addition in this analysis they may have little relevance since most of the projects surveyed are in proof of concept or beta. A brief description of these variables is shown in Table 2.2

#	Variables	Description
34	Total trading volume	Total amount swapped. Can be calculated in dollars or in the blockchain token as in the case of Solana
35	Total revenue	Revenues are often difficult to identify and rarely at such a primordial stage are there. They are mainly tracked by Token Terminals
36	Total number of User	The number of wallets that interacted with the protocol was taken into account. However, it may happen that a user has more than one wallet.
37	Total number of NFT	Total number of exchangeable NFTs within the protocol. This metric is constantly changing as a user might create a LP with new NFTs
38	Twitter follower	In the crypto world, the twitter account is an important reference. This metric could be "manipulated" by fake bought users.
39	Discord user	Discord is the most widely used social to manage the community in the crypto world. This channel has been used to find information in response to specific questions.
40	Total Value Locked	Total value locked (TVL) is a metric used to measure the amount of value that has been locked up in the platform.

Table 2.2: Performance variables description

Problem solved:

This final category strives to explore the issues that the protocol intends to address with the development of its alternative. Wherever possible, the protocol's stated goals have been taken into account, which is why it would be beneficial to create tools in the future to evaluate the protocol's success in achieving its objectives. All these problems have been analyzed and described in detail in the section *criticisms of NFTs actual exchange mechanism*. For this reason, they will be mentioned briefly. In particular they are:

- *Wash trading*: Wash trading is a fraudulent trading activity where an individual or entity simultaneously buys and sells the same financial instruments, usually with the goal of creating an artificial impression of market demand.

- *High Royalties*: Royalties initially seemed a good intention ended up penalizing the market. With the user having to pay a 10% increase in the value of the work to the artist with each transaction.
- *Centralization (off-chain)*: Exchanges take place off-chain, this problem is due to the fact that the marketplace is centralized.
- *Illiquidity*: It recurs to the problem that after a few trades the NFT is no longer traded. This problem has been amply demonstrated and explained in the section mentioned above.
- *Inability to be used as collateral*: This problem is solved the more a protocol applies tools such as: staking, led/borrow, LP farm etc. etc.
- *Low Democratization*: This issue relates to blue-chip NFTs that often have too high a value for a user with limited capital. These solutions tend to split the work so as to lower the barriers to entry and make the work more usable.
- *Low Pricing Efficiency*: The sales model based on the floor price is inefficient because it is not determined by supply/demand but by other competitive logics.
- *Not Transparent price discovery*: Price discovery is the process of finding out the price of a given asset or commodity. Price discovery is the central function of a marketplace.
- *Impossible to sell instantly*: It reports the inability to sell an NFT instantaneously.

3 Findings

This chapter presents the empirical research and its most significant findings. The analysis is divided into six sections, which exactly mirror the categories of variables illustrated in the previous chapter. Specifically, the first five sections are intended to highlight what the predominant characteristics are, while the last section - the section on problems solved by the projects - will attempt to answer the research question.

The *general information* section aims to provide an overview of AMM NFT protocols by showing mainly metrics that will later be used for cross-sectional analyses. The main objective is to understand which generic variable most influences the other.

The next two sections - *liquidity pool* and *key features* - are the two most important because they present the main and fundamental data of the protocol. They describe both how the NFT exchange mechanism was constructed, the pricing mechanism and the presence or absence of important mechanisms within the DEFI sector such as staking option, LP farming and others explained in the *variable description* section.

The *economics* section along with the *performance* section are very interesting because they show metrics of constantly changing. The data are updated to the end of February 2023. Unlike the previous sections - where the data do not change with ease - these two sections are the most interesting for future analysis regarding this area because they would allow us to study any increase in user interest in this type of protocol. An interesting tool would be to be able to update the data in these two sections in 6 or 12 months.

Finally, in the last section the survey addressed the *problem solved* illustrated above. This section aims to provide a more comprehensive analysis compared to the previous ones by cross-referencing the metrics and information in conjunction with the earlier sections. The investigation intends to identify cases where one model's adoption is more prevalent than another, and to examine the relationship between a protocol feature and the specific problem it solves. Therefore, an attempt will be

made to answer the research question. As announced in the previous chapter, it is important to note that the problem solved by the protocol was not verified in any way, but the statement of the protocol itself was relied upon as the intended goal. Further analysis could study and build tools to verify whether indeed what was stated by the projects occurred in reality. This introduction is essential to contextualize the subsequent research question and understand their implications.

3.1 General information

Project kick-off date:

The first interesting data to examine is whether or not this trend is on the rise. Figure 3.1, which displays the launch dates of various projects in the market, suggests that the trend is indeed growing. This is particularly noteworthy given that the crypto market is currently experiencing a period of low interest and focus.

When examining this graph, it is important to note three key observations. Firstly, all dates prior to June 2022 represent protocols that were already in existence and actively in use. These protocols later adopted similar NFT exchange methods following the advent of SudoSwap. Secondly, projects still in proof of concept were not reported, but these are 11 projects out of the 41 analyzed, representing an important sample in the analysis. Lastly, a decrease in the number of projects launched in January 2023 is noted, but this is not yet supported by other data confirming a reversal of the trend.

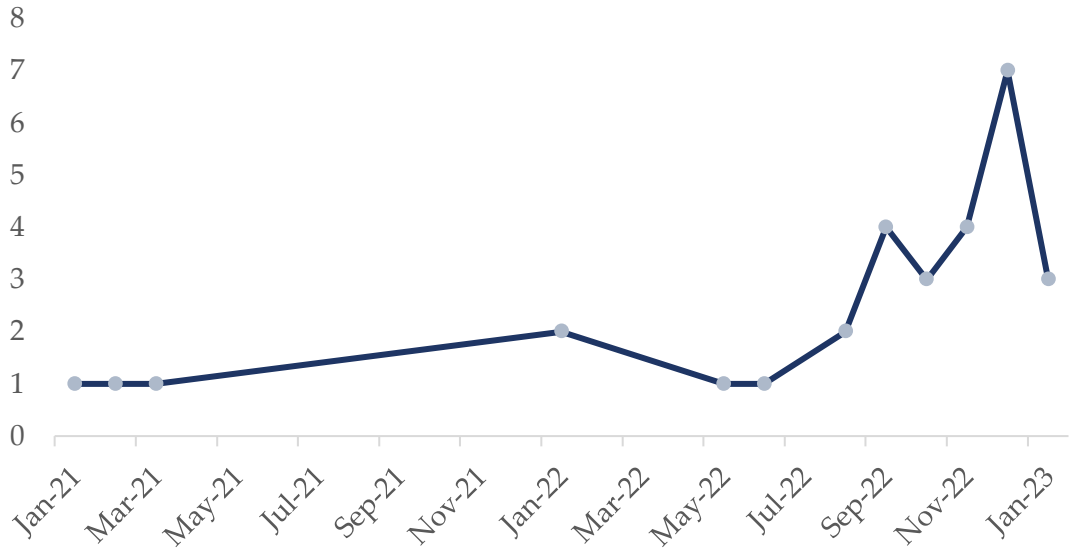


Figure 3.1: Month of launch of the projects analyzed (*basis: 41 cases*)

Status & ownership & foundation year:

Based on Figure 3.2, it emerges that the majority (64%) of the projects under consideration were created in 2022. Meanwhile, 28% of the projects were established in 2021, and only 8% were launched in 2020. The latter category of projects may have initially had fractional NFTs and later shifted to liquidity pools after seeing Sudoswap's benefits. Interestingly, there were no projects in the proof of concept phase prior to 2022 which suggests that the time needed to build a beta version of this type of product is less than a year. The same time frame can be applied to the project's beta version in testnet.

More than half of the analyzed projects (54%) were founded by developers who currently own the protocol, while 26% use DAO as their governance mechanism, and 20,51% are run by private companies. Further analysis of the ownership type based on the year of foundation reveals that projects founded in 2020 are either DAOs (2,5%) or private companies (5%), while the number of projects managed by developers increases to 41% in 2022. This may be due to the fact that projects received funding or changed the governance mechanism to DAO after receiving initial feedback from beta users.

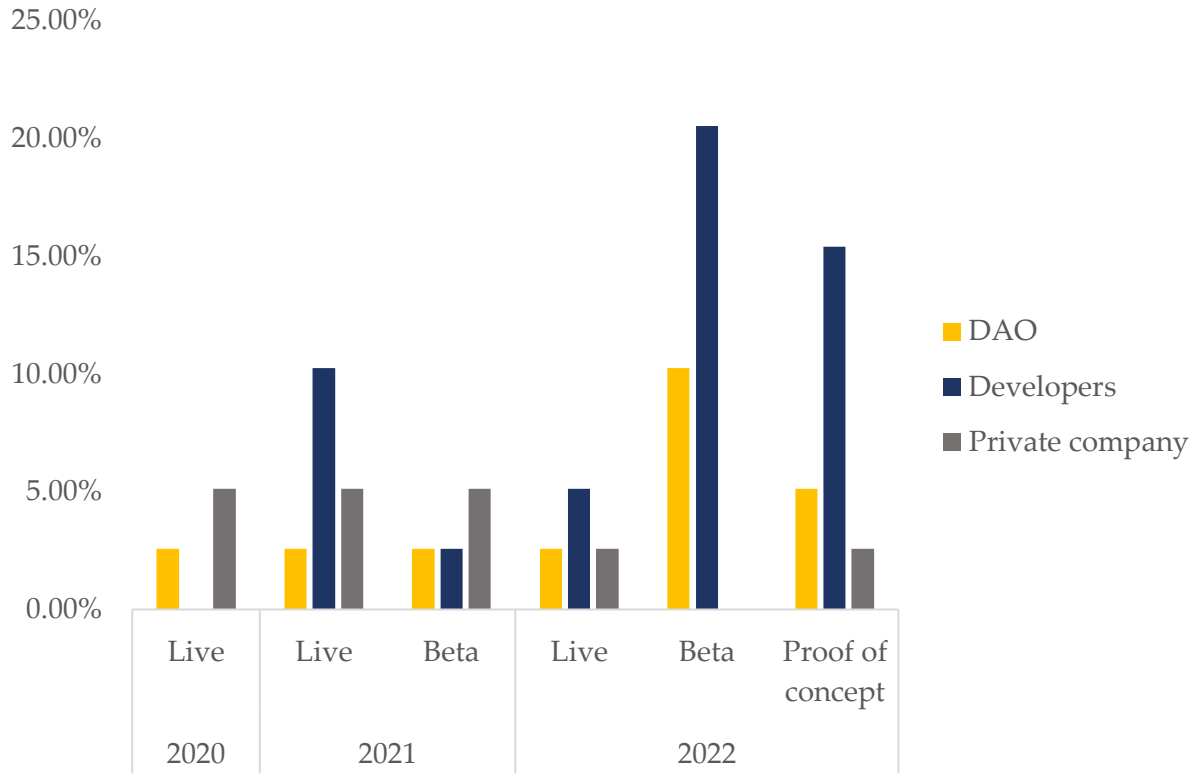


Figure 3.2: Ownership and Status distribution over the year (*basis: 40 cases*)

Blockchain used:

According to the survey, Ethereum is the preferred blockchain for the majority of the projects analyzed (55%). Solana comes in second at 21%, followed by the Binance Smart Chain at 5%. These findings are not unexpected for two reasons. Firstly, market analyses - such as Cryptoslam - have already emphasized Ethereum's dominance in the NFT sector. Secondly, Sudoswap - the first NFT AMM protocol - was built on Ethereum, making it easier for other NFT platforms to fork without significant changes. Finally - as displayed in Figure 3.3 - other blockchains are entering this particular niche. Certainly, as we will see later, it is even more interesting to see how many of these projects are building on multiple blockchain protocols, thus reaching more users.

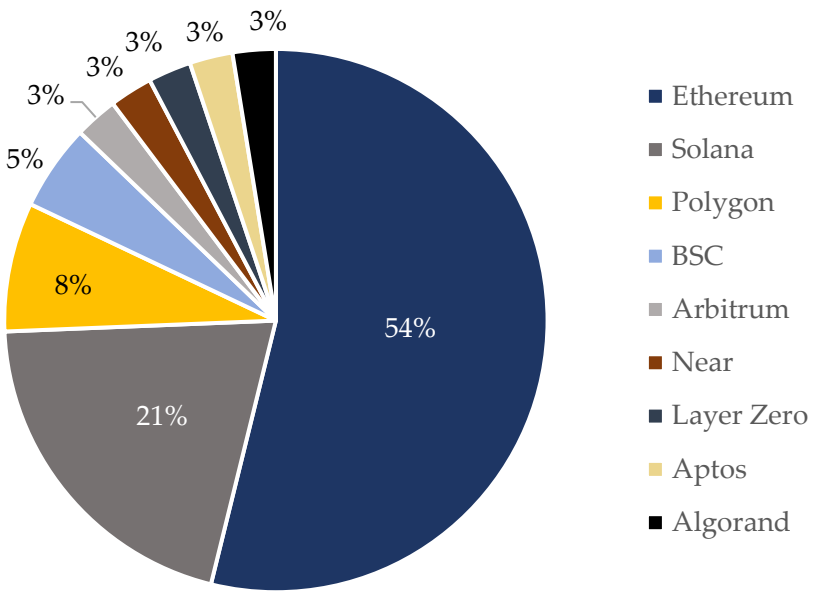


Figure 3.3: Blockchain used (*basis: 39 cases*)

Funding:

One particularly intriguing graph in this section examines the relationship between a project's status and the amount of funds raised, as shown in Figure 3.4. The data reveals that live projects – meaning those in the mainnet – have garnered a significant 85% of total investor funds invested in the analyzed projects. Specifically, they have raised 33.410.000 out of a total of 39.166.000 in capital raised by the analyzed projects. Meanwhile, beta version protocols have raised 13% of the total funds, while projects still in the development stage remain virtually unfunded.

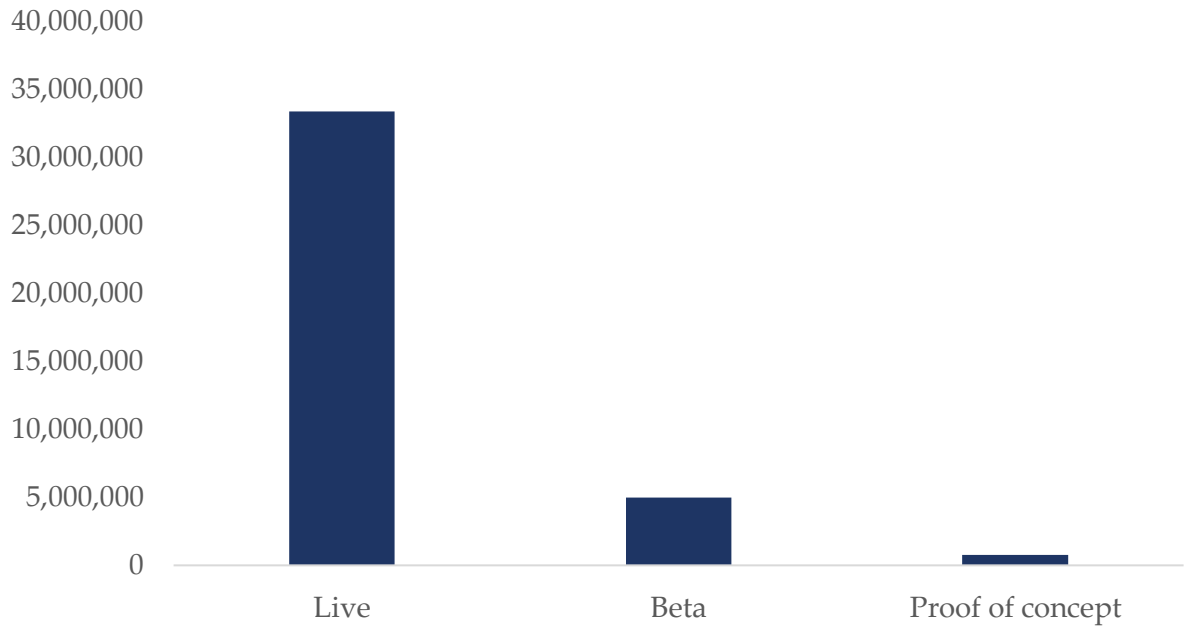


Figure 3.4: Sum of funds raised according to project status (*basis: 38 cases*)

The graph above may indicate that the *status* variable may affect the other variables being analyzed, which is not surprising given the significant differences between projects still in development, those in testing and those already on the market. These differences could have a significant impact on several metrics and variables analyzed in this report.
The analysis of the first section revealed that there is interest in this type of market despite its immaturity. Ethereum and Solana are the blockchains where projects are building the most. For the following sections, it is essential to consider *ownership* and *status* (proof of concept, beta or live) as these two variables showed a large difference between the projects under review.

3.2 Liquidity pool:

The following section is undoubtedly central to the analysis. The presence or absence of the liquidity pool mechanism used for NFT trading was the primary criterion for selecting the projects analyzed, as explained in the *projects picking paragraph*.
An important preliminary finding is that almost all of the projects analyzed utilized the asset-pair type as liquidity pool models, while only 11% of the protocols employed multi-asset LPs. The complexity of applying the multi-asset model to NFTs explains this low percentage. Furthermore, it is worth noting that 100% of the projects utilizing the multi-asset methodology did not use the original NFTs for transactions. Instead, they used fungible tokens that represented the NFTs.

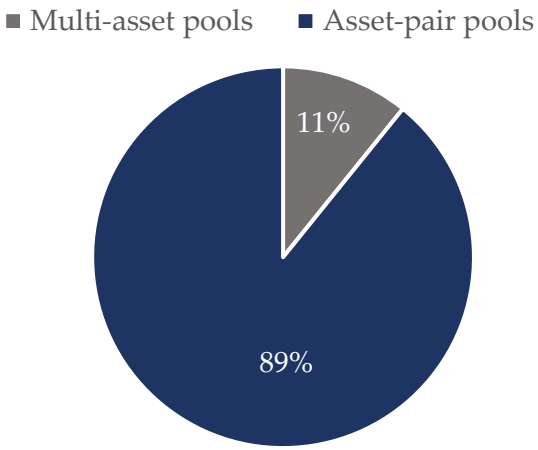


Figure 3.5: Assets in a Pool variable representation (*basis: 37 cases*)

Having seen how most of the liquidity pools are constructed, they are examined now four other key variables that will later be cross-referenced with the *status* variable due to the significance of the latter previously explained. All project numbers obtained by cross-referencing the data of the different variables have been reported in Table 3.1. In terms of liquidity pool construction, 19 out of 37 protocols analyzed allow the liquidity pool to be constructed manually by the liquidity provider (51%). The remaining 49% are divided equally between protocols that build liquidity pools through a fully automated process and hybrid models. As mentioned in the *variable's description* paragraph, manual liquidity pool construction is the easiest to adopt, but it also allows all users to build one, increasing the risk of having many liquidity pools with little liquidity, rendering them unusable due to instability caused by high price variation. Interestingly, exactly half of the projects surveyed are either a fork or built on top of another project. Among the projects where smart contracts were most widely used, Sudoswap (44%) and Uniswap (19%) stand out. These data are significant because they demonstrate both the importance and relevance of Sudoswap in the NFT AMM sector and how Uniswap remains the reference model for protocols building a smart contract for a liquidity pool. Proceeding with the analysis in the last row of table 3.1 - *overall total (1) header* - which shows total number of projects that have respectively forked characteristics, multiple pools per collection and allow swapping between two NFTs - it can be seen that 22 out of 38 of the analyzed projects allow an NFT collection to have more than one liquidity pool. As explained in the literature, the liquidity pool is a mechanism that sets the price of two or more assets through the supply-demand mechanism. This means that if there are two liquidity pools for the same collection, there is a possibility that the price will diverge, leading to arbitrage. Arbitrage is defined as: "*the simultaneous buying and*

selling of securities, currency, or commodities in different markets or in derivative forms in order to take advantage of differing prices for the same asset" [78]. It is evident that two NFTs in a liquidity pool is not a frequent occurrence, accounting for only 24% of all occurrences. Although this mechanism is attractive to protocols because it allows users to trade NFTs as if they were sticker swaps while earning fees with each transaction, it is rarely used due to its difficulty in implementation and the challenge of ensuring the counter value of the two traded assets actually equal each other.

Status	Building method	Forked/Build upon (1)	Pool for collection (>1)	NFT<>NFT swaps (1)
Live		8	7	4
	Automatic	1	0	0
	Hybrid	4	1	3
	Manual	3	6	1
Beta		6	10	2
	Automatic	1	2	1
	Hybrid	2	2	0
	Manual	3	6	1
Proof of concept		5	5	3
	Automatic	2	0	1
	Hybrid	0	0	0
	Manual	3	5	2
Overall total header (1)		19	22	9

Table 3.1: Project according to status and liquidity pool building method (*basis: 37 cases*)

Table 3.1 presents the four variables previously discussed categorized by different project's status and building method. The data that stands out the most is the absence of a hybrid model in projects that are still in the proof of concept stage and the almost non-existent use of an automatic model in projects that are already live. Eight forked projects are live (21%), while 10 projects in beta allow for a single collection to have multiple liquidity pools (27%). Among developing projects, there appears to be a preference for creating liquidity pools which enable direct NFT exchange (8%).

However, since projects are still in proof-of-concept, this number could decrease due to potential difficulties encountered, resulting in the abandonment of this concept.

Side & Parameters:

The data presented in Figure 3.6 show that most liquidity pools are created manually and offer both single-sided and dual-sided options. In fact, 19 out of 38 projects fall into the category just mentioned. Notably, protocols that enforce inflexible structures for liquidity pool creation are less favored, with only 6 projects allowing for dual-side LPs exclusively.

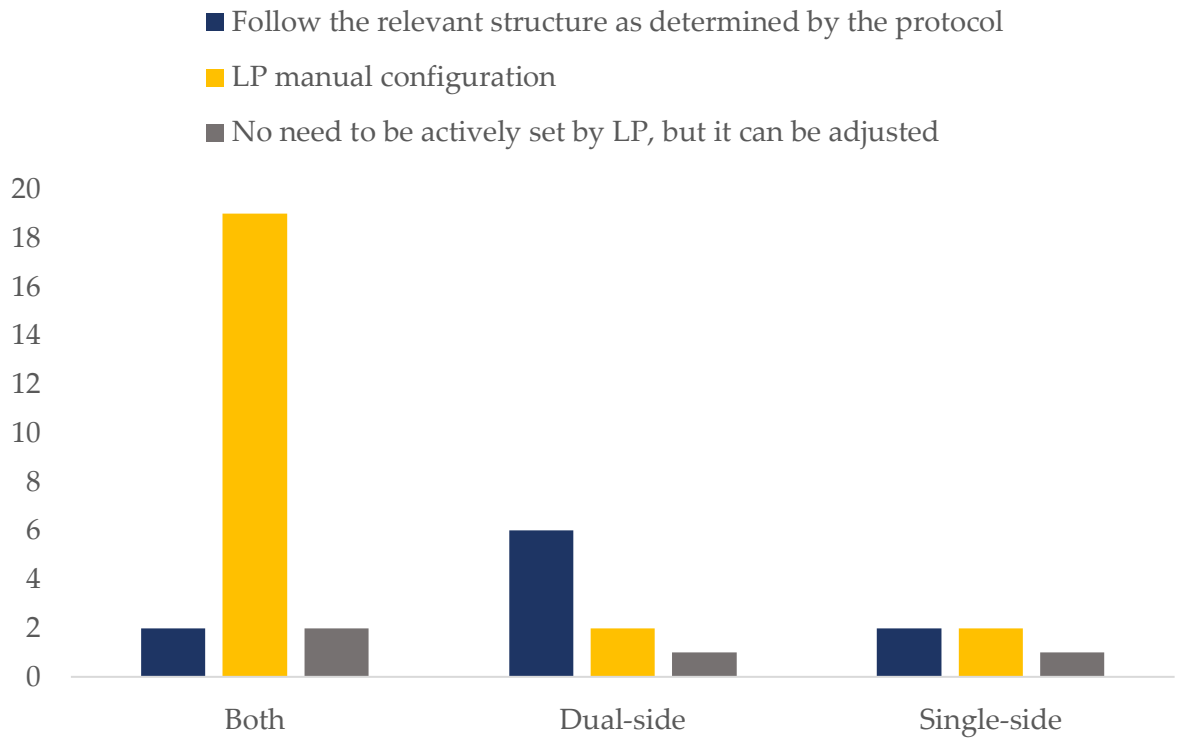


Figure 3.6: NFT AMM distribution according to side and parameters (*basis: 38 cases*)

Price mechanism:

The literature and *variable description* introduced the importance of pricing mechanisms for the projects considered. Next it will analyze the pricing mechanisms within the liquidity pool.
Figure 3.7 represents the total number of projects that used a certain type of pricing curve. It is important to note that the adoption of one type of model does not exclude the other, which is precisely the reason why the total number of projects analyzed - which in this analysis is 37 - and the sum of each type do not coincide. The majority of projects employ linear and exponential bonding curves, 51% and 49%,

respectively. These percentages are calculated from the total number of projects, in this case 19 and 18 out of 37. The sum therefore will not be 100%. Figure 3.7 shows the absolute values; in the text the percentage calculated as explained earlier will be given directly. The third category is the one that aggregates all other types of bonding curves (27%). 19% of the projects analyzed - despite aiming to propose an exchange model different from the mainstream auctions - include them in the exchange models, likely to avoid distinguishing themselves too much from the market. The constant product model - due to its difficulty in implementation - is the least used, with only 14% of projects virtually utilizing it, and only 11% using the model proposed by Uniswap for exchanging NFTs of the ERC721 type, instead of ERC20 assets.

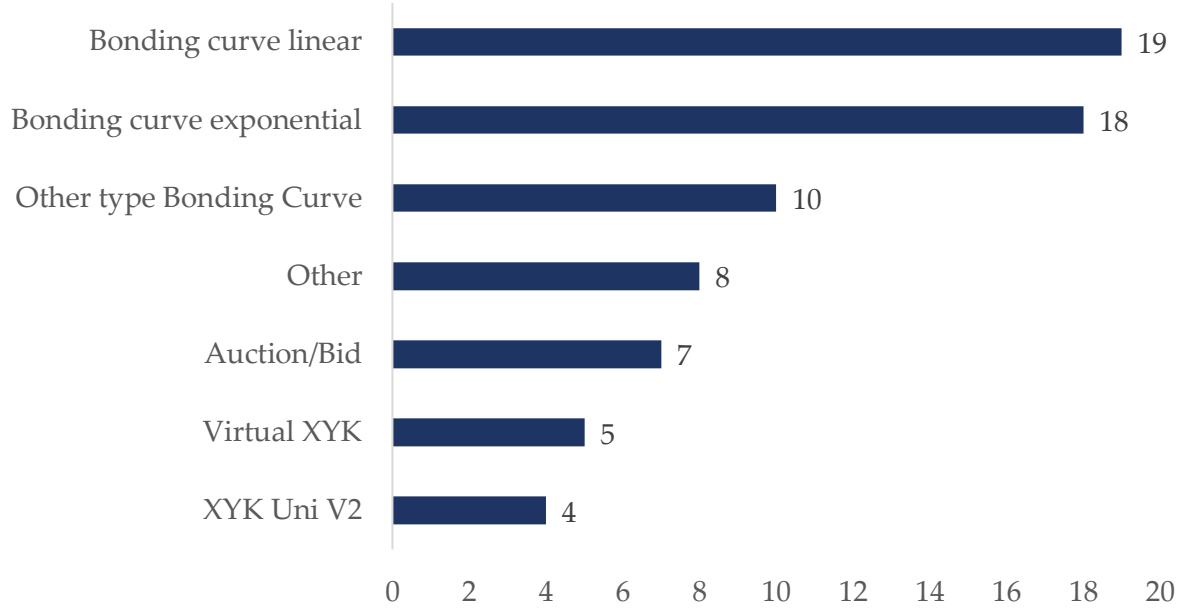


Figure 3.7: Distribution of the price mechanisms by the analyzed projects (*basis: 37 cases*)

As noted in the general information section, the status variable is of great importance, so it is interesting to understand which models are most commonly used by different protocols according to their status. To this end, Figure 3.8 shows the data of price mechanisms with respect to the status variable. It divided those results by the number of projects in live, beta and proof of concept respectively since the numbers are different. Specifically, the number of projects in live is 14, in beta it is 16, and in proof of concept it is 10. Given the small number of projects analyzed, it was decided to report the data in this manner to avoid trying to reduce the diversity between the different variables. For this reason, the sum of the values in the figure for each type of pricing method is 100%.

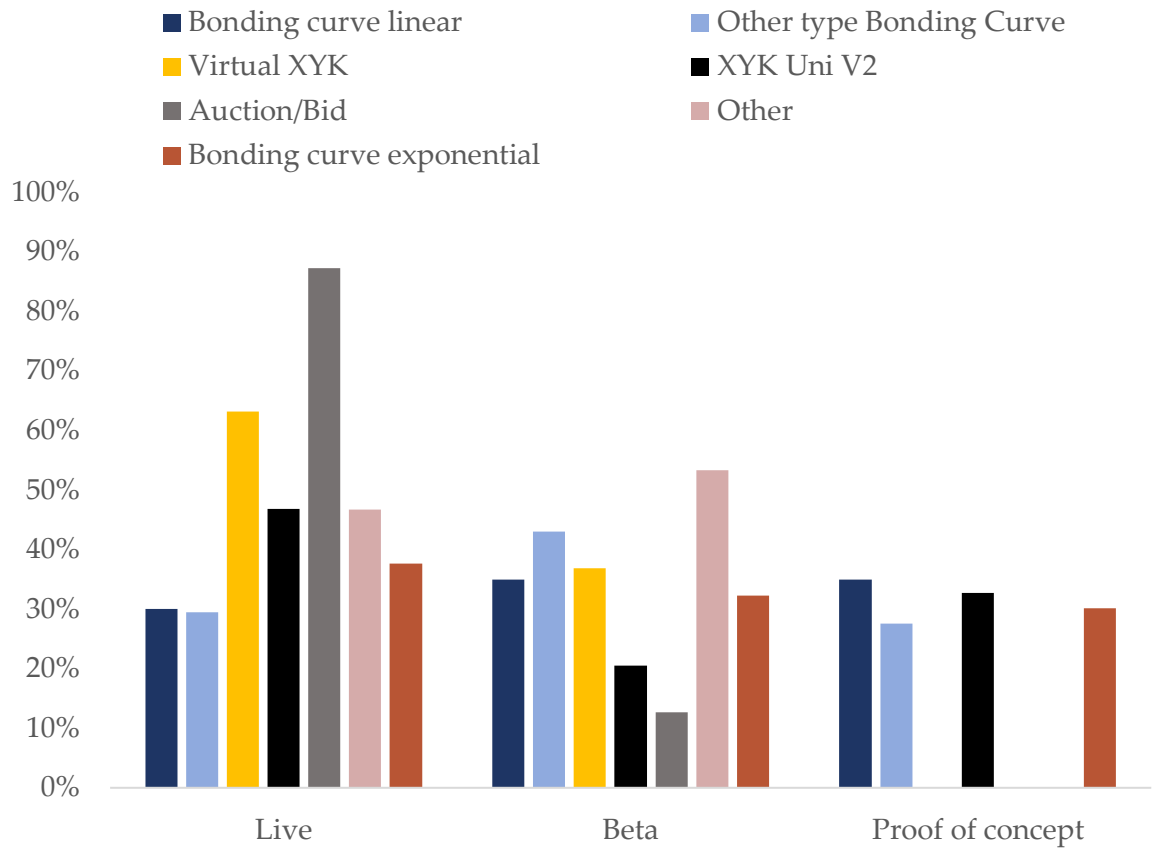


Figure 3.8: Distribution of price according to project status (*basis: 37 cases)*

The research has revealed that 87% of the auctions were adopted by live projects. This lends support to the idea that some protocols may have chosen to use the auction model because perhaps they either already adopted it or because they did not want to completely break away from the most widely used and known traditional models. The complete absence of this mechanism in proof of concept projects reinforces this thesis. The bonding curve linear and exponential models remain the most widely adopted pricing mechanisms across all project states, with no significant differences in distribution observed. However, the UniswapV2 model appears to be more popular in live projects (47%) than in beta (20%) or proof of concept (33%) projects. This may be due to the fact that beta projects analyzed in the study were launched between September-December and were likely influenced by the Sudoswap protocol.

This section highlights that the pricing mechanism is the primary factor influencing the way liquidity pools are constructed. It would be interesting to observe in the section of *solved problems* which of the various mechanisms for the liquidity pool and the *price mechanism* have tried to solve the problems highlighted in the literature in greater percentages.

3.3 Key features:

Five variables are analyzed in this section: *fractionation, multichain, loan, staking, and audit*. These variables have the peculiarity of being an additional feature of the project, unlike the liquidity pool section, which is a mandatory requirement as explained in the *project picking* section. These variables were analyzed because they could play a significant role in determining whether their presence contributes to addressing the problems outlined in the literature.

Staking:

According to Figure 3.9, 58% of the analyzed projects did not offer a staking option. Among the remaining projects, 28% allowed users to stake their LP tokens, while 14% allowed staking of the NFT itself. To understand the difference in adoption, it is helpful to define LP tokens. These are liquidity pool or liquidity provider tokens that are given to users who lend their token to a liquidity pool. LP tokens represent a user's share of the pool and are typically ERC20 tokens on the Ethereum blockchain - making them easier to stake compared to an NFT which may use a different standard, such as ERC721 - as described by Blockchain Council [79].

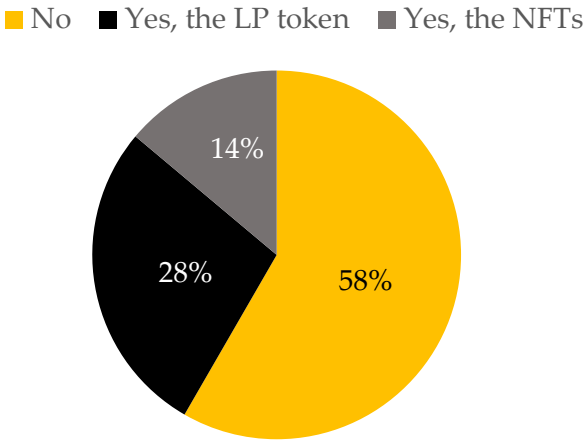


Figure 3.9: Representation of the values of the staking variable (*basis: 36 cases)*

Table 3.2 summarizes the other four variables, and it can be seen that the majority of projects surveyed had none of these characteristics. This finding is not surprising, considering that most of these projects were created to address specific problems using the liquidity pool mechanism. Additionally, the NFTfi market is still in its early stages, and projects are just beginning to emerge, which may contribute to the absence of these features.

For instance, auditing has become a necessity in the crypto industry, particularly after several bugs and failures. Many users are hesitant to invest in a project that has not been audited. However, auditing is a costly service, and companies in the developmental phase or early stages may have limited funding, which may explain why only 39% of projects underwent auditing, despite its significance.

	Fractioned	***Multichain***	***Loan***	***Audit***
Yes	27%	30%	21%	39%
No	73%	70%	79%	61%

Table 3.2: Representation of fractioned, multichain, loan, audit (*basis: 37 cases for all variables excluding Audit which has a basis of 38 cases)*

To validate the newly formulated hypothesis, it is necessary to analyze the same variables and cross-reference them with the status variable. This approach will enable to determine whether the hypothesis is reasonable or not. Figure 3.10 illustrates the analysis just described. In particular, Table 3.2 shows how 10 out of 37 projects allow the splitting of the NFT, 11 out of 37 projects are multichain, 8 out of 37 have implemented the loan mechanism and finally 15 out of 38 have audited smart contracts.

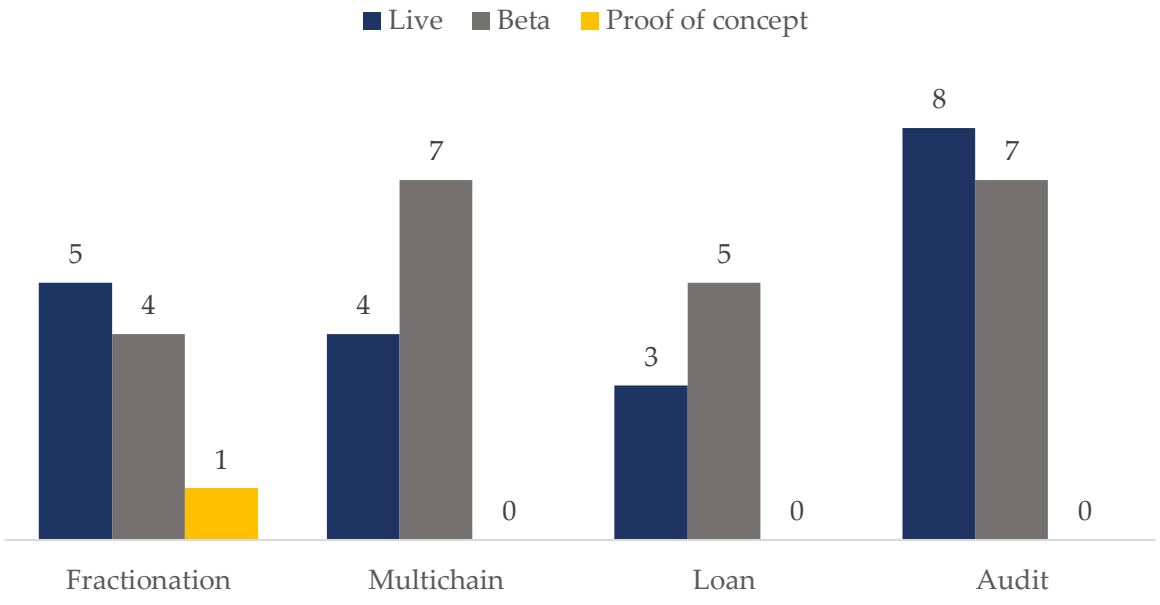


Figure 3.10: Project adopting: fractional, multichain, loan, audit; according to status (*basis respectively: 10, 11, 8, 15 cases*)

With respect to Figure 3.10, one must always consider that there are 14 projects analyzed in Live, 16 in Beta, and only 10 in Proof of Concept. The collected data suggest that the protocols in Proof of Concept lack the features present in Live or Beta projects, thus corroborating the previous hypothesis, in fact only one project presents the fractionalization feature. The audit variable reinforces this conclusion, as live protocols have a high prevalence of audits (8), despite the fact that the total number of live projects is lower than beta projects (7). Although there are two data points that deviate from the trend concerning multichain and loan, they are not significant enough to contradict the previous statements.
This section has contributed to the analysis by giving an overview of the presence or absence of some mechanisms that are not directly related to the liquidity pool but contribute to the success of a project. Mainly two data points emerged: these mechanisms are not excessively prevalent in the analyzed projects and are more present in live projects and almost non-existent in proof of concept ones.

3.4 Economics

In this section, it will be examined the tokenomics of the projects under consideration, which is a precursor to the performance analysis section. The existence or absence of a token has a significant impact on the economics and business model of the project. Even projects with similar characteristics can have a marked difference if one has created its own token. According to the survey, 54% of the projects have their own token, while the remaining 46% do not have one, at least not yet.

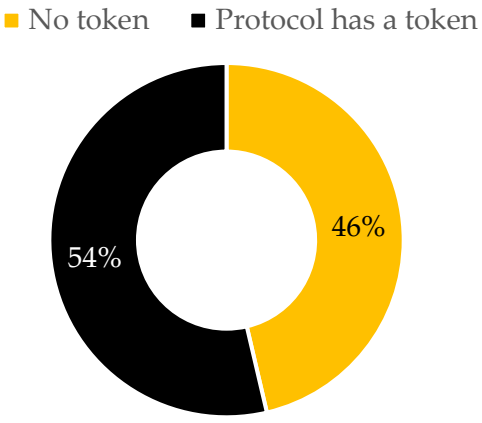


Figure 3.11: Representation of projects with their own token and without (*basis: 37 cases)*

Protocol fee

A key to the business model of a liquidity pool-based protocol is the fees it charges. If marketplaces operate via auction, they typically take an upfront percentage and then

a royalty for each change of ownership of NFTs. However, in this case, there are no royalties but the classic commissions that define the DEX world. As can be seen in Figure 3.12 of the footnote, the percentages among the three possibilities listed in the description of the variable are equivalent.

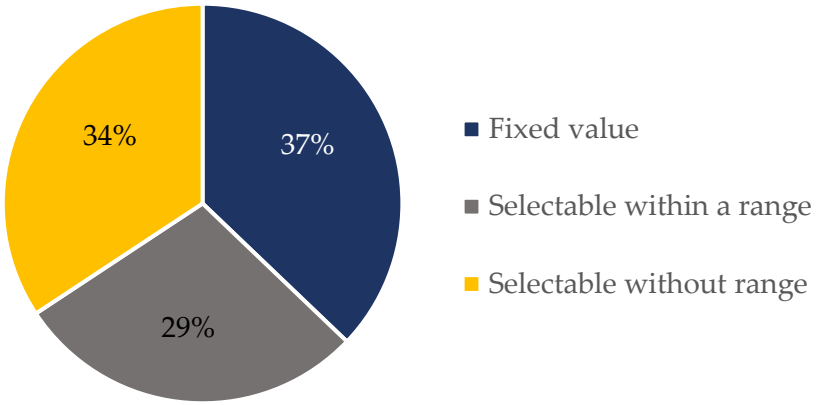


Figure 3.12: Percentages of fee construction method types (*basis: 35 cases*)

Proceeding, the average fees collected by the liquidity provider in each protocol are analyzed, differentiating for the three different fee construction mechanisms.

	Fixed value	Selectable within a range	Selectable without range
Total	2.3%	1.2%	0.6%

Figure 3.13: Fee average value by fee typology (*basis: 35 cases*)

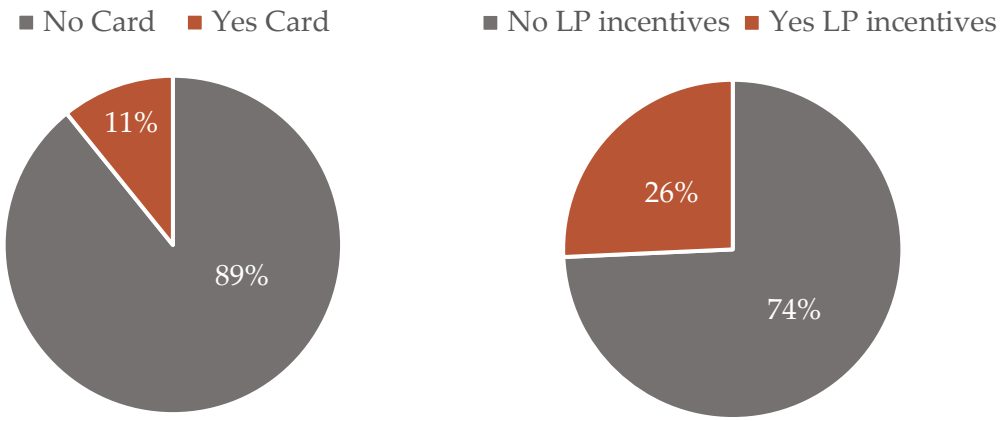
From Figure 3.13, it can be seen that the protocols that do not allow the liquidity pool creator the freedom to set fees arbitrarily only those that have the highest average fee (2,3%). Fees within a certain range are around 1,2%, but those without a range are the

lowest. The previous statement may seem paradoxical, as a liquidity provider typically chooses higher fees to increase their earnings. However, in some cases, the protocol may charge additional fees but - due to the diversity of data and the relatively small number of cases in which this occurs - it was chosen not to include these scenarios in the analysis as it would make it impractical.
To better understand the relationship between construction fee and project status, the data in Table 3.3 were analyzed where the average protocol fees were reported according to their status and the type of fee they had adopted. The adjacent column shows the percentage of the number of projects that had adopted that type of swap fee based on their current status. The AMM NFT projects with the highest average fee (2,6%) are those already in mainnet that are using the fixed value mode. Generally, the average fee is higher in already live projects (1,8%) and decreased significantly in beta projects (1,1%) before halving to 0,9% in proof of concept ones. This could be attributed to the fact that newer projects require more competitive pricing and fee structures to attract initial users and gain market share. However, Figure 3.13 displays even distribution of fee construction mechanisms across all project statuses.

Status	Swap fee	Average protocol fee	Swap fee type
Live		**1,8%**	**40,0%**
	Fixed value	2,6%	14,3%
	Selectable within a range	1,9%	14,3%
	Selectable without range	0,7%	11,4%
Beta		**1,1%**	**42,9%**
	Fixed value	2,1%	17,1%
	Selectable within a range	0,4%	11,4%
	Selectable without range	0,6%	14,2%
Proof of concept		**0,9%**	**17,1%**
	Fixed value	2,0%	5,7%
	Selectable within a range	0,5%	2,9%
	Selectable without range	0,3%	8,6%
Total average protocol fee and Total sum swap fee type		**1,4%**	**100%**

Table 3.3: Average protocol fee and fee type by status (*basis: 35 cases*)

The last two variables to be considered in the *economics* section are the integration of mainstream payment options such as credit/debit cards and incentives for liquidity providers (LP), often given in the form of the protocol's token. Figure 3.14a shows that only 11% of protocols have integrated on/off ramp tools to enable credit card payments, indicating that many of these projects target customers who are already in the crypto world and own a wallet. As for incentives, only 26% of projects offer them. This figure is consistent with the current trend in the market, which has seen a decline in DeFi projects that incentivize users to deposit cash on their platform with token rewards, in favor of the emerging trend of providing real yields.



(a) Distribution by credit card (b) Distribution by LP incentives

Figure 3.14: Representation of two metrics related to the presence or absence of credit card and incentives for liquidity providers, respectively. (*basis: 36 cases*)

3.5 Performance

This section examines the variables used to evaluate the protocol's performance. As previously stated in the literature and methodology chapter, these metrics are influenced by the fact that the market is new and underdeveloped. Due to this, beta and proof-of-concept projects cannot provide data on revenue, total value locked, and total volume exchange. Therefore, the study focuses on metrics such as the number of users on Twitter and Discord, total platform users, and the number of NFTs. These metrics are heavily influenced by the project's stage of development, as illustrated in figure 3.15.

It's worth noting that these metrics can be easily manipulated, especially the number of users on social media platforms, as there are several methods to artificially inflate

these figures. While revenue is the least manipulable metric, the lack of data makes it impossible to analyze in this case.

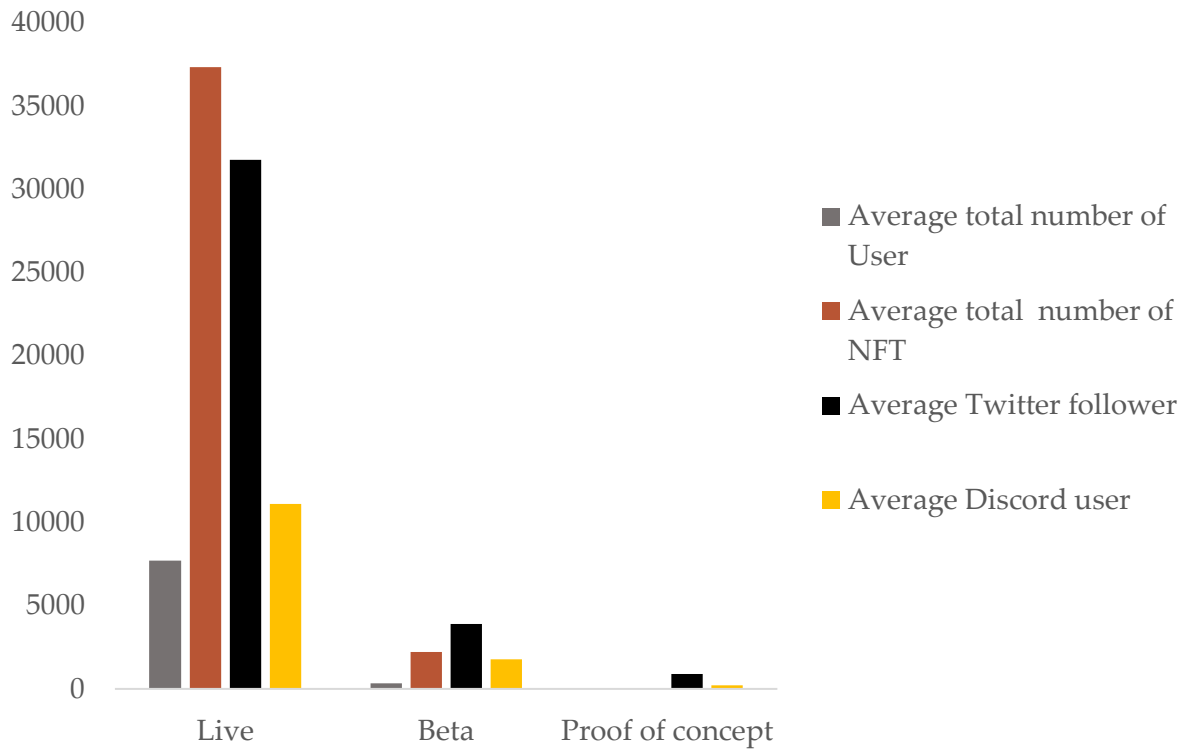


Figure 3.15: Average of user, nft, discord and twitter follower by project status (*basis: 40 cases*)

As mentioned earlier, this section does not provide significant contributions to the analysis due to the emerging nature and immaturity of the market analyzed. Nonetheless, the section was included in the research because of its methodological relevance. In fact, should anyone wish to further research this type of market, they can use the same criteria and tools described in the "selection of tool to collect data" paragraph and update the data for the variables in this section. This would lead to an improved analysis, allowing for the identification of projects with the most significant growth at the performance level.

3.6 Problem solved

This section is the one that most summarizes the purpose for which a project is being developed. As mentioned in the section on *variable description*, it should be noted that the data may not be entirely reliable, as some projects may have inaccurately reported their intentions. To address this problem - echoing the point made earlier about future analyses - a significantly useful work could be to try to build models to quantify these variables, thus succeeding in fact checking against the intentions of

the projects analyzed. Using the insights gathered in the previous sections, the goal is to provide a comprehensive analysis of the problems the projects intend to solve and their approaches to addressing them. Overall, this section aims to provide an in-depth analysis of the research question.

Problems solved general overview:

The graph in Figure 3.16 was obtained by counting for each individual problem the total number of projects that had claimed to solve it divided by the total number of projects analyzed which had this data available (36). It illustrates that 89% of the projects aim to address the issue of users' inability to sell their NFTs instantaneously. This problem is closely linked to the challenge of illiquid NFT secondary markets, with 86% of projects confirming their ability to resolve it through their protocol. The problem of centralization follows with a lower percentage (61%). Transparency in price discovery and the possibility of using NFTs as collateral (44%) are also related issues. Conversely, high royalties and wash trading are lower priority problems, with only 25% of analyzed projects addressing the latter.

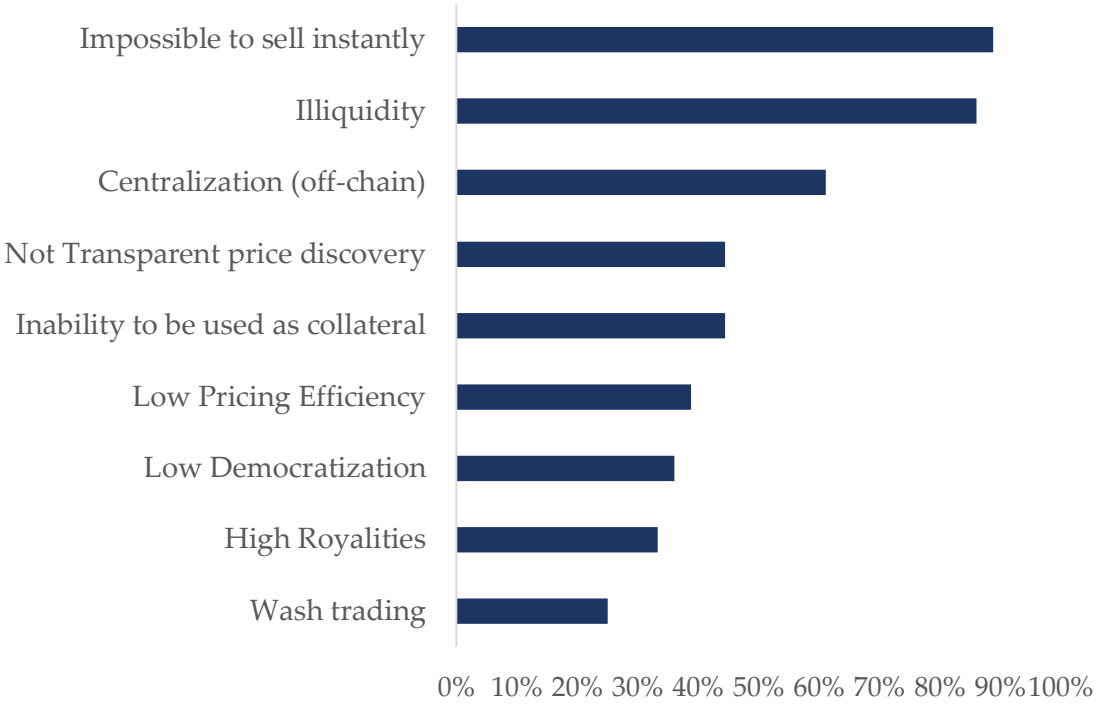


Figure 3.16: Distribution of the problems solved by the analyzed projects (*basis: 36 cases*)

As done before it has been added the *status* variable to the previous graph, which is deemed the most significant in the *general section*. Repeating what has always been done in this analysis, the percentages are obtained by dividing by the number of projects respectively in live, beta or proof of concept. In particular, projects in the

proof of concept stage excel in solving the wash trading problem, with a success rate of 55%. In contrast, live projects have a much lower success rate of 20%, suggesting that they may encounter more complex issues once in the market. It is worth mentioning that projects in the proof of concept stage perform poorly in preventing their NFTs from being used as collateral, consistent with our findings in Figure 3.10's *key features section*. It was observed that no projects in this stage had loan mechanisms or other passive return options for NFT holders. On the other hand, beta projects appear to be more successful in addressing problems related to centralization and royalties. In contrast, live projects focus more on solutions that enable NFTs to be used as collateral and generate passive income. This disparity may be due to the structured nature of live projects, which are more likely to offer individual NFT annuitization options.

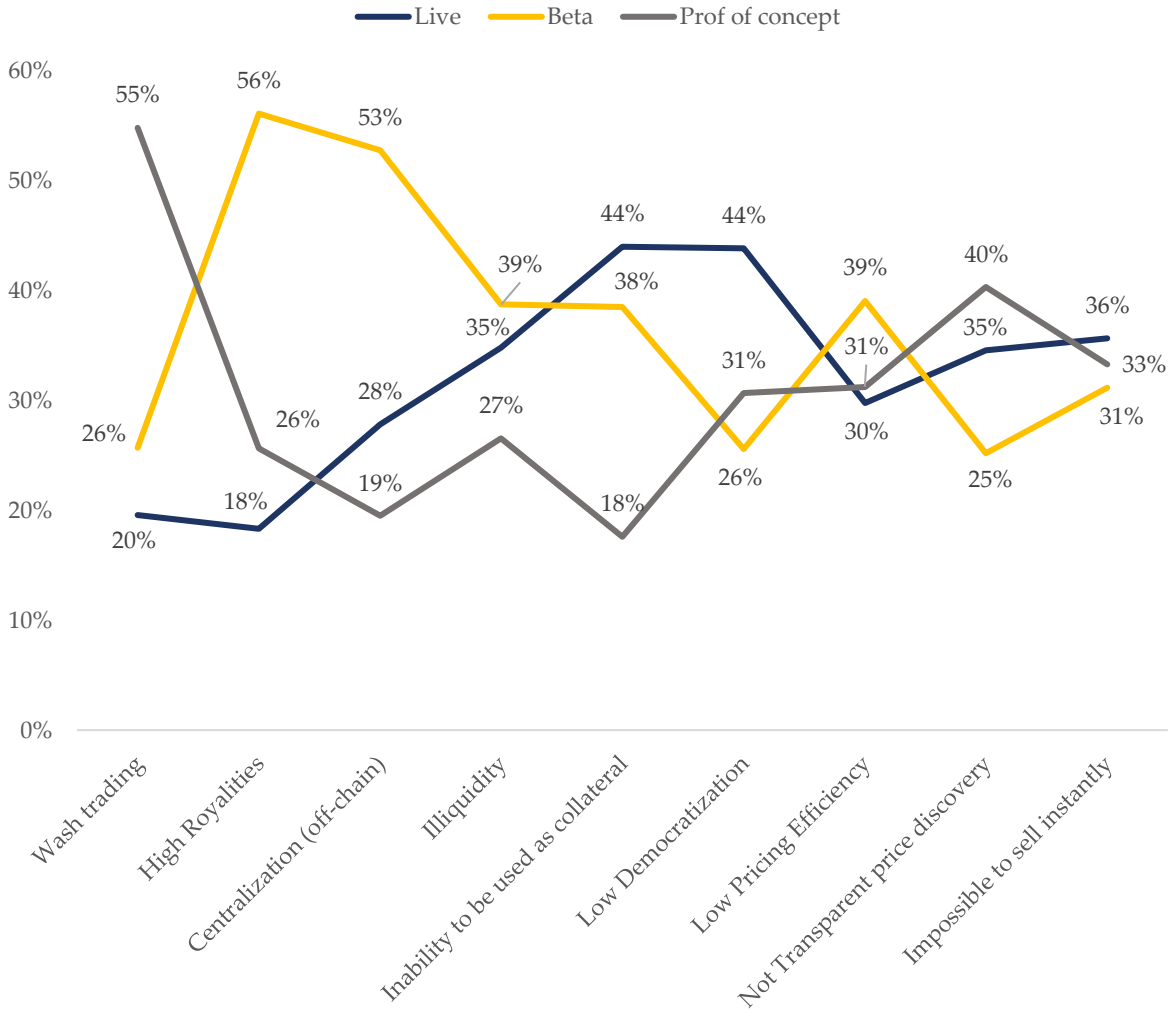


Figure 3.17: Distribution of problem solved by different project status (*basis: 40 cases*)

Price mechanism & Problems solved:

In pursuit of answering the research question, it is desired to cross-reference data between the pricing mechanism used and the problem solved. To achieve this, it has been analyzed the numbers presented in Figure 3.16 and determined which pricing methodologies contribute the most to solving specific problems. Table 3.4 presents the absolute values of problems solved by each pricing method. Since a project may use multiple pricing methods and solve multiple problems, the total number of projects adopting a specific pricing method is reported in the columns, and the total number of projects solving a specific problem is reported in the rows.

1,1	BC linear	BC exponential	Other BC	Virtual XYK	XYK Uni V2	Auction/Bid	Other	Total Project count solved
Wash trading	*2*	*2*	*3*	*1*	*2*	*2*	*2*	*9*
High Royalties	*9*	*9*	*1*	*2*	*0*	*0*	*0*	*12*
Centralization (off-chain)	*15*	*15*	*6*	*2*	*2*	*2*	*5*	*22*
Illiquidity	*14*	*13*	*8*	*5*	*3*	*5*	*8*	*31*
Inability to be used as collateral	*4*	*4*	*5*	*1*	*4*	*4*	*5*	*16*
Low Democratization	*3*	*2*	*4*	*1*	*4*	*2*	*4*	*13*
Low Pricing Efficiency	*5*	*4*	*4*	*2*	*2*	*3*	*5*	*14*
Not Transparent price discovery	*6*	*5*	*4*	*3*	*3*	*2*	*5*	*16*
Impossible to sell instantly	*17*	*16*	*7*	*4*	*3*	*4*	*6*	*32*
Projects using this price mechanism	*19*	*18*	*10*	*5*	*4*	*7*	*8*	*36*

Table 3.4: Counting problems solved by the pricing method (*basis:36 cases*)

Since Figure 3.8 indicates a disproportionate distribution of projects across various pricing methods, the data was normalized. As an illustration, the *inability to be used as collateral* row and *BC linear* column were used as a reference. The value 4 was divided by the total number of projects adopting the linear bonding curve (19) which was previously divided by the total number of projects (36), obtaining the expression: 4/(19/36). If this had not been done, it would probably have been possible to conclude that BC linear and XYK Uni V2 equally solve the problem of inability to be used as collateral, disregarding the fact that BC linear comprises only 4 out of 19 (21%), whereas XYK Uni V2 has 100% success rate.

To obtain the results presented in Table 3.5, an additional step was taken. The value obtained from the previous calculation was divided by the total sum of the row, calculated as described above, and then multiplied by the total number of problems solved as a percentage. This calculation resulted in Table 3.5, where each cell represents the percentage contribution of the pricing method to the solution of a specific problem. The last column shows the same total values showed in Figure 3.16, and the last row displays the total sum indicating the pricing method that best solves the analyzed projects as a percentage. Table 3.5 provides valuable insight into the strengths and weaknesses of each pricing method, enabling stakeholders to make more informed decisions when choosing a pricing method for their project.

1,1	BC linear	BC exponential	Other BC	Virtual XYK	XYK Uni V2	Auction/Bid	Other	% Tot prob. solved
Wash trading	2%	2%	4%	3%	7%	4%	4%	**25%**
High Royalties	11%	11%	2%	9%	0%	0%	0%	**33%**
Centralization	12%	13%	9%	6%	8%	4%	9%	**61%**
Illiquidity	11%	11%	12%	15%	11%	11%	15%	**86%**
Inability to be used as collateral	3%	3%	7%	3%	13%	8%	8%	**44%**
Low Democratization	2%	2%	5%	3%	14%	4%	7%	**36%**
Low Pricing Efficiency	4%	3%	5%	5%	7%	6%	9%	**39%**
Not Transparent price discovery	4%	4%	5%	8%	10%	4%	9%	**44%**
Impossible to sell instantly	15%	15%	12%	13%	12%	9%	12%	**89%**
% tot of problems solved by pricing	**63%**	**62%**	**62%**	**65%**	**82%**	**50%**	**73%**	

Table 3.5: % distribution price mechanism on solved problem normalized by lines (*basis:36 cases)*

Analyzing the Table 3.5 line by line, it can be observed that the *wash trading* problem is solved overall in only 25% of cases and the greatest contribution to this percentage is given once again by *XYK Uni V2* with 7% while *bonding curve linear* the lowest with 2%. However, the bonding curve methods solve the *high royalty* problem with the greatest percentage, at 11%. *Centralization* is a problem that all methods - except *auction/bid* - claim to solve to some extent. *Illiquidity* is generally resolved (86%), with *virtual XYK* and *other methods* being the most effective. In particular, among other methods, the *Quantix* [1] and *Solvent* [2] protocols are particularly interesting, as they allow to solve this specific problem through different price mechanisms and a splitting process. It would be interesting to further analyze and rank the projects that fall into this category, as they also have the highest share of the *price efficiency* issue (9%). XYK Uni V2 also has the highest non-usage resolution rate as *Inability to be used*

as collateral (13%) and *low democratization* problem (14%). It contributes significantly to solving most of the other problems, the highest of which is the *non-transparent price discovery* (10%). Almost all of the projects that adopt the *linear or exponential bonding curve* also claim to solve the problem of the *impossibility of instantly selling* NFTs - in the first case 17 out of 19 cases - helping to solve this problem in 89% of cases cases for 15%. Looking at Table 3.5 and observing the last row, it can be seen that the pricing method that has the highest percentage of problems solved is XYK Uni V2, with a percentage of 82%. This may indicate that XYK Uni V2 is the most effective pricing method for solving the analyzed problems.

After reviewing the details of Table 3.5, it is interesting to conduct a similar analysis that considers the unique mechanism of the binding curve. This approach is relevant because it was introduced by Sudoswap and is the most frequently used mechanism among the projects considered, as explained in section 3.2 on the liquidity pool. Table 3.6 presents the percentages of problems solved by projects that adopt the bonding curve mechanism (1) and those that do not (0). The analysis reveals that the projects considered present a higher percentage in solving the problem of high royalties (82%), centralization (68%) and the impossibility of sell instantly (55%). Considering all the projects that solve the wash trading problem, 22% show the presence of bonding curve linear. The collateral problem on the total of the projects analyzed is declared to be resolved in one case out of four by projects that adopt the linear bonding curve (25%).

Problem solved x Bonding curve	0	1
Wash trading	78%	22%
High Royalties	18%	82%
Centralization (off-chain)	2%	68%
Illiquidity	53%	47%
Inability to be used as collateral	75%	25%
Low Democratization	77%	23%
Low Pricing Efficiency	62%	38%
Not Transparent price discovery	63%	38%
Impossible to sell instantly	45%	55%

Table 3.6: BC linear price on the problem solved on the total number of projects (37)

Liquidity pool construction method and key protocol features

After reviewing the data on problem solving variables, both in terms of absolute values and status and pricing mechanism, this section focuses on illustrating the most interesting numbers with respect to the different methods of constructing the liquidity pool and the problems resolved.
The first variable considered is *ownership*, as identified as relevant in the *general information section*. Table 3.7 presents only the key statistics from this analysis. Interestingly, high royalties are not an issue for private companies, with 0% of them indicating they have made their own plans to address this issue. This result is particularly significant when combined with the fact that 61% of DAOs resolve it. DAOs have a decentralized form of governance and their revenue distribution is often different from that of private companies. The latter may be interested in maintaining high sales royalties to earn more from the initial sale of the NFT.

	DAO	***Developers***	***Private company***
High Royalties	61%	38%	0%
Used as collateral	32%	17%	52%

Table 3.7: Type of ownership distribution on problem solved (*base: 40 cases)*

Regarding the inability to use NFTs as collateral, private companies have the highest percentage (52%), possibly due to greater economic availability and interest in providing more solutions to increase the utility of the user's NFT. With respect to this last analyzed problem a further comes to the rescue of this analysis by confirming that it is only 21% those projects that solve the problem of inability to be used as collateral without having mechanisms of: fractionalization, multichain, loan. Figure 3.10 confirms that these mechanisms are used more by live projects (Figure 3.2), which are mostly owned by private companies. Further analysis was conducted within the corporate governance mechanism by distinguishing between those who have adopted a governance mechanism and those who have not. As shown in Table 3.3, 35% of the projects surveyed adopt a governance mechanism. The finding that emerges from the analysis is that they solve the problem of low democratization in 65%, confirming both the validity of the research conducted and the effective possibility that the use of such a mechanism could increase participation and promote a democratic mechanism of governance.

The last report to be conducted that is of interest in the analysis is the one related to the way the liquidity pool was constructed, and the related problems solved. This

type of investigation will be conducted on the three variables that emerged as significant in the *liquidity pool* section: *building method, side and parameters*.

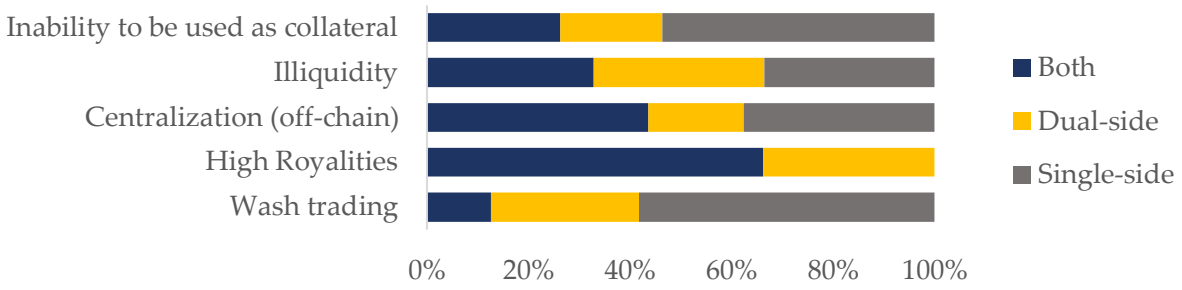


Figure 3.18: Distribution of problems solved from the analyzed projects by Side (*basis: 38 cases)*

In Figure 3.9 some of the variables of the solved problems have been brought back only because the other statistics were not interesting. It emerges that the three variables for which a difference in significant percentages appears based on the construction model of the liquidity pool are: inability to use as collateral, high royalties and wash trading. Single-sided liquidity pool construction has the largest share of the high royalty problem, with a success rate of up to 58% in resolving wash trading issue. This is due to the fact that it only allows either the purchase or sale of NFTs, which makes it difficult to falsely inflate the trading volume of an asset.

As previously mentioned, the same analysis of Figure 3.18 is shown with the building method and parameters variables. Figure 3.19 shows the two most significant data.

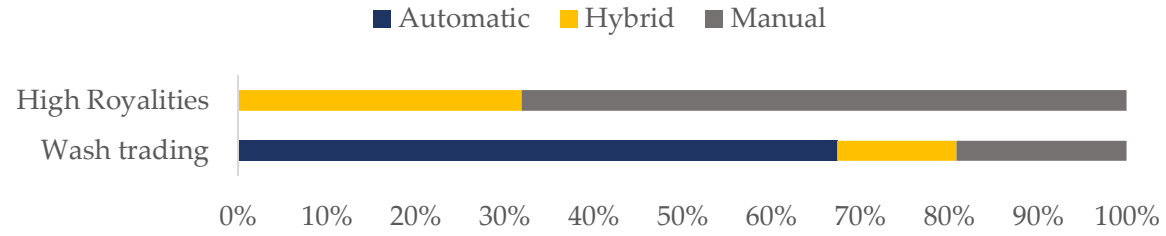


Figure 3.19: Distribution of problems solved by building method (*basis: 37 cases)*

Based on the combination of Figure 3.19 and Table 3.8, the data related to the wash trading and high royalties' problems are the most significant. The wash trading problem is more likely to be solved by projects that adopt an automatic liquidity pool construction mode (67%) or those that enforce the user to follow a specific liquidity pool structure (57%).

	Follow protocol structure	Manual pool configuration	Hybrid
Wash trading	57%	15%	28%
High Royalties	19%	81%	0%

Table 3.8: Distribution of problems solved from the analyzed projects by parameters (*basis: 37 cases)*

On the other hand, when it comes to royalties collected by protocols or artists, the statistics are completely reversed. In fact, 68% of constructed liquidity pools that have a manual process in the initial construction take into account the royalties, and this figure rises to 81% for projects that set all the parameters manually.

As mentioned in the *project objective paragraph*, the objective of this analysis was to explore the impact of liquidity pools on the secondary market of non-fungible tokens and thoroughly examine the characteristics of the projects presented. This chapter presents a comprehensive overview of this emerging market by analyzing the key factors of each project and answering the research question. While all analyses presented in this chapter are interesting, the section on problem-solving is the most informative, as it not only examines the problems solved in an absolute sense but also in relation to the key characteristics highlighted in the previous sections. Table 3.5 is particularly relevant for the reasons already described and shows how the constant product price mechanism introduced in decentralized finance by Uniswap V2 seems to be the one that could bring the greatest benefits also in the NFT AMM sector based on the analyzed projects.

As already anticipated in the project objective paragraph, a curricular internship was carried out at AerariumChain during the master thesis period. Given the alignment of activities and purposes between the internship and the research carried out, this analysis was used during the period at AerariumChain to design a management model for the secondary market NFT and implement a trading model for the same through liquidity pools. The model conceived during the months of internship at AerariumChain will be illustrated in the next Chapter.

4 AerariumChain

The literature review identified the limitations and problems of the current solutions, while the subsequent *findings* chapter presented the main characteristics of projects attempting to address the identified issues. This chapter centers on the solution implemented during the stage in AerariumChain. Its placement after the *findings* chapter is crucial since it was a crucial part of the company's work. Without *Chapter 3's* analysis, the proposed solution would be incomplete.
This chapter is divided into two parts. The first part introduces the company, project, and choices made before October, including the primary market. The second part presents the proposal for managing the NFTmicro™ secondary market - developed during the internship months - considering the preceding analysis. The same variables mentioned in *Chapter 2*'s *description of variables* will be utilized to present AerariumChain's characteristics. This is an intentional method to emphasize the analysis's continuous nature and the proposed solution's development.

4.1 Company description

AerariumChain (AEC) is a cloud-based service designed to assist in the preservation of cultural and artistic heritage worldwide. Museums, institutions, and private clients can leverage AerariumChain's advanced technology to digitize, conserve, and monitor works of art. By integrating professional 3D scans, blockchain, and artificial intelligence, AerariumChain aims to create new value for all art custodians. The project was conceptualized by Werea S.r.l., an Italian startup based in Milan that created the SweetHive collaborative platform. It gained momentum after the introduction of NFTs in 2022 and caught the attention of Borderless Capital, raising €756,000 in the Seed Round.

AerariumChain's Process: From 3D Scanning to NFTMicros

AerariumChain's innovative process begins with creating a 3D scan of the artwork to create a unique fingerprint, enabling artificial intelligence to detect any changes. Each phase of the process is authenticated on the blockchain, ensuring NFTMicro production, which museums can leverage to create new value by raising funds for the restoration, conservation, and maintenance of their assets. The project primarily provides three services: *care*, *fund*, and *show*:

- **Care process**: it is the service that allows the monitoring of the works and the creation of the digital condition report [1]. The process of this service is as follows:
    1. *3D scanning* of the artwork using advanced devices with high definition and speed to acquire accurate and detailed information, with an accuracy of up to 0.05mm, carried out by certified operators.
    2. *Saving of the 3D file* on secure servers that are accessible to the owner of the work who holds all rights.
    3. *Creation of unique keys (UVI)* through specific algorithms that process the file, which are saved in the blockchain in a recognizable, permanent, and unchangeable way.
    4. *3D image processing* that can be used for monitoring, printing, media creation, or NFT tasks.
- **Fund service**: It aims to support institutions responsible for managing cultural and artistic heritage facing budget shortfalls. NFTMicros - a specific type of NFT designed to finance the management and conservation of works of art - are directly minted by the rights holders of the artwork. This service manages the primary market, secondary market, and the AEC reserve.
- **Show experience:** It allows NFTMicro holders to experience the artwork in high-resolution 3D directly in their wallet for a unique and engaging experience. The platform is also working to connect with other platforms to create a conducive ecosystem for the end customer.

WEREA S.r.l. has already signed contracts for over €60 million NFTMicros, which will begin selling on its marketplace on April 15, 2022.

4.2 Project objective

The project in AerariumChain was carried out from October 2022 to April 2023 and focuses on the Fund service, in particular on the management of the NFTmicro™ secondary market. The secondary market management approach is critical to a successful sale of NFTMicro™. The project aims to support the design, simulation, and definition of the optimal methodology for managing trading on the secondary

market. The ultimate goal is to identify the model that aligns best with the NFTMicro™ business model and objectives. To achieve the goal, the following method and process were followed:

- Firstly, it has been conducted a thorough study of the NFT market, with a specific focus on the secondary market. It has been referred to the existing literature mentioned in *Chapter 1* for this purpose.
- A unique census of all projects that implemented liquidity pool mechanisms for buying and selling NFTs was conducted. This was the first of its kind in the industry and was documented in *Chapter 2* and *Chapter 3*.
- The NFTmicro model and objectives were studied comprehensively to gain a clear understanding of them.
- Using Pact - a leading dex on Algorand – it has been identified and developed a consistent trading model for NFTMicro™. It has been simulated the evolution of the exchange to ensure its success using the Pact SDK and created a simulator in Excel.
- Finally, a strategy it has been established for the distribution and exchange of the NFTs themselves on the secondary market for the startup AerariumChain.

4.3 Previously defined feature

To provide a comprehensive understanding of the solution, it is necessary to first outline the current situation and the decisions that have already been made. These decisions will only be illustrated, and the decision-making process will not be explained as they were made a priori by the company. This includes a description of the three primary choices that were made: the blockchain platform used for the project, the key features of the NFTmicro™, and the primary market mechanism. Only after these three introductory sub-paragraphs will the model developed during the months of internship at AerariumChain be explained which takes into account the analysis shown in *Chapter 3*.

4.3.1 Algorand

Selecting the right blockchain for a project is a crucial decision. In Chapter 3, Figure 3.3 illustrated that Ethereum, Solana, and Polygon were the most commonly used blockchains among the surveyed projects, in descending order. However, Aerariumchain made a different choice and opted for Algorand at the beginning of 2022. This decision was driven by the team's strong belief in the technology and development of the Algorand ecosystem, as well as their successful application for the Algorand Foundation Grant Program. Despite having fewer users and therefore

fewer potential customers compared to other chains, AEC identified major benefits in Algorand's technology, such as transaction speed and low cost. Specifically, the top five positive characteristics of Algorand for AEC are:

- *Pure Proof-of-Stake* (PPoS) consensus mechanism, enabling fast, secure, and scalable transaction processing. This mechanism is designed to reach consensus in seconds, instead of minutes or hours.
- *Byzantine Agreement Protocol (BA*):* Algorand employs a BA* protocol to ensure that all network nodes agree on the current state of the blockchain. This protocol ensures the security of the blockchain, even in the presence of malicious actors.
- *Fast and secure transactions*: The Algorand blockchain can process up to 1,000 transactions per second, making it one of the fastest blockchain platforms in the world.
- *Transaction fees*: Algorand boasts very low transaction fees compared to other blockchain platforms. As of March 2023, the current transaction fee on the Algorand blockchain is 0,001 Algos (ALGO), equivalent to approximately $0,0003 USD.
- *Environmental sustainability*: Algorand uses a negative carbon consensus mechanism that offsets more carbon than it consumes, making it one of the most environmentally sustainable blockchain platforms available.

4.3.2 NFTMicro™ description

The characteristic of the NFT conditions the sales method, the price and in general it is what affects the most. Three important things will therefore be explained: purpose, type, key and technical feature.

Purpose

NFTMicroTM offers an innovative way to raise funds for museums through the creation of a digital collection of authentic works of art. This initiative not only aims to bring beauty and passion for art to the digital world but also supports the conservation and restoration of cultural and artistic heritage. The AEC ensures that all NFTs issued comply with copyright and image rights regulations and are produced with the collaboration and consent of the museums. Many artworks are owned by governments or foundations, which may be unwilling or unable to sell them or their related rights. NFTMicro™ by AerariumChain generates new digital assets that can be easily purchased without compromising ownership rights. By selling NFTs online, museums can more readily fund the restoration, conservation, and maintenance of their collections while reaching a new audience of digital

collectors. In addition to the main purpose, which is to raise funds, AEC has other goals for the same NFT. They are all reported for completeness: being liquid, not generating fictitious value, making the purchase of a single NFT accessible and therefore democratic, allowing multiple transactions and consequently the creation of a real secondary market, being efficient in terms of transaction, ensure economic sustainability in the medium to long term, respect the environment.

Type:
The objective outlined above has an impact on the type and features of the NFT. As a result, AEC provides two types:

- *Only Experience Rights (OER)*: owning one or more NFTMicros of a specific artwork grants access to experience the artwork through services based on the 3D file generated on the Unique Virtual Image (UVI) of the artwork. These services can be provided by AerariumChain or other platforms authorized to access the 3D asset. The level of experience is determined by the number of NFTMicros held in the user's wallet and the associated level. All terms are subject to the complete agreement. AerariumChain has chosen the "75-20-5" model for NFTMicro (OER) to generate maximum value from both digital and physical ownership while avoiding any perception of a "double dip" on the artwork. Under this model, 75% of the fractional piece remains with the museum, which cannot sell, move, or make any transactions. 20% of the total fractional art is available for sale on the primary and secondary markets. The remaining 5% supports the AerariumChain ecosystem and covers operating costs.
- *Fractional Ownership of Rights (FOR)*: owning one or more NFTMicros of a particular artwork grants fractional ownership of the rights to the artwork in proportion to the number of NFTMicros issued for that artwork. This type of NFT can only be issued if the artwork owner agrees to sell the rights by selling their own NFT.

Key features
- The ownership rights for OER NFTs are not transferred.
- Each NFTMicro™ represents a work of art and is closely linked to the UVI NFT of the artwork.
- NFTMicro™ for different artworks are not fungible. NFTMicroTM for the same artwork are fungible.
- The NFTMicro™ for an artwork can only be generated once in the life of the artwork, and this limitation also extends to any similar issuances on other platforms.

- Only the holders of the rights to artworks can request the mint of NFTMicro.
- At the minting time, the nominal value of the entire NFTMicro™ for an artwork is equal to the estimated value of the artwork.
- NFTMicro™ are fractionated in 1,000 and multiples of 10 to have a democratic value for fractional units of NFTMicro™. The value in the primary market ranges from €0.1 to €10. In the secondary market, the value is determined by the demand/supply mechanism.

Technical features

NFTMicroTMs follow the ARC-69 Algorand L2 standard. The Json format for NFTmicro is shown in Algorithm 1, which includes key features of the artwork and the UVI ID described in the company description paragraph. The UVI can be updated, whereas the NFT remains unchanged. To avoid altering the individual NFT, the UVI ID is included in the JSON, allowing for updates to the UVI and adding information about the artwork's health status during each scan.

Algorithm 1 NFTMicro's JSON prototype

```
{
  "standard": "arc69",
  "description": "description of the artwork",
  "external_url": "link of the marketplace page where the specific work is sold"
  "uvi_asset_id": "UVI's ID. ex: 160564993",
  "mime_type": "image/png",
  "properties": {
    "TITLE": "name of the artwork",
    "AUTHOR": "author's name",
    "DATE": "date of creation of the work",
    "TYPE": "nft type: OER or FSR",
    "TIMELINE": "ex: Medieval Art, Baroque, Contemporary, etc",
    "CATEGORY": "ex: Sculpture, painting, etc",
    "TECHNIQUE": "type of technique with which it was done",
    "ESTIMATED VALUE": "estimated value at minting date",
    "COLLECTION": "name of the Museum where the collection or work is located",
    "LOCATION": "place where the work is located"
  }
```

4.3.3 Primary market

In Figure 4.1, it is illustrating the primary market of AerariumChain, which involves four main actors: the museum, the marketplace, the AEC reserve, and the user. Each of the actors is briefly illustrated.

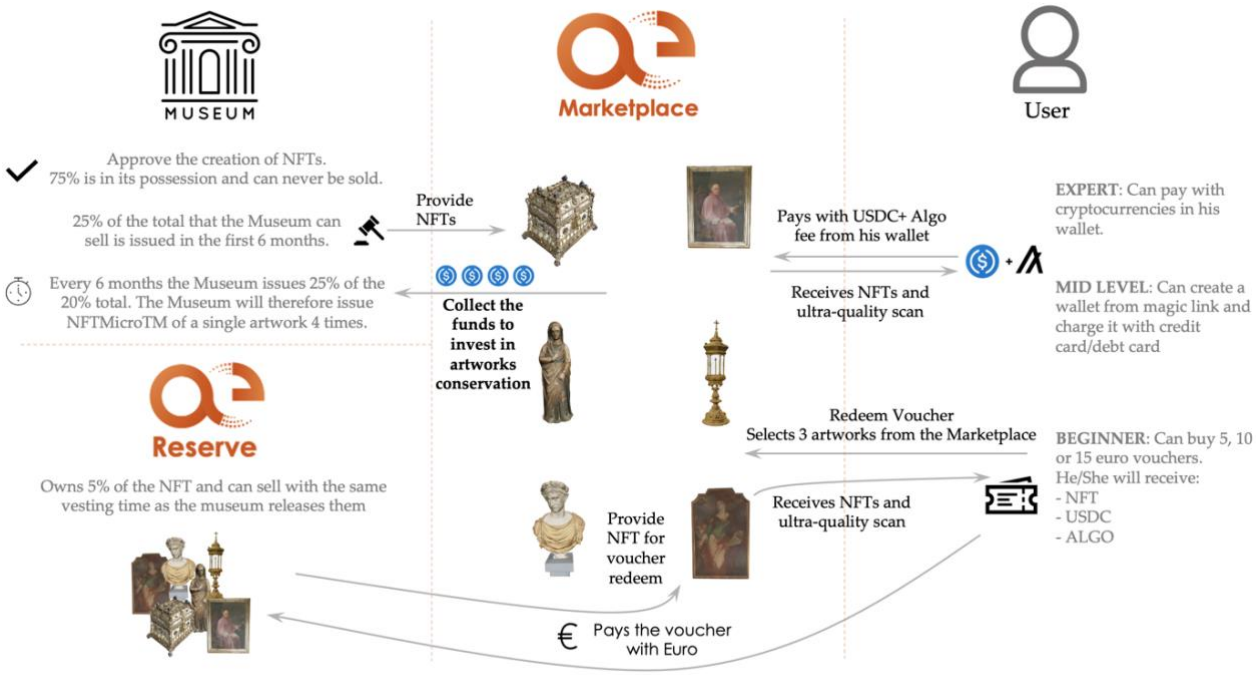


Figure 4.1: Representation main players AEC primary market (Source: By Author)

Museum

The museum plays a pivotal role in the process, beginning with approving the creation of NFTMicros. As the sole owner of the work's rights, only the museum can authorize its creation, as previously mentioned. The museum issues a fractional NFT, with 75% permanently held in its possession and never to be sold. To avoid oversupply, 20% of the salable NFT is released every six months, with the museum issuing 25% of the total amount during each period. The museum will then issue NFTMicro™ for a single artwork four times within a two-year timeframe. Additionally, the museum is contractually obliged to use the funds raised to restore and maintain the works.

Aec Reserve

The museum reserve currently holds 5% of the NFTs, which will become available for sale with the same vesting time as the museum releases them. Additionally, the reserve offers a voucher service aimed at novice users who either do not have a

wallet or prefer not to have one and keep the seed phrase. The service allows users to create a custodial wallet and receive vouchers containing NFTs, ALGOs for transactions, and USDC to make purchases.

Marketplace
The platform where the NFTs will be sold is set to launch on April 15, 2023. This platform serves as a crucial link between the objectives of AEC, the needs of the museum, and the desires of the clients. It offers a connection point that brings together all these elements in one place.

User
AerariumChain has identified three distinct user categories: experts, intermediates, and beginners. Expert users are those who already possess an Algorand wallet, have interacted with liquidity pools, and own some NFTs. These users are crucial during the initial phase of AerariumChain's launch, as they are likely to be the first to use the service. Beginners, on the other hand, are individuals who are passionate about art and culture but lack experience in the blockchain industry. This group requires a personalized, intuitive purchasing process that caters to their needs. Intermediates refer to all other users falling between the expert and beginner categories.

4.4 Achieving Liquidity: AEC Solution

Firstly, it is important to acknowledge that AerariumChain has undergone a thorough analysis, with each of its features being meticulously studied using the same set of variables outlined in the *methodology chapter*. A comprehensive breakdown of all 41 variables and their relative measures can be found in Table 4.1. While all the implemented solutions are presented in the table, the rationale behind them and the choices that led to certain values will be explained in the following paragraphs.
Of the numerous variables analyzed, particular attention will be given to four crucial categories: liquidity pools, key characteristics, economics, and problem solved.

#	Categories	Variables	Measure
1	General information	Name	AERARIUMCHAIN
2		Blockchain Network	ALGORAND
3		Founding Date	2022
4		Ownership	PRIVATE COMPANY
5		Capital Raised	756.000 €
6		Notable Investor	BORDERLESS CAPITAL
7		Categories	3D ART
8		Status	PROOF OF CONCEPT
9		Live Since	NOT LAUNCHED

10	Liquidity Pool	Token Format in the LP	ARC69
11		Forked/Build upon	1
12		Protocol name	PACT
13		Building method	AUTOMATIC
14		Asset in a Pool	ASSET-PAIR POOLS
15		Pair Asset in the Pool	NFT <-> USDC
16		Side	DUAL-SIDE
17		Pool for collection	0
18		Parameters	FOLLOW STRUCTURE AS DETERMINED BY THE PROTOCOL
19		Direct NFT ⟷ NFT swaps	1
20		Pricing Mechanism	Uniswap V2
21	Key Features	Fractionation	1
22		Multichain	0
23		Loan	0
24		Staking	NO
25		Audit	0
26		Other mechanism	FUNDRAISING FOR MUSEUM
27	Economics	Token Name	NO
28		Governance	0
29		Protocol fee	3,5%
30		Swap fee	FIXED VALUE
31		Cryptocurrencies Supported	USDC, ALGO
32		Credit Card/Debit Card	1
33		LP incentives	0
34	Performance	Total trading volume	/
35		Total revenue	/
36		Total number of User	/
37		Total number of NFT	/
38		Twitter follower	510
39		Discord user	212
40		Total Value Locked	/
41	Problem Solved		Wash trading, Centralization, Illiquidity, Low Democratization, Not Transparent price discovery, Impossible to sell instantly.

Table 4.1: Description of AerariumChain

As previously noted, the focus will now shift towards elucidating the decisions that were made. Since the introductory paragraphs of this chapter have already provided comprehensive details on the general information section, it will not delve into variables 1-9.

Key decisions: Primary/Secondary Markets, Thresholds, and Parameters

At the beginning of the project, a crucial decision had to be made that would significantly impact all subsequent choices: whether to maintain both the primary and secondary markets as trading mechanisms or not. By keeping both markets, there was a risk of creating two different prices of the same asset simultaneously, thereby presenting opportunities for arbitrage, as defined in *paragraph 3.2*. To simplify the model and, more importantly, eliminate the possibility of two trading channels, it was determined that the primary market would be closed once a

liquidity pool was created for a single collection. It's worth noting that each collection represents a single artwork that is divided into thousands of NFTs, as described in the *NFTmicro description paragraph*, giving it the appearance of being collectible. This decision had a domino effect on subsequent choices, such as determining when to activate the secondary market if only the secondary market was kept.
Therefore, the second decision to make was to **determine the conditions** under which a liquidity pool could be established for the secondary market. Specifically:

- Decide whether to activate the liquidity pool for all artworks for sale on the primary or not. In fact - some works are worth more than one million euros - others are worth a few thousand. In the event that the decision to activate only for some was upheld, the following should have been determined:
    - *Minimum threshold value* of artwork for which there will be a liquidity pool to avoid creating pools that were too small.
    - Figure out how to manage the secondary market for artworks *below* the critical threshold should it be chosen to be defined.
- The *percentage* of the primary market supply sold to *trigger the secondary market*. This refers to the minimum number of fractions to be sold in the primary market to establish a stable secondary market.
- *Minimum liquidity provided to LP* to make a swap stable under *normal* market conditions. Clearly any LP would experience large slippages and price fluctuations in the presence of high-volume swaps.
- *Ratio of circulating supply* compared to the amount of NFTs in the Liquidity Pool. This needs to be determined to avoid too many NFT holders and not enough NFTs in the LP. In a *panic sell* event, if everyone sold NFTs there would be an insufficient amount of USDC.

  This decision has an impact on all subsequent decisions regarding the **building of the liquidity pool**, in particular:
    - Consider whether to establish a *maximum swap allowed* to avoid too significant price swings or set a *maximum slippage percentage.*
    - Decide whether to construct the liquidity pool in-house or rely on third-party providers or existing decentralized exchanges or to *fork* an existing smart-contract.
    - Determine the *curve* that will be used to set *prices* within the liquidity pool.
    - Choose the *building method* the liquidity pool, such as automated or manual.

- Determine who will be allowed to act as a *liquidity provider*, including everyone, only museums and AECs, or only collectors and large funds that wish to donate to museums.
- Decide how many *collections* should be included in each liquidity pool, which *asset pair* should be used, and which *side* should be favored.
- Establish the decision-making process for setting the *parameters*.

The decisions mentioned above have a significant impact on the company's business model, the *fee* structure to be applied, and various aspects of **economics**, which including variables 27 to 33.

Minimum threshold value

The first decision was whether to activate the liquidity pool for all the works for sale on the primary market or to differentiate based on the price. None of the projects analyzed had considered the option of differentiating on the basis of price, applying the same exchange mechanism for all NFTs. However, upon analyzing the liquidity pools of the projects surveyed, it became clear that higher-value NFTs had greater liquidity and price stability within the liquidity pool. Sudoswap exhibited a correlation between the value of the total collection and liquidity. Additionally, almost half (47,35%) of the NFTmicros in the first collection from the Diocesan Museum of Mantua had a value between € 1,000 and € 10,000. If a liquidity pool were in place, an exchange of € 100 for such works would cause an unacceptable price impact. To create a standardized and transparent market, artworks were divided into five price ranges (Table 4.2).

Tier No.	Value Range	Museum of Mantua
1	€1,000 - €10,000	107
2	€10,000 - €100,000	62
3	€100,000 - €1,000,000	46
4	€1,000,000 - €10,000,000	11
5	€10,000,000 and above	0

Table 4.2: Tiers' representation and distribution of the first drop artworks by tier

In January 2021 it was calculating the average swap of a user on Tinyman and Pact - the two most important dex in Algorand. It was found that The median swap size in

the USDT/USDC pool was $ 30 over the past 90 days, while the average swap size was $ 46. Including the constant product pool with millions of TVL, the average swap size increases to $ 146 in Pact's liquidity pool. Taking these calculations into account, it was decided to include only Tier 4 and Tier 5 works (minimum value of €1 million) in the liquidity pool to ensure price stability by a wide margin. It's important to note that even Tier 4 artworks - as specified in the *NFTmicro description paragraph* - have a maximum of € 200.000 that can be sold by the museum while the AerariumChain reserve holds € 50.000. Larger swaps can reach even thousands of euros.

Regarding the secondary market management problem for other works below the chosen critical threshold (Tier 4) mentioned in the previous section, the solution for Tier 1-2-3 works will be explained at the end of this Chapter. For now, let's focus on the Tier 4-5 solution using the liquidity pool.

Triggering the Secondary Market and Ratio of circulating quantity

After reviewing the average purchase described earlier, it has also been examined the average purchase and sale of NFTs based on available data and literature. The research indicates that, on average, NFT purchases typically range from a few tens of dollars to a few hundred euros, with users rarely swapping thousands of euros on non-stablecoin asset pairs. To determine the minimum amount of initial liquidity required in the liquidity pool, an inverse method was employed. This involved simulating a purchase on traditional DEXs on the Testnet to assess the impact price. The impact price formula for a traditional liquidity pool is given by the equation:

$$Price\ Impact = 1 - \frac{Price\ before\ the\ swap}{Price\ after\ the\ swap} \qquad (5.1)$$

The price impact is a measure of the effect that a swap has on the price of the traded asset. A larger price impact indicates a greater effect on the price, while a smaller price impact indicates a smaller effect. In most liquidity pools, a reasonable slippage limit is considered to be between 1-3%, with a maximum of 10%. To calculate the price before the swap, the ratio between the reserves of the two assets is used. The price after the swap is calculated by taking the ratio between the two reserves amount, to which the quantity of tokens exchanged outside the pool is added to the denominator.

Figure 4.2 shows a simulation of a swap of $146 - which is the average of a swap in a stablecoin pool on Pact - taking into account that in reality AerariumChain's liquidity pool will not be a stablecoin pool and therefore the average would be $100 less.
The impact price of the swap is observed to decrease as the pool size increases, reaching 0,565 % in a $50.000 compost pool and its NFTmicro counterpart. On the other hand, in a very small pool like the one depicted first in the Figure 4.2, the impact price is significantly higher at 39,23 %.

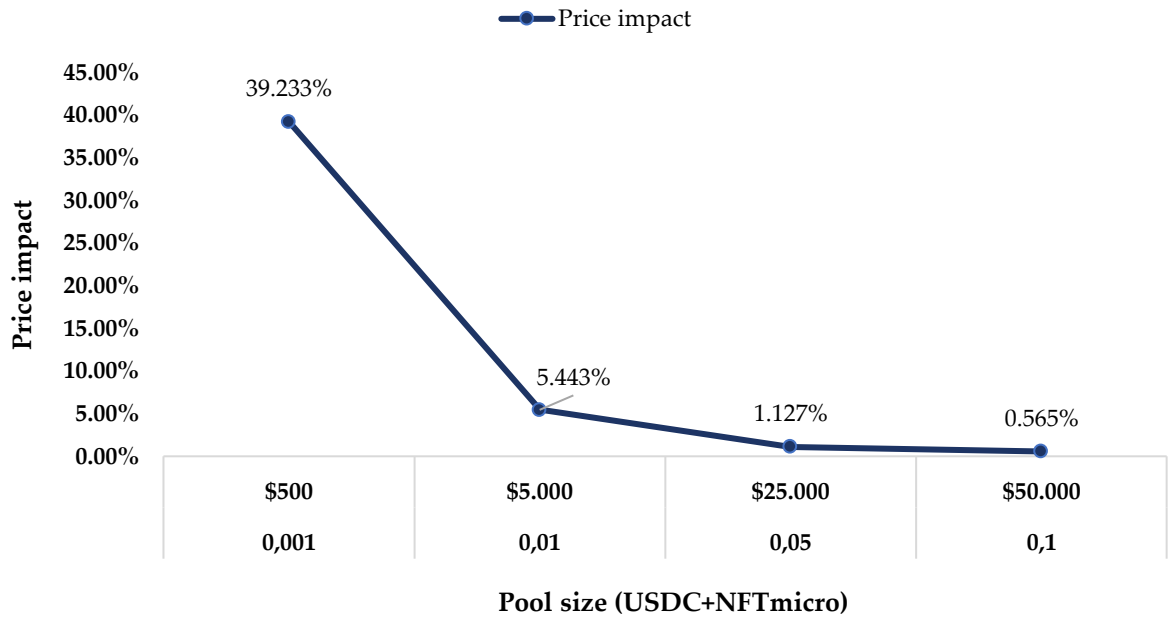


Figure 4.2: Price impact of 146$ sell order in different pool sizes

Taking into account the simulations and the analysis carried out, a minimum of 25.000 USDC liquidity and the counterparty in NFTmicro was established to reach the secondary market. If the single fraction is worth $1, 0,025 NFTmicro must be entered, i.e., 25.000 micro fractions. This value was chosen because it allows for a swap of $146 with a price impact of 1,127% and a swap of up to $ 500 with a price impact of 3,71%. The maximum exchange allowed is $ 1.500 with a 10% price slippage, which is a rare occurrence. The majority of buys or sells fall within the 1-3% range, which is the standard in this industry. It is important to note that the liquidity being discussed refers to the initial liquidity, which can only be provided by AerariumChain and the Museum. However, it is expected that the total liquidity in the pool will be higher since users can also become liquidity providers and earn commissions on each trade made. The reason user-provided liquidity was not considered in this simulation is to focus solely on the stability of an average swap, without accounting for additional variables that may or may not exist.

Ratio between circulating and salable supply

After determining the minimum amount required to enter a liquidity pool based on price impact, it is important to analyze the ratio of circulating to salable quantity within the pool. This means that the liquidity pool will not automatically activate after selling $25.000 in the primary market but more NFTs need to be sold. However, the analyzed projects did not distinguish between circulating supply and salable quantity. Therefore, other types of markets had to be studied. Traditional stock markets maintain a ratio between the two quantities that depends on factors such as market capitalization, number of shares, liquidity, and investor sentiment. Large companies with a market capitalization of over $100 billion may maintain a ratio of 10-20% of shares available for trading in the secondary market, while smaller companies may have a ratio of over 50%. Given the volatility of the sector and the higher risk associated with this type of asset, a ratio of 75% was chosen.
Using the previous example of a Tier 4 asset with a single fraction value of $1 that needs to be sold into the liquidity pool, 25.000 fractions will be placed, but at least 33.000 must be sold in the primary market to ensure liquidity in the secondary market.

Constructing the liquidity pool: key decisions

In the previous paragraph it was fully explained the reason why the liquidity pool will be activated by inserting the equivalent of $ 50.000 divided in half by NFTmicro and USDC only for those Tier 4 and 5 works and the reserve will try to maintain more or less the ratio between quantity sold and stable available quantity. This paragraph will explain how the liquidity pool will be constructed and all its *variables* that have been analyzed in the census.

The first major decision in building the liquidity pool was whether to develop the smart contract in-house or collaborate with third-party providers, such as decentralized exchanges or forking an existing smart contract. Developing a smart contract internally can cost over $ 50.000, including the audit. To evaluate the costs and benefits, simulations were launched in November. While not ruled out creating the smart contract in-house, the team also explored the benefits of working with a DEX. Simulations were performed on existing smart contracts and contacts were made with Pact. An important moment was in Dubai at the Decipher from 27 to 29 November 2022, where there was the opportunity to get to know the whole team and show the first simulations and start collaborating together. In particular in the first simulation regarding the construction of an NFT AMM the main problem was how the fees were collected.

It is now desired to report this problem in depth as it is the most technical criticality that was encountered. First of all - to run the simulation - a fractional NFT was built on the Algorand Blockchain in Testnet. The asset ID of the NFTmicro is: 105290545 and was randomly named "Sekhmet1". The liquidity pool ID is 117444971. The simulations of the transactions that took place on this test liquidity pool are verifiable on AlgorandExplorer. Table 4.3 represents five transactions – it has been chosen to represent the simplest but also most explanatory case – showing in the five columns respectively in order: the price of a single fraction of NFT, the amount deposited within the liquidity pool, the amount received by the user, the amount that should have been received without commissions and the fees. In the *Amount deposit* column, reference is made to NFTs deposited within the liquidity pool when the figures are *decimal*, while reference is made to USDC for integers values. In other words, in rows 1, 3 and 4 the user is giving NFTs to the liquidity pool in exchange for USDC. In rows 2 and 5, the reverse transaction is represented.

1 Fraction Price	Amount deposit	Amount Received	Gross Amount Received	Fee
2,81652955	0,00001	2,76048	2,788364	0,027884
2,82075945	10	0,00002	0,000034	0,00001
2,98036679	0,00001	2,920759	2,950262	0,029503
2,92075945	0,00001	2,862635	2,891552	0,028916
2,86292551	10	0,00002	0,000034	0,00001

Table 4.3: Fees problem analyzed in the simulation

Upon examining Table 4.3, a problem with the fee calculation becomes immediately apparent. The issue arises from the fact that a fraction of NFT initially has a value of approximately $ 2,81. In the first transaction, the user deposits an NFT into the liquidity pool and receives $ 2,76 in return after paying a few cents in fees, which is executed correctly. However, in the next transaction, the user gives $ 10 to the liquidity pool and should receive at least three fractions in return but instead receives only two fractions and pays a fraction of NFT as commission. The initial model called for fees to be paid out of the asset received from the liquidity pool, and as a result, when the user received USDC, fees were paid correctly, but in the opposite scenario, the smaller fraction of the NFT was charged as fee, which in this case was equivalent to about $ 3. This issue caused a user who deposited $ 10 to receive only about $ 6 after paying another $ 3 of NFT in commissions. The cause of this problem is that USDC has decimal values while NFT has integer values between the fractions.

At Decipher in Dubai, these initial simulations were shown in a conference with Pact team, and it was decided to collaborate and work together to solve this problem. AerariumChain provided knowledge of the NFT world, and Pact provided knowledge of the liquidity pool to build an innovative AMM NFT model. The collaboration resulted in a successful outcome, and the AMM is expected to be an innovative solution for the secondary market. Specifically, the innovative solution is to allow fees to be paid with a single token, thus avoiding the problem encountered previously. The collaboration and sharing of research material on the NFT AMM market led to the final decision not to fork the smart contract but to build AerariumChain's liquidity pools on Pact. Figure 3.1 showed that exactly half of the projects analyzed (50%) had forked or built the liquidity pool on other projects, notably Sudoswap and Uniswap. The choice of AEC increased this percentage. Exchange of two assets such as USDC and NFT in the same pool was also new to Pact. Modifications were made to the smart contract, and the liquidity pool was customized according to the requests of AerariumChain, who arrived at a knowledge of how it would want the liquidity pool thanks to the analysis shown in the previous chapter. This initial decision influences all the other variables that have been already seen in the analysis done and that the proposed solutions will now be illustrated, including the building method, the asset in a pool, the pair-asset, the side, the number of collections within the pool, the pricing mechanism, all the parameters, and everything attached fees and LP incentives.

Liquidity pool features:

In Figure 3.5, it is shown that the majority of projects (89%) opted to build their liquidity pool in asset-pair mode. AerariumChain's proposed solution is in line with this figure, as it provides stability and simplicity, and there is currently no multi-asset liquidity pool solution in the Pact protocol. Specifically, the exchange pair for AerariumChain's liquidity pool will consist of NFTMicro and a stablecoin (USDC) chosen for its stability, robustness, and transparency [80]. The stablecoin component provides greater stability and reduces complexity by minimizing variables that can affect the price. Solvent is the only project analyzed that took a similar approach, and it presented strong and efficient liquidity pools. While only a minority of protocols (16%) allow exclusively dual-sided LPs, AerariumChain's solution involves this type of exchange instead of single-sided LPs. This is because NFTMicros are already sold individually on the primary market, and the company wants to keep the price stable on that market without introducing a price curve. In the secondary market, both buy and sell transactions should be allowed.

Based on the data presented in Table 3.1 and Figure 3.6, an automatic liquidity pool creation mechanism that follows protocol guidelines was chosen. This decision was reinforced by the analysis in Table 3.9, where projects that applied certain rules in liquidity pool construction as an automated process improved the wash trading problem in 57% of cases and were more effective in price efficiency and price discovery transparency compared to those constructed manually or hybrid as shown in Figure 3.20.

Regarding the number of collections within a single liquidity pool, the majority of analyzed projects (59%) chose to create multiple liquidity pools for a single collection. However, AerariumChain did not follow this practice to avoid arbitrage as described in the section on whether to keep the primary market after opening the secondary market. For each NFTMicro, a 1:1 relationship between the liquidity pool and Tier 4-5 NFTMicro is maintained.

Price mechanism and fee

Before moving on to explain the solution for Tier 1, 2 and 3 artworks - meaning those below the threshold just identified - the goal is to explain the last two crucial decisions regarding the liquidity pool: the pricing mechanism and the commission.

In the beginning, it has been taken in consideration different price mechanism seen from the other project in the analysis such as: linear or exponential bonding curves, virtual constant product, Uniswap V2 constant product, auction model, or other types of models. AerariumChain's aim is to provide more democratization, instant liquidity to the user, try to solve the wash trading problem, and be transparent in price discovery while maintaining a liquid market. Analyzing the data presented in Table 3.6, it was found that the Uniswap V2's constant XYK product is the pricing mechanism that best solves the problems mentioned above. It solves more problems (4) than any other pricing mechanism and solves the highest percentage (82%) of the problems that emerged from the literature review. Therefore, despite its application in only 11% of the analyzed cases, it has been decided to adopt this pricing mechanism to build the best possible model for the user. The price curve was generated by combining two simulations to illustrate how NFTMicro prices will fluctuate based on buying and selling activity. Initially, a liquidity pool was established with 0,050000 NFTmicro and $25.000, with the value of a single NFT set at $0,5. Next, 2273 transactions were simulated where 0,0000880 NFTmicro was sold to the liquidity pool, worth approximately $46 at the start. In the second simulation, 2533 transactions were carried out where NFTs worth $46 were bought from the liquidity pool. Combining the 4906 points of the transactions resulted in the price

curve - shown in Figure 4.3 - assuming that the value of stablecoin is indeed stable against the dollar It has been chosen to simulate the variation of the price curve with purchases of $46 as it was the average amount of exchange of a user on Pact. The X-axis shows the amount of NFTmicro within the liquidity pool, and the Y-axis shows the amount of USDC. The maximum salable is 0.25 each artwork - and thus the X-axis stops at that value - while the Y-axis can go beyond the indicated value.

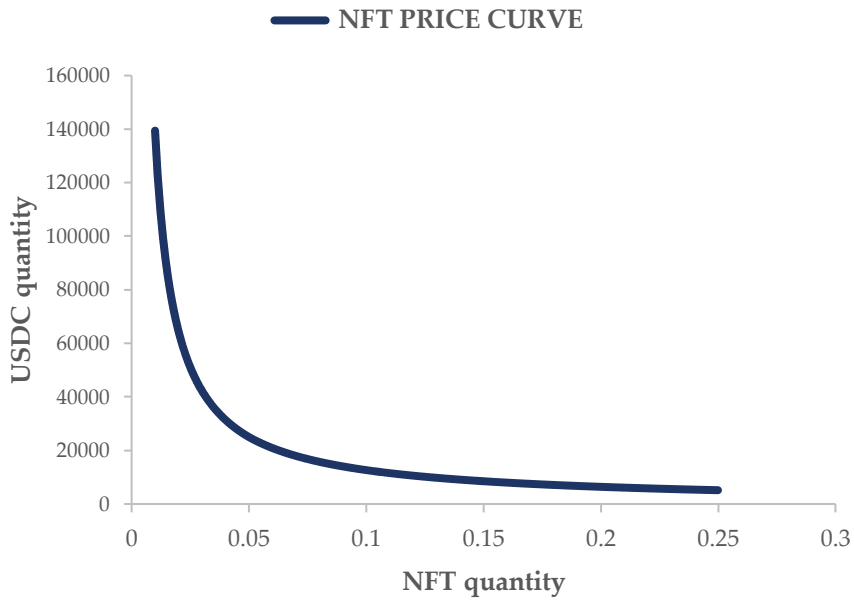


Figure 4.3: Representation of the price curve obtained by simulating 4906 transactions. USDC assumed stable at $1

In the starting situation (0,05; $25.000) - the price is $0,5 - calculated as the ratio of the two quantities divided by the total number of decimal places of the NFTmicro fractions. If many users buy NFTmicro, its quantity within the liquidity pool will reduce, leading to an increase in its value. For example, at the point (0,01; $139.433), the price will be $13,94, i.e., an increase of 2688%. Conversely, if all users sell NFTmicro and the price end up at the point (0,247384; $5.196), the price will be only $0,021, showing a -95,80% decrease from the initial price. At the start (0,05; $25.000), the price is $0,5, which is the ratio of the two quantities divided by the total number of decimal places of the NFTmicro fractions. If many users buy NFTmicro, its quantity within the liquidity pool will decrease, leading to an increase in its value. For example, at the point (0,01; $139.433), the price will be $13,94, representing a 2688% increase. Conversely, if all users sell NFTmicro and the curve ends up at the point (0,247384; $5.196), the price will be $0,021, resulting in a -95,80% decrease from the initial price. The points in the graph are discrete due to the minimum fraction of an NFT being $1 * 10^{-6}$; however, they form a curve which illustrates the price

variations based on the asset reserves within the liquidity pool. To simplify the visualization of the price change and the curve, a dashed black line is included in Figure 4.4. Moving from point 1 to point 2 on the curve requires selling asset A and buying asset B, while reversing the operation takes the user back from point 2 to point 1.

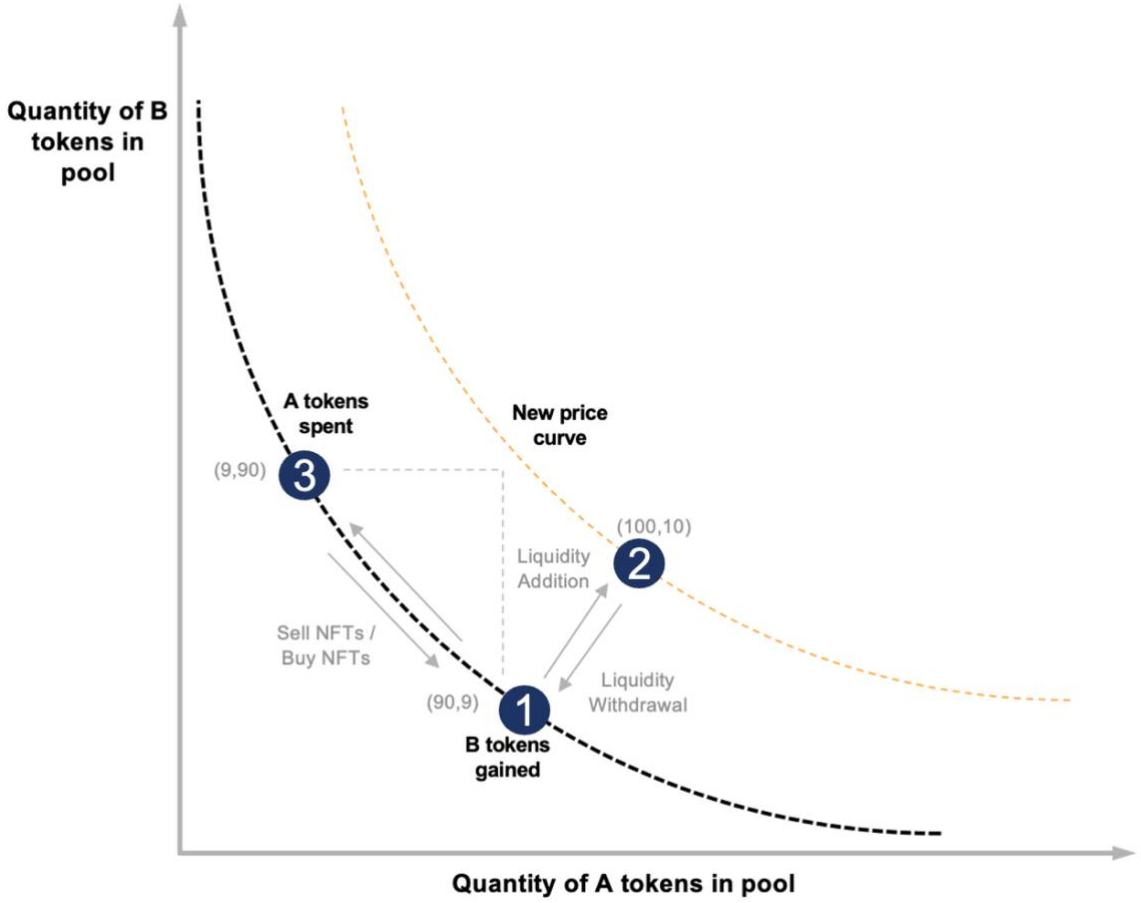


Figure 4.4: Simplified representation of a swap, and a liquidity addition/withdrawal (Source: By Author)

The transformation of the price curve happens through an addition or withdraw of liquidity, which has no effect on the price if the 50:50 ratio is maintained. The greater the liquidity, the more stable the price, as more buying and selling activity is necessary to move the price. The mechanism being discussed illustrates how it can be beneficial for the user, while also supporting the business of the museum and AerariumChain. It will now be explained how. When a liquidity provider adds funds to the pool, a new token is created that represents their proportional share of the total pool. In exchange for providing liquidity, LPs earn a portion of the trading fees collected from the pool. The mechanism for commissions within a liquidity pool is

simple. When a trader executes a trade on the pool, a commission is charged as a percentage of the trade amount, and this commission is split between the liquidity providers and the protocol itself. For AerariumChain, the fees are fixed at 3,5%, and LPs must withdraw their share of the pool to claim their earnings. However, as the value of the pool changes due to trading activity, LPs may receive a different percentage of the tokens they initially deposited. When an LP withdraws their liquidity, the AMM calculates the present value of their share of the pool and transfers it to their portfolio. LPs can make a profit by providing liquidity if the trading fees earned exceed any losses due to fluctuations in the value of the pool. AerariumChain and the Museum will provide 42,86% and 57,14% of the initial liquidity, respectively, and will receive 1,5% and 2% of the fees in the absence of other liquidity providers. Pact will take a variable percentage between 0-1% according to its business model.

To test how many transactions a user starting with $10 can make before running out of cash, a small simulation of this case study was conducted. The starting situation of the liquidity pool was always the same (0,05; $25.000). It was found that after 33 transactions, the user would be left with $0,48 and had generated a trading volume of $147,08, resulting in $6,2 in fees distributed between the Museum and AerariumChain, and $1,49 for Pact. Concluding, the census reported the total traded volume of Live projects, with an average of € 16.921.997,23 but this varies greatly among the projects. *Liquid collectibles* have only $8.000 of traded volume, while *Sudoswap* has $97.378.439. *Solvent* [2], which applies the same pricing mechanism as AerariumChain, has a total of $5.395.620 in traded volume. Applying commissions to the average yields $592.269,90 in fee income distributed between AEC and the Museum.

Secondary market for artworks of Tier 1-2-3

After explaining the mechanism for Tier 4 and 5 works, the aim now is to describe the project's solution for works that don't meet the threshold of $ 1.000.000 of artworks value described earlier. Table 5.1 illustrates how AerariumChain is intended to incorporate a swap feature between two NFTs. Only 24.32% of the analyzed projects - as shown in Table 4.1 - offer this service, making it essential to provide a secondary market for Tier 1-2-3 works. Moreover, the *exchange of stickers model* is convenient for AEC as it earns a percentage on each transaction without incurring additional costs. Specifically, the secondary market for these types of works is split into two: *NFT-NFT swap* and *ZAP*.

1. *NFT-NFT swap*: This service allows a user who has purchased a Tier 3 or lower artwork directly from the marketplace in the primary market to exchange it with another NFT. AEC Reserve offers this service while retaining a fixed commission of 1 USDC + 0,5% of the traded volume. The user can benefit from this service if:
    a) Want to exchange some NFTs - perhaps because they have many of the same work - to obtain other NFTs and have access to other 3D images without incurring further expenses.
    b) No longer want NFTs and wish to obtain their value back in USDC. Since there is no liquidity pool for this type of Tier, the user needs to exchange the NFT they own for one of the Tier 4 or 5 artworks with an LP. Then, they can sell the new NFTs through the liquidity pool, receiving the dollars back. Therefore, by completing two steps, the user will be able to receive USDC even if he had bought a Tier 1 or 2 or 3 NFT on the primary market

It's evident that exchanging two NFTs with different values doesn't always match perfectly. In such cases, the matching method is calculated as a delta that the user must pay in USDC. The formulas for calculating the delta are given in equations 4.2, 4.3, and 4.4. In the formula reported, A represents the NFT that the user is depositing, and B represents the NFT that the user is receiving through the swap.

$$Amount\ received = \frac{(quantity\ A\ *\ Price\ A)}{Price\ B} \tag{4.2}$$

$$Delta\ \$ = (Price\ B * amount\ B) - (Price\ A * Amout\ A) \tag{4.3}$$

$$Fee = (Price\ NFT\ A * Amount\ A) * (1 + 0{,}5\%) \tag{4.4}$$

In particular - the result of *amount receive* calculated as in equation 4.2 - has been rounded up to the first integer.

2. *ZAP swap* is a convenient service that allows users to trade NFTs below Tier 4 for USDC in a single step. This service simplifies the process for beginner users who can now perform the operation in one step rather than two. However, the service is more expensive, with a fee of 1 USDC + 5% of the total volume traded at the start. The 5% commission includes 0,5% swap between two NFTs and 3,5% within a liquidity pool. It is worth noting that this service is more expensive than making two independent steps of swapping NFTs and exchanging within the liquidity pool, which add up to 4% commission. It is important for users to understand that exchanging €1.000 of an NFT will not

result in receiving the full amount after deducting the 5% commission, as the impact price described above will also affect the NFT's price within the liquidity pool.

A simplified summary of the AerariumChain secondary market mechanism is reported. The artworks will be categorized into 5 Tiers, and only Tier 4-5 artworks with a value of over one million will have a liquidity pool on Pact. This will be an asset-pair, dual-side exchange market with a 3,5% fee, automatically built once the threshold value is reached on the primary market.

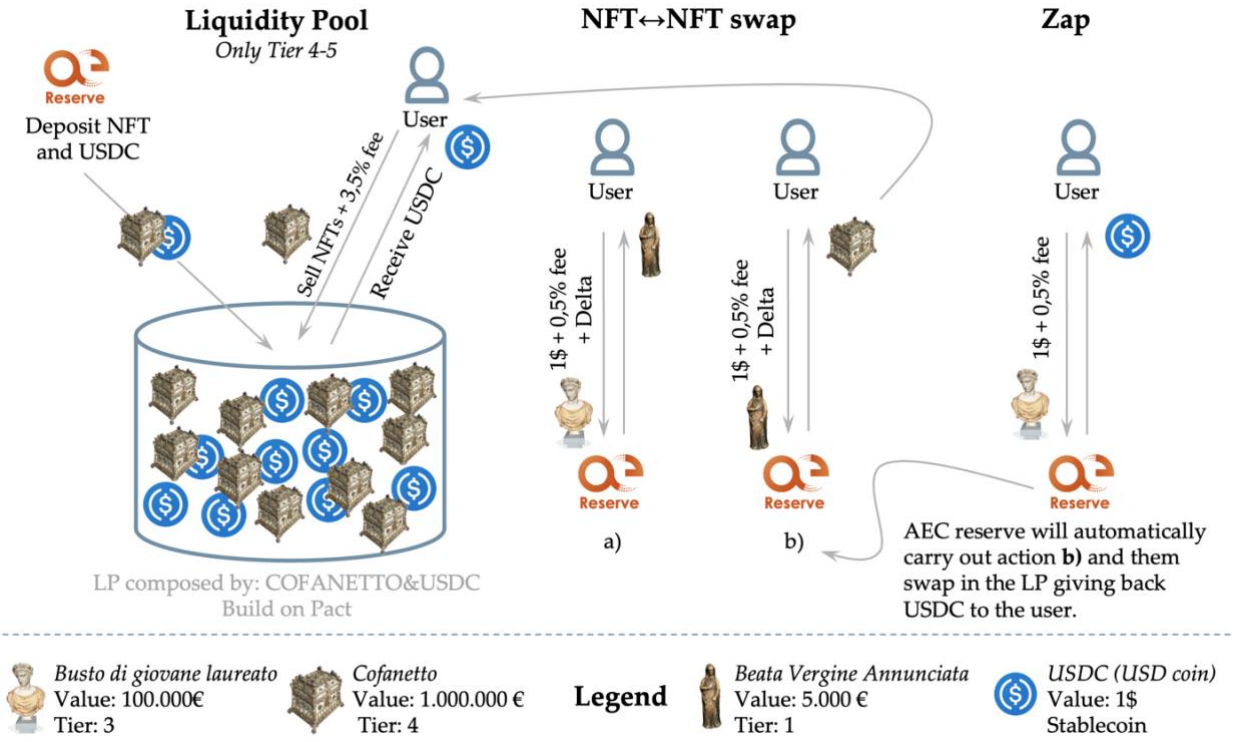


Figure 4.5: Secondary market representation of AerariumChain (Source: By Author)

For Tier 1-2-3 works, the primary market will remain available for fixed-price purchases, while their secondary market will rely on NFT-NFT swaps or ZAPs. The first mechanism allows users to exchange artworks between any Tiers with a commission of 0,5% + $1, while the exchange price is determined by some formulas, including equations 4.2, 4.3 and 4.4.

The ZAP mechanism, on the other hand, enables direct exchange of Tier 1-2-3 artworks for a stable-coin, with AerariumChain Reserve managing the intermediate transactions.

4.4.1 Advantages

The decision to differentiate the activation of the liquidity pool according to the price ranges of NFT artworks could have several advantages. This approach should provide a more stable environment for NFT sales, with greater liquidity and price stability than other designs studied. By minimizing market volatility, the risk of wash trading could be significantly reduced.
To achieve price transparency, the constant product pricing mechanism of Uniswap V2 has been adopted. This could not only provide effective pricing but also mitigate centralization issues as it relies on a DEX. With a high fee of 3.5%, users should be discouraged from wash trading by ensuring that volumes traded within the liquidity pool accurately reflect actual volumes.
By implementing the NFT and ZAP exchange mechanism for works of Tier less than 4, should be possible to allow users to instantly sell their NFTs and receive USDC without having to wait for another user to buy their NFT although the liquidity for this type of work is not a lot. This mechanism is essential to AerariumChain's business model and ensures constant liquidity in the secondary market.
The solution aims to solve the problems of wash trading, centralization and lack of democratization. With a diversified mechanism and pricing structure adopted, it is intended to ensure price effectiveness and better discovery while allowing users to sell their NFTs immediately. For those interested in becoming liquidity providers, it also offers the possibility of substantial passive income. Overall, the solution wants to provide a robust and stable ecosystem for selling NFTs, creating a level playing field for all users and maintaining a high level of price transparency and effectiveness.

4.4.2 Limits

While acknowledging the potential advantages of the proposed solution, it is important to consider the possible limitations and disadvantages that could arise from it. In particular, limitations have been identified:

- The first significant limitation is that this model is not currently commercially available yet as it has not yet been implemented, making it difficult to test the potential advantages or disadvantages of the approach. Without real-world data, it is difficult to accurately evaluate the effectiveness of the solution in solving the problem of washing, centralization and lack of democratization or price effectiveness.

- Another limitation relates to the fees that may be too high, discouraging small trades in the secondary market, leading to a lack of liquidity.
- Additionally, in the case of a panic sell or extreme situations, the lack of an incentive mechanism to reduce the supply of NFTs could cause liquidity pools to have many NFTmicros and few USDCs. To mitigate this, mechanisms such as NFT burn or staking options could be implemented.
- Furthermore, if USDC loses its peg - as happened on March 11, 2023 due to the failure of Silicon Valley Bank - the liquidity pool's proper functioning could be compromised, resulting in serious losses. This problem can be solved by trying to differentiate between the available stablecoins trying to stay up to date on the best one to use, however the risk remains in using it.

By taking these limitations into account and developing strategies to mitigate potential problems, AerariumChain can work towards creating a more robust and sustainable NFT market.

4.4.3 Future development & follow up

To achieve its full potential, the proposed model, like any new and innovative solution, requires further refinement and development. Thus, it's crucial for AerariumChain to seek feedback from users and industry experts, conduct thorough testing and analysis, and identify areas for improvement. Implementing additional mechanisms to incentivize participation and discourage panic selling, such as introducing rewards for holding NFTs for longer periods, could be explored. Furthermore, broadening the range of stablecoins available can also reduce the risks associated with potential USDC loss of the peg.

AerariumChain can follow the path of already live projects seen in figure 4.10 by implementing the possibility of offering NFTmicros on different blockchains, which can expand the number of reachable users. A solid and stable secondary market can guarantee the possibility of loans and collateralization of NFTs by increasing the use cases of the latter. Once generating revenue, investing in drafting an Audit can offer users as many guarantees as possible.

Overall, with continuous development and refinement, the proposed model has the potential to become a powerful tool for promoting the democratization and decentralization of NFT trading. It can improve efficiency and stability in the market and solve the illiquidity problems of the current NFT secondary market.

5 Conclusion

This thesis - in conclusion - provides a comprehensive empirical analysis of an aspect that has been neglected in the literature on the NFT secondary market and offers a proposed solution design developed during the internship at AerariumChain. In fact, although the literature identifies the main critical issues in the current NFT secondary market, empirical studies are scarce and there is a lack of research that examines and analyzes current projects that attempt to solve these critical issues and the mechanisms they intend to adopt. The main benefit of this research is the creation of a reliable framework that can be used as a basis for future implementations, as well as a solid design for the aforementioned startup. An attempt was made to answer the research question by presenting the main features of each project that identified the highlighted problems and developed a mechanism for trading NFTs in the secondary market through the liquidity pool.

What emerged most from the analysis on NFT AMM protocols is the potential of this market - despite being in the early stages - and that the development of NFT AMM designs is relatively rapid. The results show that most projects use linear and exponential bonding curves, while the constant product Uniswap V2 model is the least used. However, in the solved problems section, the analysis also revealed that it is precisely the least used price model - because the most complex to implement - that also appears to be the most effective in solving certain problems. Among the problems solved by the protocols, those of greatest interest to the projects are those related to the inability to instantly sell NFTs and illiquidity. Other pricing methods using innovative and singular pricing methods also show promising results. These results provide valuable information for the development of NFT AMM protocols and can guide future research and development in this area.

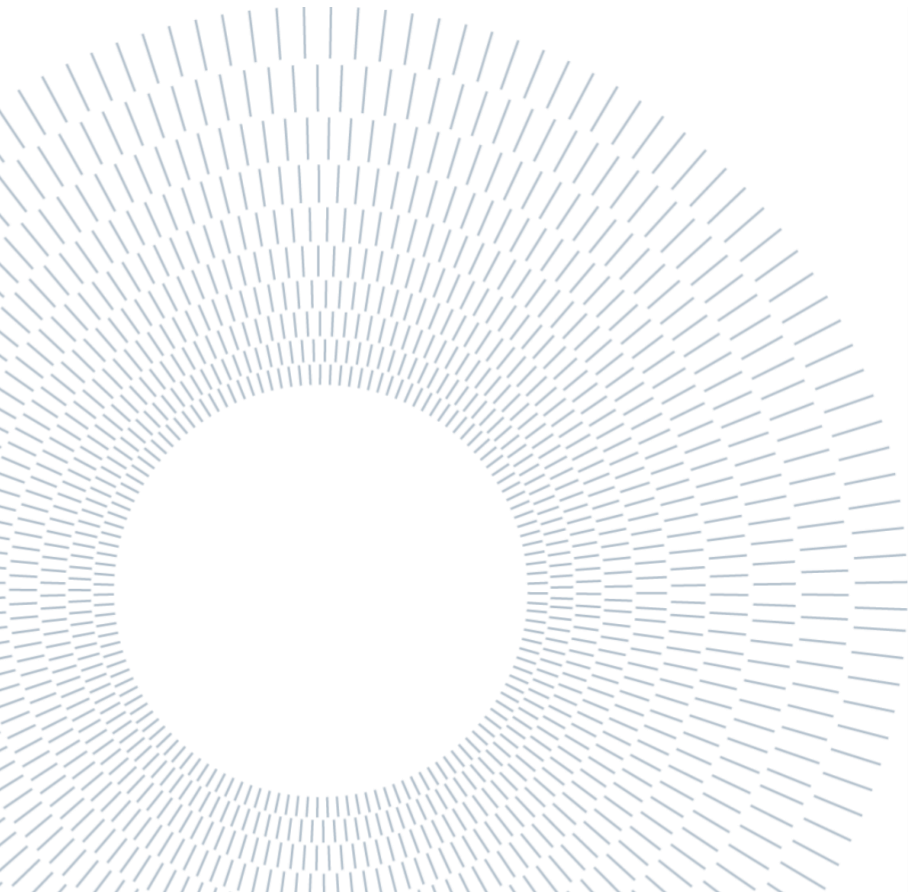
The solution proposed by AerariumChain uses precisely the model of Uniswap V2 for the secondary market and introduced an essential innovation, which is the differentiation of the type of exchange according to the value of the artwork and also what is more important is that it showed a model to make decisions and simulate the

impact price, calculate the minimum amount of liquidity to ensure a stable market and took into account the disparity of different NFTs. Indeed, understanding how the proposed solution was arrived at can be incredibly useful for developers and programmers working in NFT marketplaces today, enabling them to stay at the forefront of the industry and drive innovation by improving the solutions offered to users.

In addition, it is believed that the best exchange model for the secondary market for NFTs strongly depends on two main factors: the type of NFT and its value. In fact, what emerges from AerariumChain's model is that NFTs cannot all be treated in the same way, but must be categorized and the best exchange model must be found for each cluster of NFTs. It is hypothesized - both from the analysis performed and from experience in AerariumChain - that for all those rare and high-value NFTs, the best model would be the most widely used model, i.e., auctions and direct deals. The liquidity pool model would fit for this type of NFT only in the case of deciding to fractionalize them by making their value very accessible and the market more democratic, which is exactly the case in AerariumChain. The liquidity pool model also fits well for all collections where the value of the NFT does not vary too much between one NFT and another, thus managing to be able to trade two NFTs from the same collection at the same price. It is also noted that not all NFTs need a very liquid secondary market, one example out of all are NFTs that are used as event tickets in which the event is sporadic and there is no constant demand.

However, this paper is subject to four main limitations. First, the low number of existing NFT AMM projects reduces the robustness and consistency of the results obtained. In addition, almost all of the projects analyzed are initial pilot projects that have not yet reached full implementation, which limits the conclusions that can be drawn. As more and more projects move from the proof of concept phase to the live phase, it will be interesting to explore their performance. The second limitation concerns the lack of tools available to test the effectiveness of the proposed solutions. While the projects analyzed aimed to address inefficiencies in the current trading mechanism in the NFT secondary market, no tool was designed to verify an improvement objectively and numerically in metrics. The third limitation pertains to the AerariumChain solution, as its implementation and validation in the market could not be carried out. Finally, the last limitation relates to the fact that the liquidity pool mechanism was applied to a specific category of NFTs, and the analysis lacks a framework that compares on different axes the category of NFT, the value of NFT, and the best exchange type.

Nevertheless, these limitations may offer insights for future studies. Firstly, it is recommended to expand the set of applications to complement and/or modify the current framework over time and to survey new projects that will arise in this area in the future. Secondly, it is suggested to develop or use tools to verify whether the problem analyzed, such as wash trading, is affected differently by the liquidity pool mechanism and whether it leads to an improvement. Finally, an interesting analysis would be to survey all the exchange mechanisms used with the different pricing methodologies and analyze in detail the value of each NFT and the price difference between NFTs in the same collection and try to create a dashboard categorizing the best exchange model according to the type of NFT. Overall, this research provides a solid foundation for future studies in the field of NFT AMM projects and their potential solutions. The proposed solution design can serve as a starting point for further research and development in this rapidly evolving and exciting field. With continued development and improvement, the model has the potential to become a powerful tool for promoting the democratization and decentralization of NFT trading, improving market efficiency and stability, and solving the illiquidity problems of the current NFT secondary market.



Bibliography

[1] Quantix Protocol, 'Quantix mechanism', *https://docs-quantix.gitbook.io/documentation/project/free-market-quantix-amm*, Oct. 10, 2022.

[2] Solvent Protocol, 'What is Solvent Protocol?', *https://solvent-protocol.gitbook.io/solvent-protocol*, Feb. 20, 2022.

[3] Dapp Radar, 'NFT Industry Report 2022', *https://dappradar.com/blog/dapp-industry-report-2022-dapp-industry-proves-resilient-in-crypto-winter/#The-State-of-the-NFT-Market:-a-review-of-on-chain-metrics,-blue-chip-collections,-and-leading-NFT-marketplaces*, Dec. 21, 2022.

[4] L. Shimron, 'NFT 2022 Year-End Review', *https://www.forbes.com/sites/leeorshimron/2022/12/21/nft-2022-year-end-review/*, Dec. 21, 2022.

[5] A. Wright and P. De Filippi, 'DECENTRALIZED BLOCKCHAIN TECHNOLOGY AND THE RISE OF LEX CRYPTOGRAPHIA'. [Online]. Available: http://ssrn.com/abstract=2580664Electroniccopyavailableat:https://ssrn.com/abstract=2580664Electroniccopyavailableat:https://ssrn.com/abstract=2580664Electroniccopyavailableat:http://ssrn.com/abstract=2580664

[6] S. Nakamoto, 'Bitcoin: A Peer-to-Peer Electronic Cash System'. [Online]. Available: www.bitcoin.org

[7] M. Bal and C. Ner, 'NFTracer: A Non-Fungible Token Tracking Proof-of-Concept Using Hyperledger Fabric', May 2019, [Online]. Available: http://arxiv.org/abs/1905.04795

[8] F. Regner, A. Schweizer, and N. Urbach, 'NFTs in Practice-Non-Fungible Tokens as Core Component of a Blockchain-based Event Ticketing Application Completed Research Paper', 2019.

[9] O. Leech, 'What Are NFTs and How Do They Work?', *https://www.coindesk.com/learn/what-are-nfts-and-how-do-they-work/*, Aug. 23, 22AD.

[10] F. Valeonti, A. Bikakis, M. Terras, C. Speed, A. Hudson-Smith, and K. Chalkias, 'Crypto collectibles, museum funding and openGLAM: Challenges,

opportunities and the potential of non-fungible tokens (NFTs)', *Applied Sciences (Switzerland)*, vol. 11, no. 21, Nov. 2021, doi: 10.3390/app11219931.

[11] J. T. White *et al.*, 'The role of the media in speculative markets: Evidence from non-fungible tokens (NFTs) *', 2022. [Online]. Available: https://ssrn.com/abstract=4074154

[12] Y. Assia and -Rotem Lev Rotem, 'Coloredcoins.org Github'.

[13] A. Steinwold, 'The History of Non-Fungible Tokens (Nfts)', *https://medium.com/@Andrew.Steinwold/the-history-of-non-fungible-tokens-nfts-f362ca57ae10*, Oct. 07, 2019.

[14] L. Du, M. Kim, and J. Lee, 'The Art NFTs and Their Marketplaces', Oct. 2022, [Online]. Available: http://arxiv.org/abs/2210.14942

[15] S. Allen, A. Juels, M. Khaire, T. Kell, and S. Shrivastava, 'NFTs for Art and Collectables: Primer and Outlook', 2022.

[16] T. Locke, 'CryptoPunks NFTs were free when they started—now Christie's sold a collection for $17 million', *https://www.cnbc.com/2021/05/12/christies-sold-cryptopunks-nfts-collection-for-millions.html*, May 12, 2021.

[17] A. Serada, T. Sihvonen, and J. T. Harviainen, 'CryptoKitties and the New Ludic Economy: How Blockchain Introduces Value, Ownership, and Scarcity in Digital Gaming', *Games Cult*, vol. 16, no. 4, pp. 457–480, Jun. 2021, doi: 10.1177/1555412019898305.

[18] Christie's, 'EVERYDAYS: THE FIRST 5000 DAYS', *https://onlineonly.christies.com/s/beeple-first-5000-days/beeple-b-1981-1/112924*, Feb. 21, 2021.

[19] S. Corbet, Y. (Greg) Hou, Y. Hu, C. Larkin, B. Lucey, and L. Oxley, 'Cryptocurrency liquidity and volatility interrelationships during the COVID-19 pandemic', *Financ Res Lett*, vol. 45, Mar. 2022, doi: 10.1016/j.frl.2021.102137.

[20] D. Aharon and E. Demir, 'NFTs and Asset Class Spillovers: Lessons from the Period around the COVID-19 Pandemic', *Financ Res Lett*, vol. 47, p. 102515, Oct. 2021, doi: 10.1016/j.frl.2021.102515.

[21] H. Bao and D. Roubaud, 'Non-Fungible Token: A Systematic Review and Research Agenda', *Journal of Risk and Financial Management*, vol. 15, no. 5. MDPI, May 01, 2022. doi: 10.3390/jrfm15050215.

[22] B. Baker, A. Pizzo, and Y. Su, 'Non-Fungible Tokens', *Sports Innovation Journal*, vol. 3, pp. 1–15, Mar. 2022, doi: 10.18060/25636.

[23] R. Browne, 'Trading in NFTs spiked 21,000% to more than $17 billion in 2021, report says', *https://www.cnbc.com/2022/03/10/trading-in-nfts-spiked-21000percent-to-top-17-billion-in-2021-report.html*, Mar. 10, 2022.

[24] Verified Market Research, 'Non-Fungible Tokens Market Size And Forecast', *https://www.verifiedmarketresearch.com/product/non-fungible-tokens-market/*, Jun. 10, 2022.
[25] A.-D. Popescu, 'Non-Fungible Tokens (NFT)-Innovation beyond the craze', vol. 66, p. 2021, [Online]. Available: https://ethereum.org/en/nft/#internet-
[26] Q. Wang, R. Li, Q. Wang, and S. Chen, 'Non-Fungible Token (NFT): Overview, Evaluation, Opportunities and Challenges', May 2021, [Online]. Available: http://arxiv.org/abs/2105.07447
[27] O. Ali, M. Momin, A. Shrestha, R. Das, F. Alhajj, and Y. K. Dwivedi, 'A review of the key challenges of non-fungible tokens', *Technol Forecast Soc Change*, vol. 187, Feb. 2023, doi: 10.1016/j.techfore.2022.122248.
[28] D. Geroni, 'Understanding The Attributes Of Non-Fungible Tokens (NFTs)', *https://101blockchains.com/nft-attributes/*, Sep. 10, 2021.
[29] Pastel, 'How Are NFTs Authenticated?', *https://pastel.network/how-are-nfts-authenticated/*, Jan. 04, 2022. https://pastel.network/how-are-nfts-authenticated/
[30] Market Decipher, 'Collectibles Market and NFT Market Size, Statistics, Growth Trend Analysis and Forecast Report, 2022 - 2032', *https://www.marketdecipher.com/report/collectibles-market*, Dec. 01, 2022.
[31] NonFungible.com and Atelier BNP Paribas, 'Quarterly NFT Market Report Q3 2022', Oct. 2022.
[32] rejolut.com, 'Top-30-NFT-Use-Cases-For-Enterprises-compressed_1'.
[33] S. Oh, S. Rosen, and A. L. Zhang, 'Investor Experience Matters: Evidence from Generative Art Collections on the Blockchain Investor Experience Matters: Evidence from Generative Art Collections on the Blockchain *', 2022.
[34] M. Nadini, L. Alessandretti, F. Di Giacinto, M. Martino, L. M. Aiello, and A. Baronchelli, 'Mapping the NFT revolution: market trends, trade networks, and visual features', *Sci Rep*, vol. 11, no. 1, Dec. 2021, doi: 10.1038/s41598-021-00053-8.
[35] D. Das, P. Bose, N. Ruaro, C. Kruegel, and G. Vigna, 'Understanding Security Issues in the NFT Ecosystem', in *Proceedings of the ACM Conference on Computer and Communications Security*, Association for Computing Machinery, Nov. 2022, pp. 667–681. doi: 10.1145/3548606.3559342.
[36] R. Bhardwaj, T. Kadam, S. Waghule, B. Sarag, and S. Shendurkar, 'NFT MARKETPLACE WITH DIGITAL CURRENCY EXCHANGE'. [Online]. Available: https://ssrn.com/abstract=4362944
[37] A. IVEY, 'Primary vs. secondary markets: Key differences', *https://cointelegraph.com/news/primary-vs-secondary-markets-key-differences*, Mar. 15, 2023.

[38] Nansen.io, 'NFT Trends & Indexes', *https://pro.nansen.ai/nft-trends*, Apr. 01, 2023.
[39] Lucas Matney, 'NFT market OpenSea hits $1.5 billion valuation', *https://techcrunch.com/2021/07/20/nft-market-opensea-hits-1-5-billion-valuation/*, Jul. 20, 2021.
[40] 'Blockchain Technology and Non-Fungible Tokens: Reshaping value chains in creative industries Sylve CHEVET Under the supervision of Alain BUSSON', 2017.
[41] T. Warner, 'Blur Beats OpenSea Two Days in a Row', *https://luckytrader.com/news/blur-beats-open-sea-two-days-in-a-row-1*, Mar. 10, 2023.
[42] H. Aliyev, A. Faruk Aysan, and U. N. Kayani, 'Future Readiness with Non-Fungible Tokens (NFTs): Prospects and Challenges', 2023, doi: 10.20944/preprints202302.0424.v1.
[43] A. Arditi, P. Garimidi, D. Hirsch, and I. Milionis, 'COMS 6998-006 Foundations of Blockchains An Initial Framework for NFT Auction Mechanism Design: Impossibility Results and Solutions'.
[44] J. Milionis, D. Hirsch, A. Arditi, and P. Garimidi, 'A Framework for Single-Item NFT Auction Mechanism Design', in *DeFi 2022 - Proceedings of the 2022 ACM CCS Workshop on Decentralized Finance and Security, co-located with CCS 2022*, Association for Computing Machinery, Inc, Nov. 2022, pp. 31–38. doi: 10.1145/3560832.3563436.
[45] M. Rengers and O. Velthuis, 'Presidents' Prize Paper Determinants of Prices for Contemporary Art in Dutch Galleries', 2002.
[46] M. Fazli, A. Owfi, and M. R. Taesiri, 'Under the Skin of Foundation NFT Auctions', Sep. 2021, [Online]. Available: http://arxiv.org/abs/2109.12321
[47] D. Thompson, *The $12 Million Stuffed Shark The Curious Economics of Contemporary Art*. Aurum, 2010.
[48] N. F. Campos and R. L. Barbosa, 'Paintings and numbers: An econometric investigation of sales rates, prices, and returns in Latin American art auctions', *Oxf Econ Pap*, vol. 61, no. 1, pp. 28–51, 2009, doi: 10.1093/oep/gpn020.
[49] nftnate, 'How Liquid Is an NFT?', *https://blog.cryptostars.is/how-liquid-is-an-nft-a9a1d8e617a4*, Jan. 12, 2022.
[50] Kyros Ventures, 'NFTFi: An Overview', *https://blockworks.co/news/nft-lending-market-reveals-a-need-for-liquidity*, Oct. 08, 2022.
[51] X. Liang, J. Wu, and C. Hong, 'RBHLT: A High Liquidity Technology for Non-fungible Token', in *2022 International Conference on High Performance Big Data and Intelligent Systems, HDIS 2022*, Institute of Electrical and Electronics Engineers Inc., 2022, pp. 315–319. doi: 10.1109/HDIS56859.2022.9991606.

[52] out.eth, 'AMM fot NFTs', *https://www.lotus-eaters.org/posts/nft-amm*, Dec. 15, 2022.
[53] C. Zou, Y. Cao, C. Cui, and P. Wang, 'Blockchain Research NFT Liquidity Solutions and Regulation'.
[54] 'Danu An Automated Market Maker (AMM) for Non-Fungible Tokens (NFTs)', 2022.
[55] Kristof Lommers, Jack Kim, and Mohamed Baioumy, 'NFT Market Making', *https://kristoflommers.substack.com/p/nft-market-making*, Oct. 22, 2022.
[56] J. B. Cho, S. Serneels, and D. S. Matteson, 'Non-fungible token transactions: data and challenges', Oct. 2022, doi: 10.1080/26941899.2022.2151950.
[57] V. von Wachter, J. R. Jensen, F. Regner, and O. Ross, 'NFT Wash Trading: Quantifying suspicious behaviour in NFT markets', Feb. 2022, [Online]. Available: http://arxiv.org/abs/2202.03866
[58] A. LIAN, 'The scourge of NFT wash trading', *https://forkast.news/how-to-detect-nft-wash-trading/#:~:text=Wash%20trading%20is%20a%20form,sides%20of%20an%20NFT%20transaction*, Oct. 18, 2022.
[59] X. Wen, Y. Wang, X. Yue, F. Zhu, and M. Zhu, 'NFTDisk: Visual Detection of Wash Trading in NFT Markets', Feb. 2023, [Online]. Available: http://arxiv.org/abs/2302.05863
[60] B. Kalkavan, 'DEPARTMENT OF INFORMATICS Towards an Online Service to Detect NFT Wash Trading Activities on the Ethereum Blockchain'.
[61] CHAINALYSIS TEAM, 'Crime and NFTs: Chainalysis Detects Significant Wash Trading and Some NFT Money Laundering In this Emerging Asset Class', *https://blog.chainalysis.com/reports/2022-crypto-crime-report-preview-nft-wash-trading-money-laundering/*, Feb. 02, 2022.
[62] hildobby, 'NFT Wash Trading on Ethereum', *https://community.dune.com/blog/nft-wash-trading-on-ethereum*, Dec. 16, 2022.
[63] J. Howell, 'What Are NFT Royalties And How Does It Work?', *https://101blockchains.com/nft-royalties-explained/*, Jan. 02, 2023.
[64] 'Dore-Legal-issues-to-watch-in-navigating-the-secondary-market-for-NFTs-Daily-Journal-04-27-2021'.
[65] jai, 'Parameterized Unrealized NFT Royalties', *https://dune.com/jai/parameterized-nft-royalties*. 2023.
[66] Š. Barauskas, R. Ripamonti, and E. Ragnoli, 'Rogue Protocol: A Framework For NFT Royalties Tokenisation', Oct. 2022, [Online]. Available: http://arxiv.org/abs/2211.00063

[67] D. Tripathi, 'Centralization is Crippling — The Industry Needs Decentralized NFT Marketplaces', *https://www.nasdaq.com/articles/centralization-is-crippling-the-industry-needs-decentralized-nft-marketplaces*, Jul. 01, 2022.
[68] É. Pereira, P. Ferreira, and D. Quintino, 'Non-Fungible Tokens (NFTs) and Cryptocurrencies: Efficiency and Comovements', *FinTech*, vol. 1, no. 4, pp. 310–317, Oct. 2022, doi: 10.3390/fintech1040023.
[69] M. Dowling, 'Fertile LAND: Pricing non-fungible tokens', *Financ Res Lett*, vol. 44, Jan. 2022, doi: 10.1016/j.frl.2021.102096.
[70] Vitalik Buterin, 'Alternatives to selling at below-market-clearing prices for achieving fairness', *https://vitalik.ca/general/2021/08/22/prices.html*, Aug. 21, 2021.
[71] M. Dowling, 'Is non-fungible token pricing driven by cryptocurrencies?', *Financ Res Lett*, vol. 44, Jan. 2022, doi: 10.1016/j.frl.2021.102097.
[72] 'MEng Individual Project NFT.finance Leveraging Non-Fungible Tokens', 2020.
[73] H. Davies, 'NFT Loan Platform Development — Experience the Benefits of NFTs with NFT Loans', *https://blog.cryptostars.is/nft-loan-platform-development-5ead59ae78bf#:~:text=A%20lender%20will%20put%20up,borrower%20gets%20their%20collateral%20back.*, Feb. 02, 2023.
[74] Dreamer Club, 'How NFT AMM Provide Liquidity to NFT?', *https://mirror.xyz/0xA7D741926c9582Ccf133a6D6d0a8Bb9E5FCe5371/yE5pDtJY2lXvjg7_i0zJGG9skIGgoYUnK33GuRTV4u0*, Oct. 22, 2022.
[75] C. Zou, Y. Cao, C. Cui, and P. Wang, 'Blockchain Research NFT Fractionalization and Liquidity Solution'.
[76] 0xhamachi, 'Sudoswap whitepaper', *https://docs.sudoswap.xyz/*, Aug. 10, 2022.
[77] H. Adams, N. Zinsmeister, and D. Robinson, 'Uniswap v2 Core', 2020.
[78] J. FERNANDO, 'Arbitrage: How Arbitraging Works in Investing, With Examples', *https://www.investopedia.com/terms/a/arbitrage.asp*, Mar. 20, 2023.
[79] A. Banerjee, 'Difference Disclosed: ERC20 Vs. ERC721', *https://www.blockchain-council.org/ethereum/erc20-vs-erc721/#:~:text=The%20main%20distinction%20between%20ERC20,Furthermore%2C%20ERC721%20is%20not%20divisible*, Nov. 21, 2022.
[80] M. Egorov, 'StableSwap-efficient mechanism for Stablecoin liquidity', 2019.

List of Figures

Figure 1.1: blockchain: a block of information plus chain of hash identifier. Source: Blockchain 101 22

Figure 1.2: NFT Timeline - History of NFTs designed by Ownest 24

Figure 1.3: Volume per type. Source: Non-Fungible.com Report NFT market 2022... 27

Figure 1.4: Trading Volume of NFTs on ETH across Multiple Marketplaces from April 2022 – April 2023. Source: Nansen.io [38] 33

Figure 1.5: Pareto chart of the fraction sold of collection, and their median, against the number of transactions for the twenty most traded profile picture (PFP) – based collection on OpenSea. Source: DanuFinance [54] 39

Figure 1.6: NFT trading volume on ETH. Source: Dune [62]..... 41

Figure 3.1: Month of launch of the projects analyzed (*basis: 41 cases*) 66

Figure 3.2: Ownership and Status distribution over the year (*basis: 40 cases*) 67

Figure 3.3: Blockchain used (*basis: 39 cases*)..... 68

Figure 3.4: Sum of funds raised according to project status (*basis: 38 cases*)..... 69

Figure 3.5: Assets in a Pool variable representation (*basis: 37 cases*)..... 70

Figure 3.6: NFT AMM distribution according to side and parameters (*basis: 38 cases*) 72

Figure 3.7: Distribution of the price mechanisms by the analyzed projects (*basis: 37 cases*) 73

Figure 3.8: Distribution of price according to project status (*basis: 37 cases)* 74

Figure 3.9: Representation of the values of the staking variable (*basis: 36 cases)* 75

Figure 3.10: Project adopting: fractional, multichain, loan, audit; according to status (*basis respectively: 10, 11, 8, 15 cases*) 76

Figure 3.11: Representation of projects with their own token and without (*basis: 37 cases)* 77

Figure 3.12: Percentages of fee construction method types (*basis: 35 cases*)..... 78

Figure 3.13: Fee average value by fee typology (*basis: 35 cases*)..... 78

Figure 3.14: Representation of two metrics related to the presence or absence of credit card and incentives for liquidity providers, respectively. (*basis: 36 cases*)..... 80

Figure 3.15: Average of user, nft, discord and twitter follower by project status (*basis: 40 cases*) 81

Figure 3.16: Distribution of the problems solved by the analyzed projects (*basis: 36 cases*) 82

Figure 3.17: Distribution of problem solved by different project status (*basis: 40 cases*) 83

Figure 3.18: Distribution of problems solved from the analyzed projects by Side (*basis: 38 cases)* 88

Figure 3.19: Distribution of problems solved by building method (*basis: 37 cases)* 88

Figure 4.1: Representation main players AEC primary market (Source: By Author) . 97

Figure 4.2: Price impact of 146$ sell order in different pool sizes 103

Figure 4.3: Representation of the price curve obtained by simulating 4906 transactions. USDC assumed stable at $1 108

Figure 4.4: Simplified representation of a swap, and a liquidity addition/withdrawal (Source: By Author)..... 109

Figure 4.5: Secondary market representation of AerariumChain (Source: By Author) 112

List of Tables

Table 1.1: Top 10 NFT Marketplace by volume exchanged. Source: Dapp Radar 34

Table 2.1: Variables framework representation 49

Table 3.1: Project according to status and liquidity pool building method (*basis: 37 cases*) 71

Table 3.2: Representation of fractioned, multichain, loan, audit (*basis: 37 cases for all variables excluding Audit which has a basis of 38 cases)* 76

Table 3.3: Average protocol fee and fee type by status (*basis: 35 cases*) 79

Table 3.4: Counting problems solved by the pricing method (*basis:36 cases*) 84

Table 3.5: % distribution price mechanism on solved problem normalized by lines (*basis:36 cases)* 85

Table 3.6: BC linear price on the problem solved on the total number of projects (37) 86

Table 3.7: Type of ownership distribution on problem solved (*base: 40 cases)* 87

Table 3.8: Distribution of problems solved from the analyzed projects by parameters (*basis: 37 cases)* 89

Table 4.1: Description of AerariumChain 99

Table 4.2: Tiers' representation and distribution of the first drop artworks by tier .. 101

Table 4.3: Fees problem analyzed in the simulation 105