Universiteit Leiden

ICT in Business and the Public Sector

Redesign Mutual Fund Settlement Process with Distributed Ledger Technology

Name: Xinning Cheng
Student-no: S2623501
Date: 2020/08/30
1st supervisor: Drs. Pieter M. Kwantes
2nd supervisor: Dr. Michael T.M. Emmerich

MASTER'S THESIS

Leiden Institute of Advanced Computer Science (LIACS)
Leiden University
Niels Bohrweg 1
2333 CA Leiden
The Netherlands

Foreword

This master's thesis is for the completion of MSc. ICT in Business at Leiden University. The topic of this thesis was sparked by an internship in a Dutch asset management company, combined with the thesis topic initiated by Drs. Pieter M. Kwantes around DLT in financial infrastructures. Therefore, I would like to express my gratitude towards the following people:

Firstly, I wish to express my special thanks to my first supervisor, Drs. Pieter M. Kwantes, for his incredible patience, continuous encouragement, and insightful guidance throughout the whole journey of this thesis. I also wish to thank my second supervisor, Dr. Michael T.M. Emmerich, who provided valuable feedback on this thesis. Secondly, I want to express thanks to all the professors during my master's study, and Ms. Esme Caubo for her administrative help throughout my master's program. Thirdly, I wish to thank my interviewees who helped me understand the as-is environment and shared their opinions on the technology. Last but not least, I am grateful to my parents and my friends, without whose emotional support, I wouldn't have finished my degree.

Abstract

Asset Management Companies (AMCs) have been plagued by inefficiencies in the mutual fund settlement process. Throughout the settlement process of an investor's order, multiple stakeholders are involved, including brokers, transfer agents, fund administrators, custodians, and asset managers. The intermediated process leads to a situation in which every stakeholder works to execute the same order and same data elements from the investor, but with their own processes and standards (Van Verre, 2017). The need for communications and reconciliations on the same data objects among all the intermediaries is resource-intensive while non-value-adding, which is one of the major reasons causing the inefficiency of the mutual fund operations.

Distributed ledger technology (DLT) has shown its potentials to disrupt the post-trade settlement process for mutual funds with its capabilities of creating a shared ledger as a single source of truth and deploys smart contracts to automate repetitive manual tasks. The capabilities of the technology provide opportunity to redesign the mutual fund settlement process transformationally. However, according to information systems scholars, the redesign of the business process cannot be accomplished by simply applying the technology to the current business process, but requires a thorough analysis of the as-is business processes and problems, assessment of the technology capabilities, so as to redesign the business process with the enabling technology.

This thesis explores how the DLT enables the redesign of the mutual fund settlement processes. Business process redesign faces two problems: unclear as-is process and poor understanding of the current problems, and little information of the to-be processes with DLT as the enabling technology. Following a business process redesign (BPR) and design science research methodology, this research models the current process of mutual fund settlement and identifies the primary entities, activities, communications, and the problems and potentials with DLT. The process redesign takes into consideration on Garcia-Banuelos's DLT enabled business process redesign heuristics (2020) and ECB tokenization models in securities settlement (2021). As a result, a redesigned settlement process model is proposed for the asset managers and related financial service providers when adopting DLT in improving the mutual fund settlement process.

Keywords: Distributed Ledger Technology (DLT), Mutual Fund Settlement, Asset Management Company (AMC), Business Process Redesign (BPR)

Table of Contents

List of Figures

List of Tables

Acronyms

AMC: Asset Management Company

API: Application Programming Interface

ASX: Australian Stock Exchange

BPMN: Business Process Model and Notation

BPR: Business Process Redesign

CSD: Central Securities Depository

DAG: Direct Acyclic Graph

DApps: Distributed Applications

DLT: Distributed Ledger Technology

DSR: Design Science Research

ERD: Entity Relation Diagram

FA: Fund Administrator

ICO: Initial Coin Offering

KYC/AML: Know Your Customer/Anti-Money Laundering

NAV: Net Asset Value

NFO: New Fund Offer

OTC: Over The Counter

SME: Small and Medium-sized Enterprise

STO: Security Token Offering

SWIFT: Society for Worldwide Interbank Financial Telecommunication

TA: Transfer Agent

1. Introduction

1.1. Background

A mutual fund is a pool of money collected from many investors to invest in a portfolio that diversifies its investment in equities, debts, money market instruments, and other assets. The mutual funds are operated by professional managers such as asset management companies (AMC) who allocate the funds' assets and attempt to produce capital gains. The mutual fund has been a popular investment for investors, as the money is in professional hands, and the expertise shall give the investment a good return. An estimation on the European mutual funds' overall net inflows amounts to 483.5 billion euros for 2020, marking the second-highest inflows from 2004 till now despite the impact of COVID-19 (Glow, 2021).

However, inefficiencies have plagued the mutual fund industry, especially in the post-trade operational business processes, which relies a lot on communication among financial service intermediaries such as brokers, transfer agents, fund administrations, custodians, resulting in extensive manual processes. A slow and painful fund transfer means they cannot be invested in the fund they want whenever they want. Today's manual processes have the inherent chance for human errors from incorrect keying data between systems, delays of getting a signature, and forgetting to action a piece of paper. Mainelli et al. (2016) estimated the total cost of post-trade clearing and settlement processes worldwide had reached 40 billion dollars annually, and most of the cost comes from data reconciliation and manual operations. Deloitte (2014) estimated the fund distribution cost in the Luxembourg market. The cost of errors and reconciliations amounts to 355 million euros out of the total 1155 million processing cost, about 30% of the total processing cost.

The asset managers are continuously seeking levers to optimize their mutual fund trading operation processes with new technologies, and blockchain technology or its underlying distributed ledger technology (DLT) shows its potential beyond Bitcoin and cryptocurrencies in the capital market and has gained successful results in improving the securities settlement processes. With the cryptographic, decentralized, tamper-proof, and consensus-based feature, the technology has the potential to disintermediate the intermediated processes and simplify the systems both within and across firms through a shared 'joint back office' with reduced reconciliation and data silos and possibilities for reducing intermediary processes (Thompson, 2016). Boston Consulting Group (2021) estimated that DLT is particularly well suited for optimizing balance sheet management, automating or eliminating manual data reconciliation processes, and removing non-value-adding counterparty risk and complexity. DLT use cases tested and implemented in the financial services, capital markets, payment, and other areas are concluded by KPMG and shown in figure 1. It is demonstrated that DLT has the potential of great use in addressing problems with 'multiple parties generate transactions that change information in a shared repository, parties need to trust that the transactions are valid, intermediaries are inefficient or not trusted as arbiters of truth, and security is needed to be enhanced to ensure the integrity of the system' (Deloitte, 2016). Ultimately, it may allow mutual funds to reduce operational costs and risks and improve operational processes efficiency in the fund settlement.

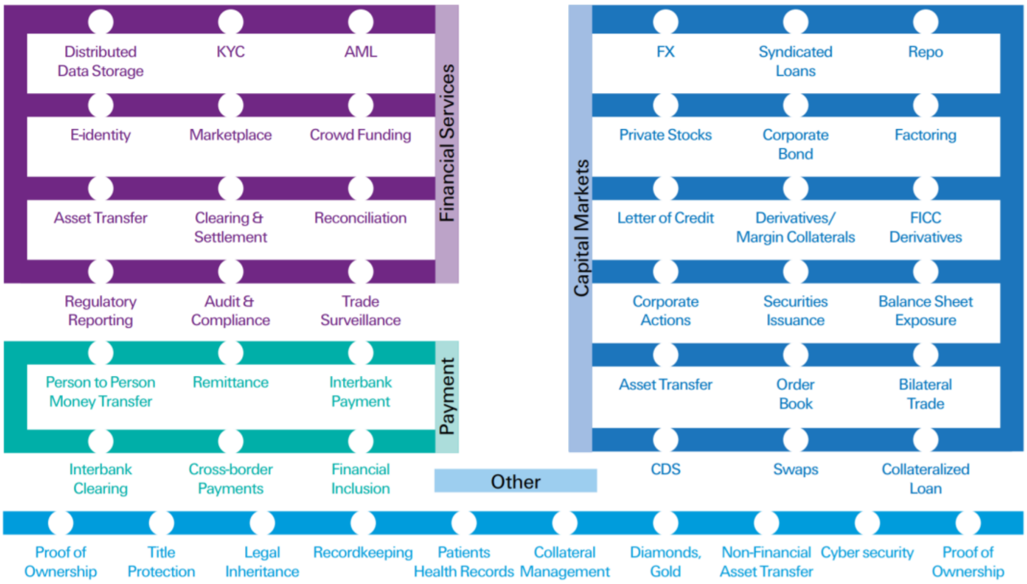


Figure 1: DLT use cases been tested and implemented (source: KPMG)

1.2. Problem Statement

The impact of distributed ledger technology on business processes has been estimated to have a similar magnitude as process automation did for manufacturing and service industries in the 1990s (Milani et al., 2020). DLT bears the potential to support the execution of inter-organizational business processes in an efficient way and furthermore addresses various notorious problems of collaboratively designing choreographies and overcoming a lack of trust (Mendling, 2018). Studies are conducted on the applicability of transforming clearing and settlement, mainly focusing on the equity trading which happens on the exchanges, and some applications have been developed. For example, the Australian Stock Exchange (ASX) has planned to replace the current post-trade platform – CHESS with the DLT system developed by Digital Asset[1]. Figure 2 illustrates a study by Egelund-Müller et al. (2017) on how financial contracts can be automated by blockchain with a shared ledger. The successful implementations of DLT on the settlement in the stocks market stimulate the mutual funds also to adopt this technology to improve the settlement process.

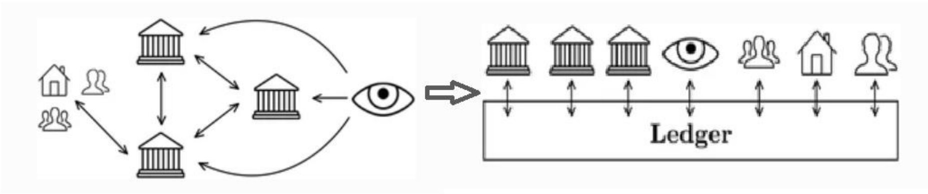


Figure 2: Current vs. distributed settlement system (source: Egelund-Müller et al., 2017)

However, even though the widespread public sentiment thinks that DLT has the potential to disrupt current business processes to offer efficiency, transparency, security, and reduce counterparty risk to the mutual fund sector, there's neither enough detail on how this could occur nor a concrete proposal for the implementation to address the current business process problem in the mutual fund settlement area. Although the equity market and mutual fund market share some similarities in terms of the post-trade business processes, the operational processes have many differences due to the different features of these financial assets: for example, the transaction price of equity stocks in the secondary market is based on the seller's amount to sell and the buyer's amount to pay, while the transaction price of mutual fund units is based on the calculated net asset value (NAV)[2] per open day, therefore the real-time settlement with DLT applied to stock market cannot be applied in the same way as the settlement of stocks in settlement of mutual fund.

While asset managers seek to improve the settlement processes and reduce costs with a DLT solution, the transformational technology cannot be simply applied to the mutual fund settlement without thorough considerations of the redesign of business processes. It is difficult for developers to develop DLT applications and connect to current infrastructure for the mutual funds without a feasible and valid new business process model as a reference. The complexity not only comes from the application of DLT in the process but also comes from the understanding and clarification

[1]https://www2.asx.com.au/markets/clearing-and-settlement-services/chess-replacement/about-chess-replacement

[2] The shares of a mutual fund can be purchased or redeemed as needed at the fund's current NAV, unlike the fluctuating stock prices. The activity of purchasing shares from the fund is called Subscription and the selling of shares is called Redemption. The NAV is settled at the end of each trading day after market close.

of the current business processes among fragmented participants in a transaction. In all, how the DLT could redesign the settlement processes of mutual funds to positively impact the business processes appears to be an exciting and valuable topic to investigate.

1.3. Research Question

This research is an exploratory study of the implementation of distributed ledger technology in redesigning the mutual fund settlement business process to analyze how the current costly and inefficient mutual fund settlement processes can be improved with a business process redesign approach based on DLT solutions. The research problem is defined as:

> *How can the distributed ledger technology (DLT) serve as an enabler to redesign the post-trade mutual fund settlement process?*

In order to answer the research problem, the following questions need to be answered:

Question1: What are the DLT's capabilities in the business process redesign for the mutual fund settlement?

Question 2: What is the current mutual fund post-trade settlement landscape, and what are the problems?

Question 3: How can the business process of mutual fund settlement be redesigned with the identified DLT capabilities?

1.4. Research Approach

Exploratory research is a research approach used to investigate a problem that is not clearly defined. It is conducted to have a better understanding of the existing problem, and it is often referred to as the grounded theory approach or interpretive research as it is used to answer the question of what, why, and how. This research requires an exploratory research approach to understand the problems in the mutual fund settlement process and how DLT can enable the business process redesign. The primary research methods of exploratory research usually include surveys/polls, interviews, focus groups, and observations, and the secondary research methods include online research, literature review, and case study.

This exploratory research follows a design science research (DSR) approach, assisted by research methods including literature review, case study, and expert interviews. The theoretical explanations of the business process redesign and design science research methodology are introduced in chapter 2. The knowledge base is built upon the literature study on the DLT and analysis of its capabilities in the mutual fund settlement area. A case study on the mutual fund settlement process of an asset management company is conducted, providing the corporate environment with the need for the improvement on the mutual fund settlement processes. It enables the identification and extension of the problem and the define of objective as mentioned above – to redesign the mutual fund settlement process with DLT-based solutions. In the meantime, semi-structured interviews are conducted to give the impression of the corporate context of the settlement process. The environment needs lay the foundation to apply the knowledge base of the distributed ledger technology capabilities and current application cases to answer why and how DLT can address the problem. Further, by combining the identification of environment needs and knowledge base, the IS research constitutes an artifact of the redesigned securities settlement process with DLT-based solutions.

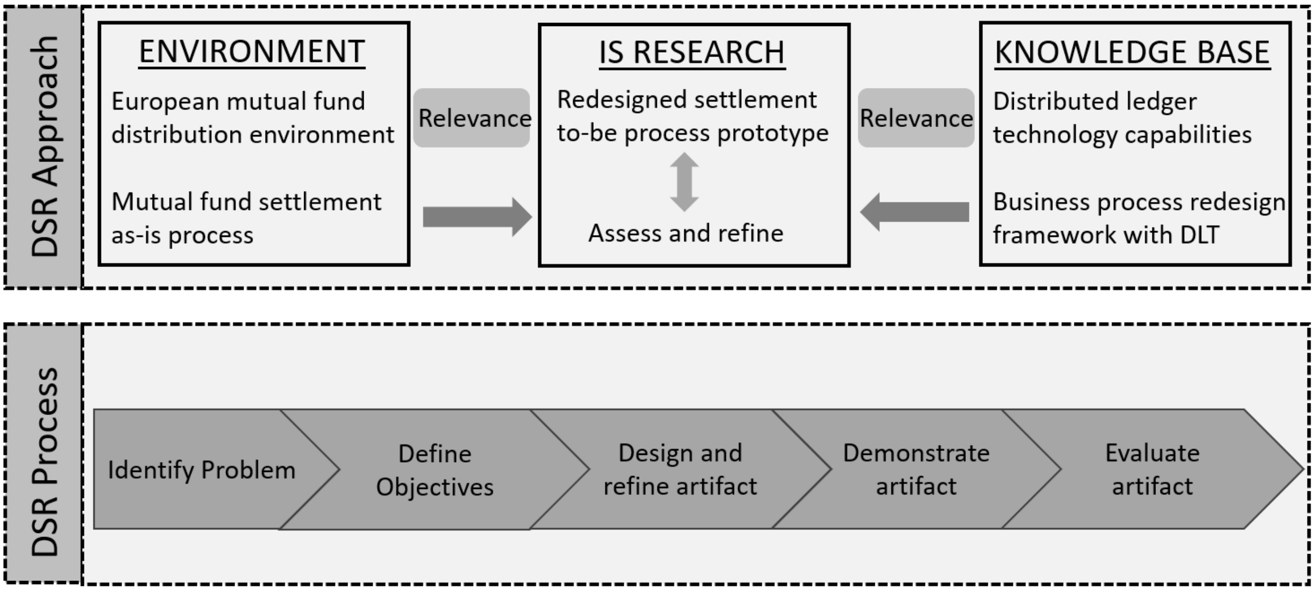


Figure 3: Research approach and process with DSR

1.5. Research Relevance

The financial industry has identified the DLT technology to have the potential to yield benefits. Goldman Sachs (2016) estimated DLT could reduce costs related to securities clearing and settlement by 11-12 billion dollars. Gartner identified the blockchain technologies in the hype cycle in 2020 that asset tokenization, blockchain interoperability, and smart contracts are rising to the peak of the hype. Because the application of DLT technology is relatively new in the financial industry, many projects are in the early proof-of-concept and pilot phase and limited-scale production. In the financial sector, continuous efforts have been made to utilize nascent technologies to improve efficiencies, reduce costs and risks. The opportunity to achieve peer-to-peer transactions in securities settlements has the potential to disintermediate financial service intermediaries within the securities settlement ecosystem (Gartner, 2020).

In academia, information systems scholars have been encouraging applied researches on ostensible synergies between the nascent technology and various use cases (Ross & Jensen, 2019). On the one hand, the ongoing transformations in the financial service industry and the fast development in fintech have stressed the importance of harvesting technologies to improve efficiency and robustness on processes for asset managers. On the other hand, the cumbersome and multiparty-engaged process in the fund settlement has the potential to be addressed with DLT solutions. However, there is neither much literature around the back-office operations processes and problems of mutual funds nor the application of DLT in this use case. From the business process redesign view, little literature is covering the analysis of business process redesign in the operational processes of the mutual fund, and little research has been done on whether and how DLT will reform the business processes. This research may throw some new light for both the industry and academia on redesigning the mutual fund settlement process and application scenarios of the distributed ledger technologies.

1.6. Thesis Layout

The following of this thesis is structured as follows:

Chapter 2 covers the theoretical frameworks of this research. It includes a general introduction of mutual fund and settlement, as well as the scope of the thesis; then analyzes the DLT and its applicability in the settlement process; further, the business process redesign (BPR) and the design science research (DSR) methodology, which is the basic methodology for this research are elaborated. Furthermore, this chapter studies the business process redesign heuristics with DLT as the enabling technology, and the heuristics are used as the basis for the process redesign;

Chapter 3 introduces the environmental foundations for the fund settlement, covering both the current mutual fund process general framework in the European financial market and a case study of mutual fund settlement process in an asset management company. The problems of the current process are then identified and analyzed;

Chapter 4 presents the redesigned fund settlement process model with the DLT technology and the implementation heuristics based on the frameworks discussed in chapter 2, then discusses the implications of the to-be process model compared to the as-is model;

Chapter 5 discusses the answering of research questions, the limitations of this research, and introduces future works in this area.

2. Theoretical Framework

This section includes the theoretical framework for this thesis based on a literature review. Firstly, the general concept of mutual fund and mutual fund settlement are introduced in 2.1; secondly, the distributed ledger technology and its applicability in the mutual fund settlement processes are introduced and analyzed in 2.2. Then we explain the business process redesign and design science methodology, which supports this research in 2.3; Following, the heuristics and frameworks of business process redesign with DLT are explored in 2.4.

2.1. Mutual Fund

2.1.1. Mutual Funds Explanation & Scope

A mutual fund is a vehicle for investors to invest their money in the stock or bond market indirectly. Mutual funds, together with exchange-traded funds (ETF), money market funds, and hedge funds, are major types of investment funds. The mutual fund is popular among individual investors because it reduces investment risks through a diversified portfolio of financial assets. By purchasing one mutual fund unit, the investment can be diversified to 20 to 30 different securities. The underlying theme is not to put all eggs in one basket. Instead of directly engaging the secondary marketing and trading securities like stocks, the mutual funds are managed by professional asset managers who design the investment portfolio and actively adjust securities investment based on the investment strategy.

Based on its structure, pricing and sales, the mutual fund can be classified to open-ended fund and closed-ended fund:

- *Open-ended fund*: The investors invest their money in an open-ended mutual fund by buying shares at the net asset value (NAV), which is the market value of the fund's assets at the end of each trading day minus any liabilities divided by the number of outstanding shares. The NAV changes every trading day because of the fluctuations of the stocks and bonds prices of the fund. The critical feature of open-ended funds is liquidity, thus the open-ended fund typically does not limit the number of shares they can offer and are bought and/or sold on demand. When an investor purchases shares (which is called a subscription) in an open-end fund, the fund issues those shares, and the investor buys with cash. When an investor sells shares (which is called a redemption), the fund shares are bought back by the fund, and the fund pays the investor using cash on hand or may have to sell some of its investments to pay the investor. Typically, the open-ended funds do not have a fixed maturity period[1] which is in contrast to the close-ended funds.

- *Closed-ended fund*: The closed-ended mutual fund issues a fixed number of shares that are traded on the stock exchanges or in the over-the-counter market. They are issued through a new fund offering (NFO) to raise money and then traded in the open market, similar to stocks. When the shares are sold, the fund does not issue more shares. Though the value of a closed-ended fund is based on NAV, unlike open-ended funds, the actual price is proportional to supply and demand as it can be traded at prices above or below its value. Therefore, the closed-ended funds can be traded at premiums or discounts to their NAVs. Units of closed-ended funds are purchased and sold via brokers, and the funds have a fixed maturity period.

Table 1: Comparison of mutual funds and stocks

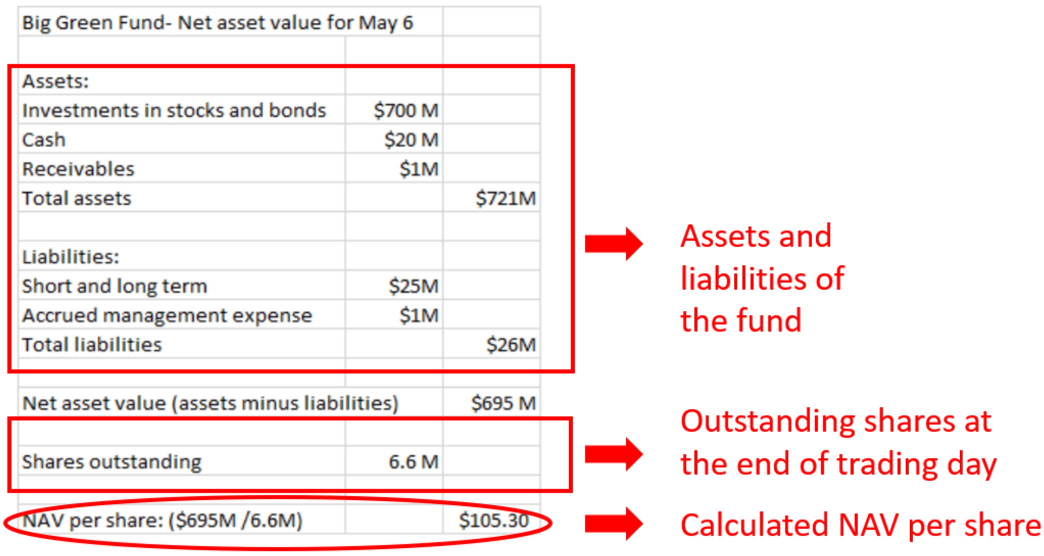
	Stocks	**Mutual Funds**
Ownership	Shares of a single company	Shares of a fund product
Voting rights	Yes	No
Form of investment	Direct	Indirect
Value	Per-share price	Net asset value
Management	Investor	Fund manager
Diversification	No	Yes
Trading	Throughout the day at the prevailing price	Only once at the end of the day
Commission	Paid when a stock is traded	Can be paid either at subscription or redemption or both times
Accessibility	Via broker	Via broker or other intermediaries
Settlement time	2 business days	1-3 business days

The processing of mutual funds and stocks trading have fundamental differences, which can be found in table 1. The buying and selling of stocks are processed on a continuous basis, as the share prices are decided by the auction process where buyers and sellers place bids and offers. A bidding price is a price that someone wishes to buy, and the offering price is the price someone wishes to sell. When the bidding and offering prices coincide, a trade is made. As for the mutual fund, the

[1] Maturity period of the mutual fund is the agreed-upon date in which the investment ends, often triggering the repayment to the investors.

subscription and redemption orders per trading day are aggregated and processed in batches. At the end of each trading day, the NAV per share of the fund on the trading day is calculated, all the orders within the timeframe of the trading day will be settled based on the calculated NAV per share, and the settlement of the cash usually takes 1 to 3 days.

Figure 4 illustrates how the NAV per share is calculated. The net asset value is calculated by deducting liabilities from assets. Assets include investments in stocks and bonds, cash, and receivables. Liabilities include short-term and long-term liabilities and accrued management expenses. Outstanding shares are calculated based on the fund inflow and outflow data from the investor’s fund orders. The NAV per share is then calculated by dividing the net asset value by outstanding shares. The calculation of NAV per share is performed by either an internal accountant of the AMC or by the nominated fund administrators. The value of a mutual fund increases when 1) the interest and dividends earned on the fund’s investments are passed through to the shareholders; 2) the fund manager sells investment securities at a profit – the net capital gain and loss are passed through to shareholders; 3) the NAV per share increases.



Big Green Fund- Net asset value for May 6		
Assets:		
Investments in stocks and bonds	$700 M	
Cash	$20 M	
Receivables	$1M	
Total assets		$721M
Liabilities:		
Short and long term	$25M	
Accrued management expense	$1M	
Total liabilities		$26M
Net asset value (assets minus liabilities)		$695 M
Shares outstanding	6.6 M	
NAV per share: ($695M /6.6M)		$105.30

Figure 4: NAV calculation example

The scope of the mutual fund discussed in this thesis focuses on the open-ended type of mutual fund and has the following characteristics:

1. The asset management company issues and manages the mutual fund;
2. The transaction happens directly with the mutual fund product;
3. Follows an open-ended scheme, the mutual fund shares are subscribed, redeemed, and switched on demand;
4. The price of one unit of a mutual fund share is based on the NAV per share, which is fixed

for one trading day.

2.1.2. Mutual Fund Settlement & Scope

The mutual fund operation flow is a loop with the fund manager (asset manager) in the middle of investors and securities (figure 5). Investor's money is pooled in the mutual fund managed by the fund managers, then invested in the securities. With the fluctuations of securities prices and investment strategies implemented by fund managers, returns on the investment are generated from the securities and passed back to the investors. As is illustrated in figure 5, the fund managers sitting in the middle between investors and securities have operations on both sides. On the clients' (investors) side, the fund manager settles the investors' subscription, redemption, and switch of mutual fund shares with the investor's cash. On the fund side, the fund manager settles the trading of securities with the investors' money.

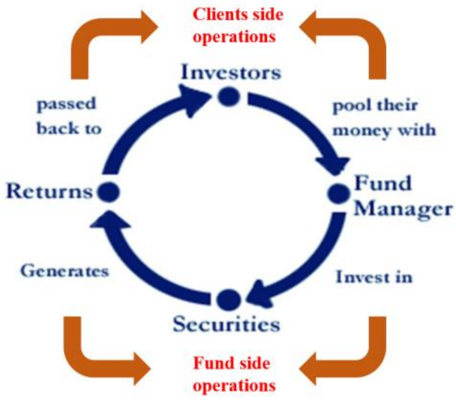


Figure 5: Mutual fund high-level operation flow (source: Sogani, 2008)

Settlement means transferring money from the buyer to seller and/or transferring an asset's title from seller to buyer. There are two types of settlement in the abovementioned loop due to the two sides of operations. On the clients' side, the fund managers settle fund units and money with the investors; On the fund side operations, the fund managers settle the shares of stocks and bonds, with the money pooled from investors.

The scope of mutual fund settlement of this thesis focuses on the settlement on the clients' side, from the investors' decisions to subscribe, redeem or switch certain shares in a mutual fund to the settlement of cash and the proof of ownership in fund shares, following a non-CSD settlement model (further explained in 3.1). The detailed settlement environment and the process will be discussed in Chapter 3. This process involves multiple parties and manual processes that can be potentially disintermediated and automated by DLT. In comparison, the latter settlement case involves professional decisions on the mutual fund strategy from the asset managers, which is the value-generating part of the business processes. Improving the business processes on the first type of settlement can help the asset manager focus more time and resources on the activities that generate real value to the investors.

2.2. Distributed Ledger Technology

2.2.1. DLT Systems

The concept of distributed ledger technology existed before Bitcoin and blockchain technology from a study of the Byzantine Generals Problem (Lamport et al., 1982) on computer systems in handling conflicting information in an adversarial environment. The first occurrence of the 'blockchain' concept can be traced back to Haber & Stornetta (1991) and Bayer et al. (1992), who introduced the notion of a chain of cryptographically-lined data blocks to efficiently and securely timestamp digital data in distributed systems using cryptographic hashing functions and Merkle trees. The application of blockchain as a DLT archetype in financial transactions has initially been theorized in a white paper authored under the pseudonym Satoshi Nakamoto (2018): *Bitcoin: A Peer-to-Peer Electronic Cash System.* There are various definitions of what a DLT system should be like, and many publications have their own unique definitions from narrow to broad:

Pinna & Ruttenberg (2016) from European Central Bank defined DLT as 'a technology that allows their users to store and access information relating to a given set of assets and their holders in a shared database of either transactions or account balances. The information is distributed among users who could then use it to settle their transfers of securities and cash without needing to rely on a trusted central validation system'. The World Bank (2017) defines DLT systems as 'a specific implementation of the broader category of shared ledgers, which are simply defined as a shared record of data across different parties'. Some definitions do not differentiate DLT and blockchain: for example, Cong & He (2018) defines it as 'a distributed database that autonomously maintains a continuously growing list of public records in the unit of blocks secured from tampering and revision'. While Rauchs et al. (2018) in their study of conceptualizing the framework for DLT to clarify it beyond the blockchain archetype as: 'A system of electronic records that enables independent entities to establish a consensus around a shared ledger – without relying on a central coordinator to provide the authoritative version of the records.'

Irrespective of the scope and focus of the definition, an ideal DLT system should, in general, fulfill the following five features (Hileman and Rauchs, 2018):

- *Shared recordkeeping:* DLT systems enable multiple parties to collectively create, maintain and update a shared set of authoritative records – the ledgers;
- *Append only and tamper-proof:* The system is designed for incremental data entries only unless maliciously compromised or fundamentally restructured, the entered data cannot be deleted or modified;
- *Independent Validation:* Each participant can independently verify the state of their transactions and integrity of the system;
- *Consensus driven:* A data entry is recorded into the system only if an agreement has been reached among nodes regarding its validity. If permissionless, the consensus does not rely on a single party and ex-ante trusted relationships between parties; If permissioned, the consensus is through multiple record producers who have been approved and bound by some forms of contracts or agreements;
- *Cryptographically secure:* The core of DLT systems' security is cryptography, ensuring authenticity, traceability, and data integrity. The encryption mechanisms also vary between different designs of DLT systems.

In this thesis, because the focus is on the technology in general to serve as an enabler for redesigning the business processes, we adopt a broader definition by Dubovec and Castellano (2020) and explore its capabilities:

The DLT system is an umbrella term that describes distributed computerized systems that enable participants (nodes) to submit, validate, and store information into a database that is disseminated, synchronized, and maintained fully or partially across the distributed ledgers.

A distributed ledger (DL) is in essence a database that exists across several locations or among multiple participants, which is in contrast to the centralized database in a fixed location. The distributed ledger is decentralized to eliminate the need for a central authority or intermediary to process, validate or authenticate transactions or other types of data exchanges. While ‘blockchain’ is a type of DLT where transactions are recorded chronologically with an immutable cryptographic signature called a hash. Although blockchain is a sequence of blocks, the distributed ledger does not necessarily require such a chain thus has better scaling options.

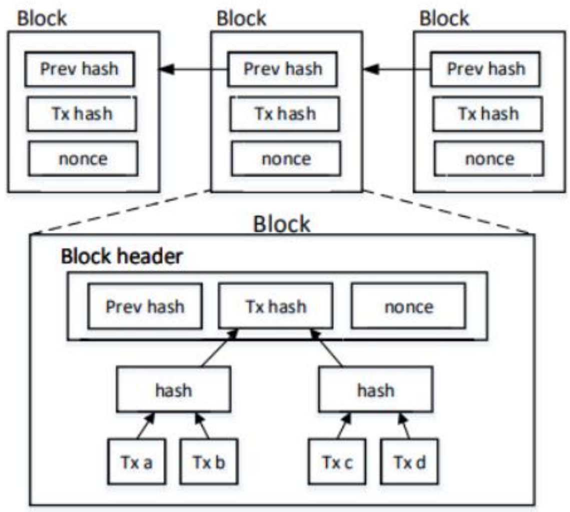


Figure 6: Block structure of blockchain

Besides the mostly-known blockchain archetype, new DLT archetypes are recently developed to increase throughput rate, making up for the limitations of blockchain which increases in a linear manner. For example, one archetype different from blockchain is the Directed Acyclic Graph (DAG) DLT. This archetype allows submitting, validating, and recording large numbers of data entries simultaneously, which greatly exceed the throughput capabilities of the blockchain DLT.

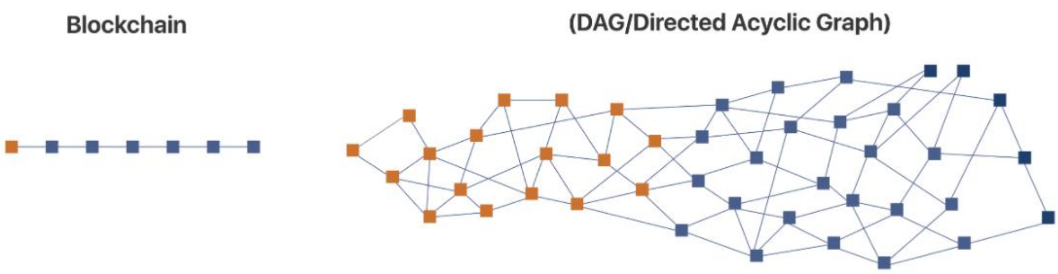


Figure 7: Blockchain archetype vs. DAG archetype

It should be emphasized that DLT is not one single, well-defined technology, but a plurality of blockchains and distributed ledgers are active or are under development today and their designs and precise configurations vary depending on the purpose and development stage. The term 'distributed ledger technology' refers to all initiatives and projects that are building systems to enable the shared control over the evolution of data without a central party, with individual systems referred to as 'distributed ledgers'. The system with global data diffusion and uses a data structure of chained blocks are 'blockchain'.

For this thesis, the umbrella term 'distributed ledger technology' and its acronym 'DLT' is used when referring to this technology, and ‘blockchain’ is only used when referring to the specific archetype mentioned above.

2.2.2. Permission Models

Different types of DLT systems offer different degrees of transparency depending on the domain of their application. In the case of Bitcoin transactions, the ecosystem is open, and data is shared by any user joining the network; other cases when transactions take place is a closed ecosystem where the data need to be confidential and participants need to be authenticated, the requirement of the level of transparency will be different. These different levels of transparency and access rights can be distinguished between the different types of permission models. There are three main types of permission that can be set when configuring a DLT network:

- Read: who can access the ledger and see the transactions
- Write: who can generate transactions and send them to the network
- Commit: who can validate and update the state of the ledger

The four main DLT types are shown in table 2, where ‘public/private’ refers to the *Read* capability, and ‘permissionless/permissioned’ refers to the *Write* and *Commit* capability:

Table 2: Main types of DLT segmented by permission model (source: Rauchs et al., 2017)

		Read	Write	Commit	Example
Open	**Public permissionless**	Open to anyone	Anyone	Anyone[1]	Bitcoin, Ethereum
	Public permissioned	Open to anyone	Authorized participants	All or subset of authorized participants	Sovrin
Closed	**Consortium**	Restricted to an authorized set of participants	Authorized participants	All or subset of authorized participants	Multiple banks operating a shared ledger
	Private permissioned (‘enterprise’)	Fully private or restricted to a limited set of authorized nodes	Network operator only	Network operator only	Internal bank ledger shared between parent company and subsidiaries

[1] Requires significant investment either in mining hardware (proof-of-work model) or cryptocurrency itself (proof-of-stake model)

Public permissionless DLT operates in a hostile environment with unknown actors, which requires a combination of game theory and economic incentive design to incentivize participants to behave honestly and to keep the network censorship-resistant. In contrast, private permissioned DLT operates in an environment where participants are already known and vetted. Participants are held liable via off-chain legal contracts and agreements. Legal prosecution of misbehavior instead of the ‘crypto-economics’ will incentivize the participants to act honestly (Hileman & Rauchs, 2017). In practice, public and permissionless DLT have become the domain for cryptocurrencies and the financial market, while consortium and permissioned blockchains have entered the domain of businesses and institutional practice. The permission models for mutual fund settlement should be decided based on the environment and the requirements on the permissions to create, read, update and delete the data, therefore it will be illustrated in chapter 4.

2.2.3. Smart Contracts

A smart contract function enables users to create business applications that can be deployed and executed on the distributed ledger, and the applications are called decentralized applications (DApps). The term "Smart Contracts" is, in essence, computer scripts that automatically execute all or parts of an agreement and is stored on a DLT-based system. The computer scripts can either be the sole manifestation of the agreement between participating parties or might complement a traditional contract and execute specific provisions. A simple example is to transfer funds from A to B. The scripts are replicated across multiple nodes in the DLT system therefore can benefit from the immutability and security of the DLT system. The trigger of smart contracts execution is predefined parameters such as when a new block is added to a blockchain. Therefore, if no transactions are executed, the script will not take any steps. The input parameters and execution steps need to be specified clearly and objectively. For example, if "x" occurs, execute step "y". Since the conditions for execution are pre-defined, smart contracts are precise, transparent, secure, also can act as repositories of data.

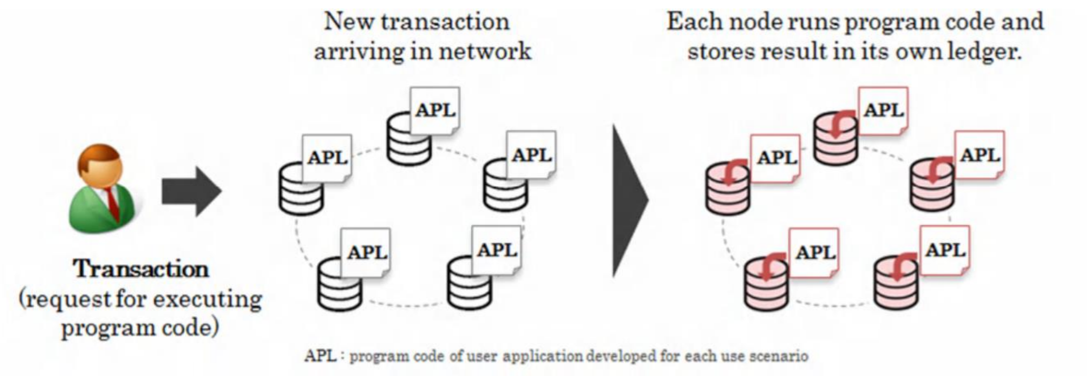


Figure 8: Overview of smart contracts (source: Levi & Lipton, 2018)

Currently, there are two types of transactions on DLT systems that can be automated by smart contracts: One is to ensure the payment of funds when a certain event is triggered. Escrow (use as a third-party control money or assets until two other parties involved in a transaction meet certain conditions) is one common use case of smart-contract enabled service; The other is to impose financial penalties if certain objective conditions are not satisfied (Levi & Lipton, 2018). Human intervention including through a trusted escrow holder or judicial system is not required with the automation of smart contract, therefore it has the potential to be applied into the settlement process to improved automation by eliminating the "procedure-to-pay" gaps, thereby reduce intermediate steps and cut back settlement frictions and costs.

2.2.4. Consensus Mechanism

The consensus mechanism is a method of authenticating and validating a value or transaction of the shared data on a distributed ledger without the need to trust or rely on a central authority. The DLT systems are built on consensus, which means the systems have tolerance (with limits) of malicious actors attempting to attack the system and unreliable yet honest participants. The capability of maintaining data integrity in an adversarial environment[1] separates DLT systems from traditional databases. Because there is no centralized administrative role in verifying the transaction data, the consensus is a critical aspect that all (or majority in some mechanisms) participants in the network come to an agreement on the state of the ledger. Incentive and punish mechanisms are created to guarantee the validity of the transaction data.

The consensus mechanisms mainly have two types: Byzantine and non-Byzantine consensus mechanisms (Zhang, 2019). The Byzantine consensus mechanism is used for solving the

---

[1] An adversarial environment means the presence of malicious actors inside or outside the system, who undermine the system by using it in ways it was not intended for.

Byzantine General's problem, which is to achieve consensus under malicious failure scenarios. The Byzantine consensus mechanism is applied mainly in public and permissionless DLT, where any node including the malicious node, can become a miner in the system. The current application of this type of consensus mechanism includes proof of work (PoW), proof of stake (PoS), delegated proof of stake (DPoS), and proof of importance (PoI).

The non-Byzantine consensus mechanism is applied in a non-malicious failure scenario to ensure convergence on agreement of a state value or a sequence of actions even if specific nodes fail. In contrast to the Byzantine case where the failure comes from some nodes deceiving the other nodes, the non-Byzantine case failure comes from a failed stop or failed stuck of a node. The state is consistently observed by all participants, and they agree that the node has failed with the correct stop pr stuck semantics. This mechanism is mainly applied to the permissioned DLT systems that are less concerned with malicious nodes. The onboard of participants follow strict rules to ensure the nodes in the network can be trusted with their reputation stake in the network, so the permissioned DLT systems are able to use a non-Byzantine consensus to increase performances in terms of transaction throughput and scalability. The non-Byzantine consensus mechanisms include proof of elapsed time (PoET), proof of authority (PoA), and ordering-based consensus (Zhang et al., 2018).

Table 3: Comparison of consensus mechanisms (source: Zhang et al.)

Consensus Mechanism	**DLT permission**	**Degree of decentralization**	**Scalability**	**Randomness in miner selection**
Proof of Work (PoW)	Permissionless	**High:** Allows any node to join the network and become a miner (however, the hardware requirement may cause less decentralization)	**Low:** Low transaction throughput due to the cryptographic puzzle requires mining power	**High:** the puzzle can only be solved with brute force and can be any miner
Proof of Stake (PoS)	Permissionless	**Medium:** Allow any node to join the network, but only nodes with higher stakes can become miners	**High:** no need to solve complex puzzles to reach a consensus	**Medium:** nodes with higher stakes in the system will be more likely to be miners
Proof of Elapsed	Permissioned	**Low:** Miners are required to have	**High:** Transactions can be produced	**High:** specialized hardware used to

Time (PoET)		specialized hardware	and processes with high speed without the need of solving puzzles	generate a random timer to determine the next miner
Proof of Authority (PoA)	Permissioned	**Low:** Anyone who is willing to be verified of identity can be appointed as an authority to generate blocks	**High:** A small set of authorized nodes are responsible for processing transactions and generating blocks	**Low:** Miners are most likely to be selected from nodes with verified identity and established reputation
Ordering-based Consensus	Permissioned	**Low:** It is resilient to faulty nodes but not malicious attacks. Tighter control is therefore needed	**High:** A single leader orders transactions at a time and replicates the changes to all followers	**High:** The leader selection is based on a random timeout period

In conclusion, the consensus mechanisms for the permissioned DLT systems offer higher control over the nodes and higher scalability, this is important to the mutual fund settlement process as the high volume of transactions requiring higher throughput to improve efficiency. This addresses the concerns of skeptics on DLT for the transaction settlement, which is on the low scalability caused by the inefficient mining.

2.2.5. Digital Tokens and Asset Tokenization

The DLT systems have coins/tokens to record the existence and the transfer of digital assets, either exclusively or alongside other data entries unrelated to these coins or tokens. Tokens in the DLT systems can be used to transfer ownership and rights or can be used as evidence of an event occurrence at a specific time (such as proof of voting).

Nakavachara et al. (2019) in their analysis on classifications of digital tokens made the classification based on whether the tokens are ICO (initial coin offering) or non-ICO[1], whether

[1] ICO is a method of fundraising in which companies issue digital tokens to investors in exchange for their fund investing into the companies; non-ICO tokens are digital tokens that were not created via ICO process, they could have been mined or could have been initially distributed for free to certain groups of people with existing wallet.

the tokens are native or non-native[1], and whether the tokens are minable or non-minable[2]. The ICO tokens have a primary market and have the initial price. Similar to IPO, the companies exchange tokens with investors with funds and distribute future returns. In comparison, non-ICO tokens do not have a primary market and have no initial price. The tokens are created either with a mining process or created by companies and distributed for free via an airdrop process.[3] In the public permissionless DLT systems, tokens can be mined and used as incentives for the members to validate the system (such as Bitcoin). In such cases, tokens are considered as either tradeable equities or the fuel to help with the running of the systems. In the permissioned DLT systems, as the participants are held liable via off-chain legal contracts and agreements, and little incentives are needed to keep the system's integrity with tokens, the tokens are usually non-minable. Native tokens are implemented by the protocol that governs a DLT system, and they are integral to its operation. Non-native tokens are implemented and managed by applications that exist within a DLT system. The tokens typically serve as participation rights or access to services.

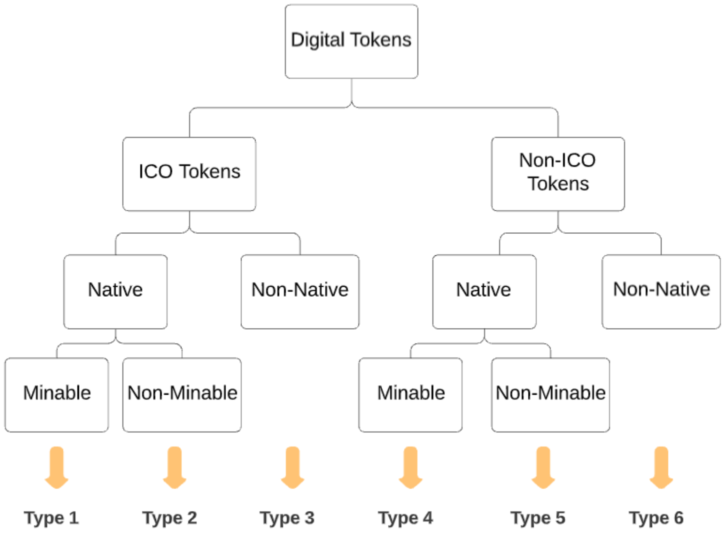


Figure 9: Digital tokens classification (source: Nakavachara et al. 2019)

[1] Native tokens have their own blockchain and can operate independently; non-native tokens do not have their own chain therefore reside on other chains (usually on Ethereum).

[2] Minable tokens can be created during transaction verification process involving solving mathematical problems, such as Bitcoin. ICO and non-ICO tokens that are non-native are non-mineable (Nakavachara et al., 2019).

[3] Airdrop is the process of giving out digital tokens for free to certain groups of people (in their existing wallet).

Besides, the digital tokens can also be classified based on functions (FINMA[1], 2018) and can be payment tokens/cryptocurrencies, utility tokens, or asset tokens. Payment tokens or cryptocurrencies are used as payment tools. Examples are Bitcoin and Ether. Utility tokens are tokens that can be exchanged for specific products/services. Examples are Bancor, Basic, Attention Token, etc. Asset tokens or security tokens are debt or equity claims against the issuers. Examples are Paragon Coin, AirToken.

Stable coins are digital tokens that have their value pegged to other fiat currencies or other assets, and they fall into type 5 or type 6 in figure 9. The stable coins can be fiat-collateralized (Tether, TrueUSD, Gemini Dollar), crypto-collateralized (DAI, BitUSD, BitEUR, BitCNY), or non-collateralized (NuBits, Carbon, Basis). The stable coins are not directly subject to the forces of supply and demand, therefore less volatile compared to cryptocurrencies because they are pegged to the value of a low-volatility asset. Security tokens are equity or debt claims against issuers, the issuance of security tokens is called security tokens offering (STO) and is a subset of ICO. They fall into type 2 or type 3 in figure 9.

The token features of the DLT systems give rise to the tokenization of assets in the financial industry. Asset tokenization is the process of digitally representing an existing real asset on a distributed ledger (Hileman & Rauchs, 2017). It involves the representation of pre-existing tangible assets on the ledger by linking or embedding by convention the economic value and rights derived from these assets into digital tokens created on the distributed ledgers (OECD, 2020). There are two types of tokenization corresponding to the native and non-native tokened DLT systems. The first type is similar to the concept of 'securitization'[2]. It can be considered as a proxy for asset-backed securitization on DLT systems, where native or non-native tokens represent the pre-existing real asset. In theory, any conventional financial assets, non-financial assets (e.g., real estate, art), and commodity (e.g., gold) can be represented by the tokens, and the tokens can either be traded on-chain or off-chain. This type of token can be integrated into the conventional financial transaction operating processes since the tokens are backed by tangible assets existing outside the distributed ledger. Security tokens mentioned above are used for this type. Another type is similar to the concept of 'dematerialization', where tokens are native to the system and can

[1] The Swiss Financial Market Supervisory Authority

[2] The financial practice of pooling various types of contractual debt such as residential mortgages, commercial mortgages, auto loans or credit card debt obligations and selling their related cash flows to third party investors such as securities. Securities backed by mortgage receivables are called mortgage-backed securities (MBS) and those backed by other types of receivables are asset-backed securities (ABS).

only exist and be traded on-chain. This type of token is independent of the conventional part of the financial markets since the tokens are not backed by assets, and they fall into type 1 and type 2 in figure 9.

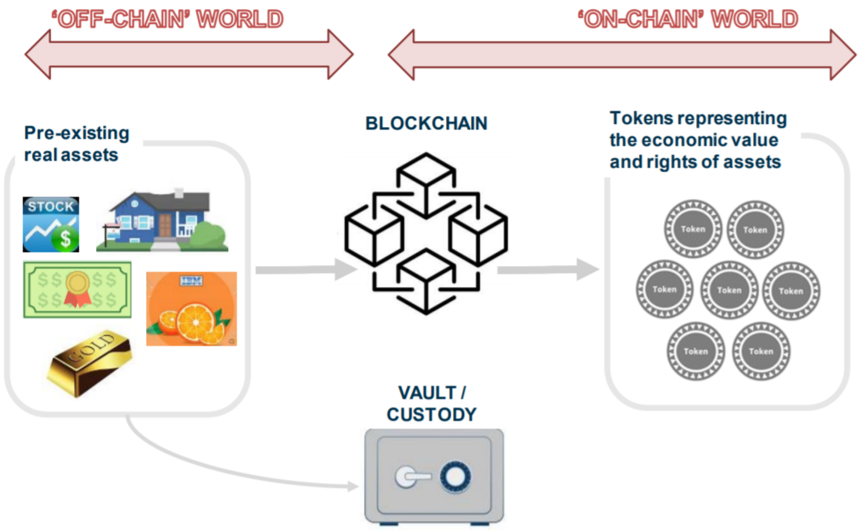


Figure 10: Tokenization of real assets exist off-chain (source: OECD)

Through asset tokenization on DLT systems, illiquid financial assets can be converted into liquid marketable securities, this could be valuable for the transactions of the asset with less liquidity and therefore benefit small and medium enterprises (SMEs) and Private Equity/Venture Capital (PE/VC) investment funds (OECD, 2020).

In conclusion, in mutual fund transactions, digital tokens representing mutual fund share units can be issued and transacted in the DLT systems. The value of the mutual fund is backed by the assets under management, and as discussed above, the tokenization of the mutual fund is similar to the process of 'securitization'. Tokens issued to represent the mutual fund units are security tokens, which are equity and debt claims against the issuer. Therefore, the issuance of mutual fund tokens can be via the security token offering, and can be native non-minable, or non-native. The studies on tokenization of securities in post-trade settlement are discussed on 2.2.6, and the tokenization of mutual funds will also be further discussed in chapter 4.

2.2.6. DLT Application Scenarios in Settlement Process

Even though there hasn't been an adequate study on the DLT in addressing the complex mutual fund settlement process problem, various studies towards the applicability of DLT in the securities settlement process has been studied, providing implications for the application of DLT in the mutual fund settlement area:

2.2.6.1. *Tokenized assets in post-trade settlement*

The European Central Bank (2021) studied the use of DLT in the post-trade process, focusing on the scenarios of tokenized assets in the post-trade settlement processes. A clear distinction is drawn between two tokenized assets: (1) the security is native to the distributed ledger (represented with native tokens) and (2) a reference to a security that has already been issued and recorded (in fund registers) and kept outside a distributed ledger while being represented by tokens (native or non-native) on the distributed ledger.

Two models and related sub-models were proposed for the issuance, custody, and post-trade handling of securities in the DLT network:

- Model 1: Securities issued as native digital assets

For this model, the securities do not have other representations outside the DLT network. The issuance and recording of the securities are only on the distributed ledgers represented by native tokens. The native tokens directly represent the underlying DLT with an intrinsic value, such as Ether on the Ethereum network. The native digital assets are held custody and safekeeping using the distributed ledger and cleared and settled on the DLT system. From the pure operational viewpoint, the native digital assets could be traded similar to the conventional execution venues following the existing rules.

- Model 2: Securities issued in the conventional system and enabled in a DLT environment

With this model, the issuance of securities is executed in the conventional system, while DLT enables the recording and post-trade operations. This model is further broken down into three scenarios:

    - Scenario 1: Securities are issued and recorded in the conventional system. The conventional system is held responsible for the custody and safekeeping of the securities until the migration to the DLT system is completed. The transactions happen on the DLT system and are further cleared and settled on-chain. The transactions might be updated on the conventional ledger upon requirement, but the distributed ledger will be the source of truth, and the conventional system gradually phases out until the securities are fully migrated into the DLT system.

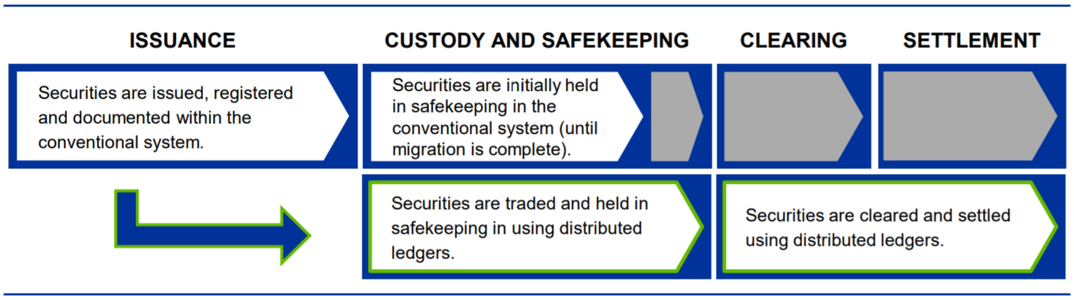


Figure 11: Scenario 1 - securities issued in the conventional system and migrated into DLT system (source: ECB)

- Scenario 2: The assets are available either in the conventional system or in the DLT system. In this scenario, the DLT system serves as a parallel system to the conventional system. Therefore, there is a 'functional split' with some activities performed on DLT systems, and some are administered in the conventional system. This scenario requires synchronization between the two systems and adds complexity to the existing process with additional reconciliations. Therefore, it will not be a preferred scenario.

Figure 12: Scenario 2 - bridging conventional and DLT system (source: ECB)

- Scenario 3: securities are issued and recorded in the conventional system and subsequently tokenized in the distributed ledger[1]. The tokens can be referred to as assets with a 1:1, 1:n, or 1:1/n relationship based on requirements. The transfer of securities in the conventional system is reflected with the transfer of tokens on DLT systems, tokens are not considered securities themselves. The system is mainly used for record-keeping using tokens and can also be run by other entities different

[1] The 'issuance of tokens' should be distinguished with the 'issuance of securities', the process if issuing tokens merely means to represent the securities in a technical matter, while not treated as 'transferable securities'.

from the issuer. To date, this model appears to have been used mainly for back-office operations, collateral transfer, or lending facilities.

Figure 13: Scenario 3 - securities issued in the conventional system and referenced by tokens in DLT system (source: ECB)

2.2.6.2. Governance on distributed ledgers

Pinna and Ruttenberg (2016) identified one of the main obstacles in the adoption of DLT that could also hinder the interoperability among the participating institutions: the need for technical standardization, standard business rules, and proper government arrangements. This is adding to the interoperability problem mentioned in 2.2.6.1., and is more focused on the interoperability problems among the participating institutions. In this case, even though the executive functions of the intermediaries in the post-trade settlement landscape could be potentially reduced by the DLT, their roles might still be needed but switched to oversight and administrative role on the distributed ledgers. The two major governance types are categorized as trusted bridging and trustless bridging:

1. Trusted bridging: The network members choose a trusted third party to validate transactions or information (usually off-chain). With this model, the existing intermediating parties (transfer agents, custodians) can shift their roles from operational to merely oversight, they do not participate in the operation of the securities settlement anymore (they are not nodes in the DLT network), but act as validators for the transactions.
2. Trustless bridging: The intermediaries are completely removed from the securities settlement process. Complex technical arrangements (smart contracts or atomic swaps) are set up for the interoperability of on-chain and between-chain transactions.

There are three scenarios derived from the two governance types:

- *Using DLT to improved internal efficiency, leaving the business practice 'as is':* In this scenario, institutions develop their preferred DLT technologies internally to improve internal operational efficiencies. There are few considerations on the linkage with other counterparties. In this case, the existing business processes arrangements can be replaced by an equivalent process made up of different distributed ledgers. The interoperability of different DLT systems still needs to be considered, and the problem of duplicated data storage and reconciliations still exists.

- *Intermediate core players adopt market-wide distributed ledgers*: The key players in the settlement – CSDs or custodians adopt the DLT and securities and trades can be serviced and settled in a shared distributed ledger instead of siloed databases. The smart contracts can automate the tasks currently performed by the intermediaries, thus the operating functions of the intermediaries will be redundant, their roles in the settlement process can either be eliminated or shifted to an oversight role.
- *Issuing companies, governments, or fintech companies take over the lead in implementing peer-to-peer systems for securities transactions:* This is an extreme assumption that can be applied in small and medium enterprises (SMEs) to streamline financing processes, as well as performing know-your-customer (KYC) and anti-money-laundering (AML) rules.

2.2.7. Conclusion

Based on the research on DLT systems and the investigations of the current studies in the securities market, we conclude the capabilities of DLT in redesigning the business processes to answer the research question 1: *What are the DLT's capabilities in the business process redesign for the mutual fund settlement?*

Table 4: DLT capability in mutual fund settlement

DLT capabilities	**Impact**	**Potential Application**
Shared record keeping	High	The complexity of the mutual fund settlement process comes from the data silos of the different participants. The transaction data are kept by each participant with an individual ledger and communicated bilaterally. The reconciliation of data and communications on confirmations holds back the efficiency of the process and leaves room for errors. A shared record where every participant can read and update on the same ledger can increase the information transparency, reduce reconciliations and communications, reduce risks, and improve settlement efficiency.
Consensus algorithms	High	The validation of the shared ledger to reach a consensus has a similar function as the conventional reconciliation process. The aim is to reach a consensus of the state of the ledgers, which is the accounting ledgers of all the participants with information on the units of shares in one subscription, the settled price, etc. Communications and reconciliations of data will be reduced with a shared ledger, therefore the focus will move to the

		consensus of the ledger which can be enabled with the consensus mechanisms.
Smart contract	High	The process of mutual fund settlement involves a high volume of manual tasks. There is ample space to automate and standardize the workflows with smart contracts. The capabilities of smart contracts can either be used to automate calculations and transactions and even perform asset servicing based on pre-defined rules or ensure compliance with regulatory and internal requirements and reduce risks. In general, any crediting and debiting of accounts in the ledger can be triggered by an event and executed with a smart contract, the execution can be verified among the distributed ledger.
Peer to peer communication	Low	The main purpose of peer-to-peer communication in the conventional process is to exchange and reconcile trading data. With a distributed ledger, the bilateral communications among participants can be replaced with direct access to the distributed and synchronized ledgers.
Public permissioned authorization	High	As the mutual fund transactions are facing all investors, the read access to the ledger should be open to all and distributed ledger should be made public. The investor's KYC/AML checked needs to be done before transactions can be made. Therefore a public permissioned authorization model can facilitate this need.
Asset tokenization	Medium	Tokens are to be used to represent the mutual fund units in the DLT systems. While the units are stored in the investors' accounts in a digital form, the three scenarios proposed by ECB in 2.2.6.1 model 1 and model 2 scenario 1 provide potential solutions for the tokenization of the issuance of new mutual funds and the migration of existing mutual funds.

2.3. Business Process Redesign and Design Science Research Methodology

A business process is defined as 'a set of logically related tasks performed to achieve a defined business outcome' (Davenport & Short, 1990), and a process is "a structured, measured set of activities designed to produce a specific output for a particular customer or market" (Davenport, 1993). Most organizations' business processes remain an abstraction of "the way things work around here" and have no physical manifestation of the organizational structure, Information Technology (IT) architecture, or building design (Lyons, 1995). Modeling and business process design has been acknowledged as critical for the development of business practices and information systems (Harmon, 2010). The business process models are used for several purposes, such as describing existing practice (as-is) and designing the future process (to-be), so as to analyze, design, and evaluate information systems (Bandara et al., 2006; Davies et al., 2006).

With the evolution of information technologies and the increasing demand to improve business process quality and cut down overhead costs, business managers seek to redesign their business processes to seek optimized business processes. IT was viewed as the central enabler of business process redesign (BRP), and as the practice of BPR matures, software tools and enabling technologies entered as drivers for BPR. The term business process redesign/reengineer was pioneered in the 1990s following Michael Hammer's publication: *"Reengineering Work: Don't Automate, Obliterate,"* implying that instead of focusing on the adaptation of technology to existing business processes, business leaders should adapt business processes to match technology and shed the obsolete tasks and processes along the way (Hammer, 1990). Teng et al. (1994) define BPR as "the critical analysis and radical redesign of existing business processes to achieve breakthrough improvements in performance measures". This requires a review of the organization's current business process structure and overhauling it to make it more efficient.

However, the finding of Stoddard & Jarvenpaa (1995) is contrary to Hammer: "although reengineering can deliver radical designs, it does not necessarily promise a revolutionary approach to change. Moreover, a revolutionary change process might not be feasible given the risk and cost of revolutionary tactics".

Kugel (2017) raised the idea of *digital process reengineering* based on the BPR concepts in the 1990s. The digital process reengineering uses digital technologies to give organizations more options to redefine how existing tasks are performed or to extend the range of tasks that the company's technology system manages. "The objective of digital redesign isn't just to gain efficiency, it is to use new technologies to redefine business models advantageously or alter an industry's competitive balance of power – in other words, to create digital disruption".

To conclude, the business process redesign is usually triggered by information technologies that provide the possibility for a more efficient business process and moreover, provide an opportunity for the business to gain a competitive advantage. The redesign of the business process is not simply adopting the technology to the current business, but requires a thorough analysis of the current business processes and problems, clear targets of what to be achieved, and assessment of the technology capabilities, so as to design the process enabled by the technology.

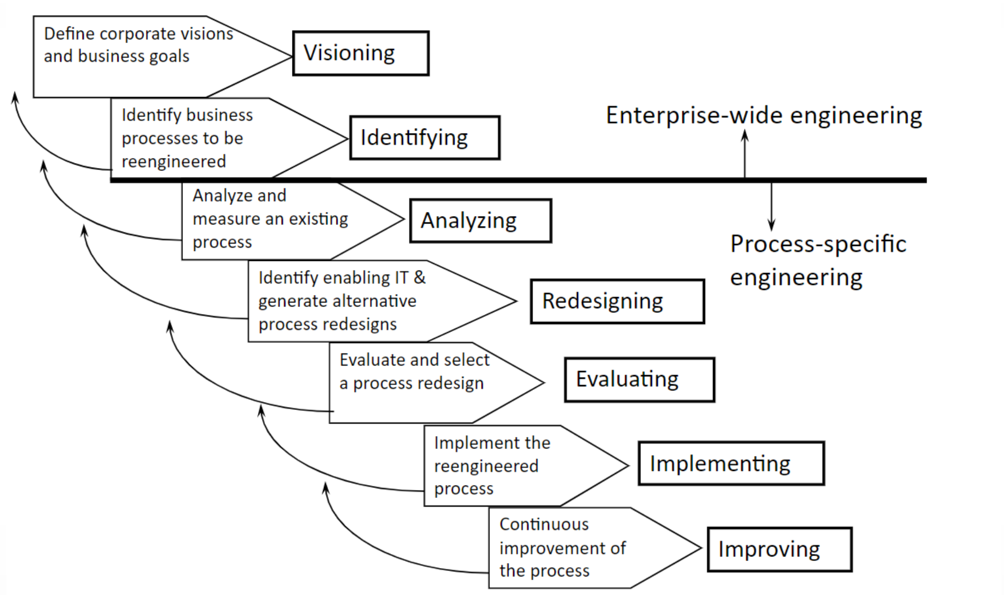


Figure 14: Business process redesign lifecycle (source: Kumer et al. 1993)

BPR follows a five-step approach before the implementation prescribed by Davenport & Short (1990) and assessed by Malhotra (1998):

1. *Develop the business vision and process objectives: BPR* is driven by a business vision that implies specific business objectives such as cost reduction, time reduction, output quality improvement, etc.
2. *Identify the process to be redesigned:* Firms use different approaches to identify the important processes that conflict with the current business vision and prioritize them in the order of redesign urgency.
3. *Understand and measure the existing process:* avoid old mistakes and provide a baseline for future improvements.
4. *Identify IT levers:* this is to assess the technological capabilities and how the technology should influence the process redesign.
5. *Design and build a prototype of the new process:* the actual design of the process should not be viewed as the end of the BPR process but rather a prototype with successive iterations.

While the BPR provides a theoretical backbone for the business process transformation driven by technologies, the emphasis has been given to languages and notations for modeling the process instead of the guidance for how to design models, how to use models, or how actual modeling should be performed (Tolvanen & Lyytinen, 1992, Lind et al. 2014). The design science research methodology was therefore developed to develop knowledge about how artifacts can be constructed to address the unsolved problems. And since process models are major artifacts for

BPR, the design science research appears to be an executable approach to address how to construct process models (Hevner et al., 2004; van Aken, 2004).

Design science research (DSR) is an approach to utilize gained knowledge to solve a business problem with a technology-based solution, create change or improve existing solutions with a viable artifact, and generate new knowledge, insights, and theoretical explanations (Hevner et al., 2004; Horvath, 2007; Bakerville et al. 2015). Hevner's DSR approach focuses on three components – Environment, IS research, and knowledge base.

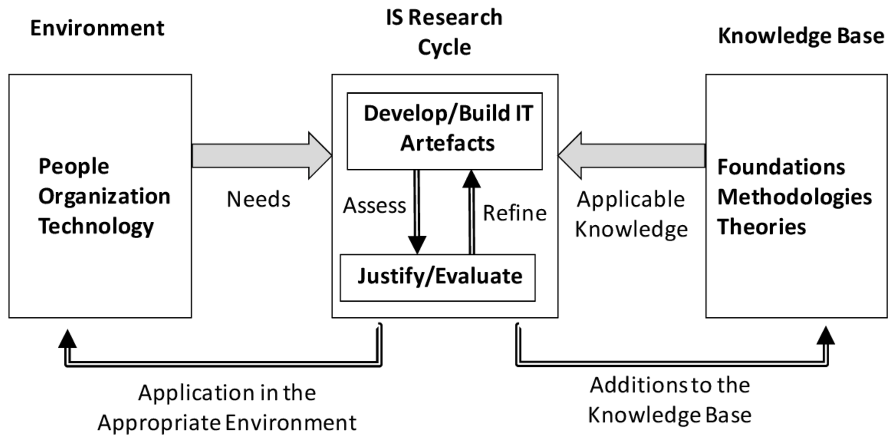


Figure 15: Illustration of Henver's design science research methodology (source: Weber, 2012)

The commonly recognized DSR approach follow steps: (1) identification of the problem and motivation; (2) defining objectives; (3) design and development of artifacts such as algorithms, human/computer interfaces, process models, and languages; (4) demonstration by using the artifact to solve problems; (5) evaluation of solution (Peffers et al., 2007; Lapão et al., 2017; Teixeira et al., 2017). This thesis follows procedures of the DSR approach for the redesign of the mutual fund settlement process with DLT. The author’s interpretation of this approach and the procedures has been shown in 1.4.

2.4. Business Process Redesign with DLT

Even though there hasn’t been an adequate study on how DLT will redesign the mutual fund settlement process, DLT as the information technology to disrupt and redesign business processes has been studied by various scholars, providing a backbone of how the redesign of the business process can be studied with the DLT as enabling technology.

2.4.1. DLT enabled Business Process Redesign Heuristics

Mendling (2018) concluded that there are three impacts of the utilization of new information technology on a given business process: automational, informational, and transformational:

automational impact occurs when the new technology is used to automate manual tasks; informational impact occurs when the new technology can better track, monitor and analyze the business; while transformational impacts relate to changes in the mechanisms of coordination, including disintermediation, outsourcing, and off-shoring. Mendling identified the major impact of blockchain technology on business processes would be transformational, especially in addressing inter-organizational business process bottlenecks. Considerations have been raised of redesigning business processes with blockchain and shown in table 5:

Table 5: Considerations on blockchain supported BPR (source: Mendling, 2018)

Number	**Challenge Area**	**Detailed Considerations**
C1	Execution	The execution data can be fragmented and involves off-chain data, therefore either data involved in the process should be captured on-chain, or off-chain data should be integrated.
C2	Analysis Methods	There are few methods for business process analysis based on blockchain, on-chain transactional data could be potentially useful for the process analysis.
C3	Process Redesign	It is hard to understand how business processes can be best innovated using the potentials of blockchains, design science and management science methods can be used to arrive at insights in this context.
C4	Adoption	Identification of which circumstances business processes shall be best put on the blockchain and to which extent this will be valuable. Research on which characteristics of blockchain as a technology best meet the requirements of the specific process is needed.
C5	Strategy	How blockchain-enabled activities should be allocated to separate business units to facilitate the business strategy remains an open question.
C6	Corporate Culture	Cultural shifts towards the new technology can be challenging.

Dumas et al. (2018) classify redesign techniques into two types: heuristic process redesign based on an extensive set of redesign options to refine the existing business process, and a product-based design, which is a radical re-engineering of process replacing rather than refining the existing process. Milani and Garcia-Banuelos (2018) developed seven principles of redesigning business processes using blockchain, based on Hammer’s (2001) business process redesign framework that aims for a radical redesign that has transformational impacts. This theory was further developed by combining the process redesign theories of Van der Aalst (2001) and Buzacott (1996) and concluded to business process redesign heuristics for blockchain solutions which are evaluated with various case studies (2020). The research provides an insightful framework towards blockchain in redesigning business processes not merely by eliminating redundant participants.

The capabilities of a DLT-based system are concluded as: (1) shared data storage, (2) computation (smart contracts), (3) data communication, and (4) asset management. Garcia-Banuelos's heuristics contain four categories corresponding to the capabilities: the first is *collaboration of entities,* which corresponds the shared data storage; the second category is *case management structure*, which uses the computational capabilities of blockchain such as smart contracts to execute activities; the third category is *data management* which proposes information-based redesigns; and the fourth is *tokenization*, which draws on the capability of blockchain systems to manage assets.

1. *Collaboration of entities – a centralized inter-organizational process with share ledger*

   The idea of collaboration of entities is twofold: First is to consider that separate entities involved in the process are potentially connected to each other and can interact through a shared ledger. In this case, the geographically dispersed resources can be treated as centralized and exchange easily. The second is to integrate related linear business processes with customers and/or suppliers. In the context of DLT, the participating entities can be integrated with the process running on a shared data ledger, therefore, can provide and receive data instead of comparing and reviewing outcomes at the final stage. Based on the two ideas, two heuristics are developed and shown in table 6 H1 and H2.

2. *Case Management Structure – smart contracts as the basis for task execution*

   The idea of case management structure is around task elimination and automation with smart contracts, process triage, and resequencing. The goal is to re-organize processes around outcomes instead of tasks and minimize the number of involved parties to reduce the efforts and frictions of coordination. In the DLT-based processes, a set of connected smart contracts can access the needed data, execute the predefined tasks, and can be connected to other smart contracts. Duplicated processes performed by several entities should be performed once, and non-value-adding, redundant, and control tasks can be eliminated. A general task can also be split into several tasks, as well as several tasks can be integrated into a general one. Sequential activities can be made parallel with the automation of smart contracts. Based on the case management structure, heuristics are developed and shown in table 6 H3 to H8.

3. *Data Management – blockchain for data communication and transfer*

   While the shared data ledger enables the data storage, DLT platforms allow accessing data from participating entities and external data sources via application programming interfaces (API), and therefore transport data among entities of the inter-organizational processes. This idea is based on the pre-condition that providing the same data for the decision or production is more efficient than re-doing the same work for another participating party. External data can be captured with trusted data sources such as Oracle, and control addition is needed for the completeness and correctness of the data. Without the DLT system, participating entities usually have their own information system that needs to be populated with the same data, which adds cost and time and is error-prone. With a DLT-based system, data can be captured once at the source and be transmitted with the network, and a standardized interface is preferred when manual data capture is required. Based on the data management, the heuristics H9 to H13 are developed and shown in table 6.

4. *Tokenization – DLT tokens for asset management*

With the tokening capability of DLT systems, tangible assets or intangible objects can be digitally represented, and the status can be tracked with smart contracts. One of the most used cases is for the Internet of Things (IoT) to automatically identify and track objects. In the financial industry context, the tokenization of assets as a use case for adopting DLT is also widely discussed. Based on this, the heuristic is H14 developed and shown in table 6.

The 14 heuristics explored and developed based on the four categories provide detailed considerations of process redesign with DLT:

Table 6: Business process redesign heuristics for DLT-based solutions (source: Milani & Garcia-Banuelos, 2020)

Collaboration of Entities	
H1	Consider all participating entities required to achieve the objective of the inter-organizational process as if they are centralized.
H2	Consider integrating participating entities' business processes or activities therefore in the inter-organizational process.
Case Management Structure	
H3	Consider organizing inter-organizational processes around their outcomes and use connected smart contracts for task execution.
H4	Consider outsourcing complete processes or parts of it executed by participating entities, in particular duplicated, to smart contracts.
H5	Consider eliminating unnecessary tasks in the inter-organizational business process.
H6	Consider separating variants of the process into separate contracts.
H7	Consider defining smart contracts that can, given the required data, make autonomous decisions with no or as few manual interventions as possible.
H8	Consider which smart contracts can be executed in parallel and if they can be optimized by resequencing their order of execution.
Data Management	
H9	Consider using the insights produced by participating entities across the inter-organizational processes.
H10	Consider using trusted sources of external data such as Oracle.

H11	Consider moving controls closer to the data entry and, when needed, implementing control addition for more complete and correct data capture.
H12	Consider storing data that is frequently used by smart contracts but not often updated on the shared data ledger and subscribe to updates.
H13	Consider capturing data once and at its source from participating entities.
Tokenization	
H14	Consider digitally representing assets that are used in the inter-organizational process with tokenization.

2.4.2. BPMN in Modeling Blockchain

Business Process Model and Notation (BPMN) is becoming a standard for modeling and specifying business processes to build software or automate specific parts of the processes (Gonzalez-Huerta et al., 2017). The BPMN 2.0 standard is designed to use semi-formal notation to model various perspectives of distributed information systems (Corradini et al., 2020). It is intended to cover different types of process modeling and allows the design and redesign of business processes. There are three types of end-to-end BPMN model types: orchestration, choreography, and collaboration. An orchestration process describes a process within a single business entity that is contained within a pool and normally has a well-formed context. A collaboration process shows the participants and the interactions between them. It contains two or more participants shown by pools and has a message flow between the activities. A choreography diagram aims to show the interaction between participants in different formats and concentrate on the message flow instead of the individual detailed tasks of a process. Both collaboration and choreography diagrams show the interactions of different systems. The choreography diagram shows the interactions among system components without exposing their internal structure, and the collaboration diagram indicates the internal behaviors of various participants (Corradini et al., 2020). Markovska et al. (2019) studied the suitability of BPMN collaboration and choreography to model blockchain-based solutions. It is concluded that BPMN is suitable to model blockchain-based business processes with choreography and collaboration models. The choreography BPMN models can be used for a high-level overview of blockchain and external parties' message exchanges, and collaboration BPMN models can be used to capture detailed processes both inside and outside the blockchain and the corresponding message exchanges.

In this thesis, both the collaboration diagram and choreography diagram will be used to model the mutual fund settlement as-is and to-be processes. The choreography diagram will be used to demonstrate the bilateral communication of each choreography task throughout the process, and the collaboration diagrams will be used to illustrate the activities of each participant and the message exchanges among them.

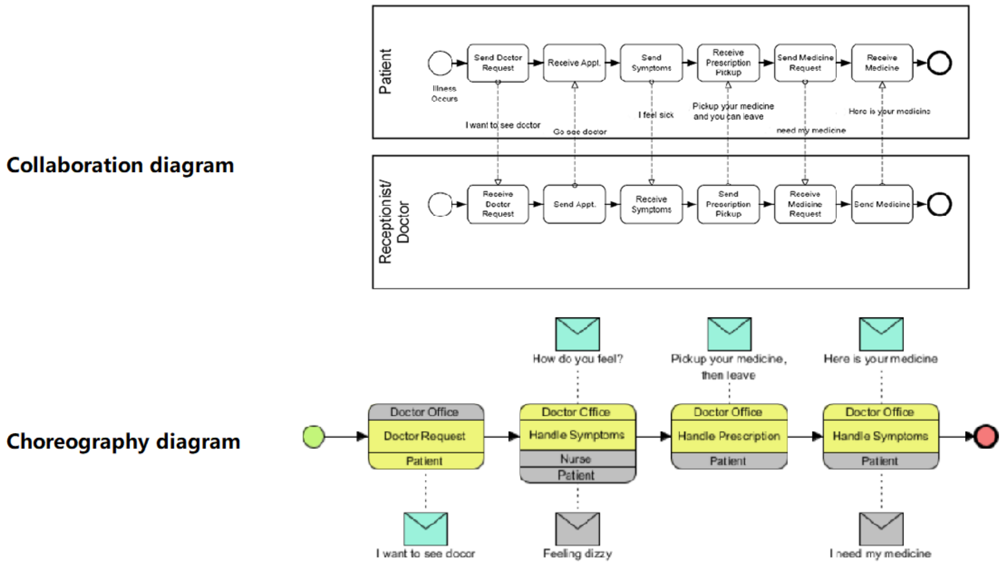


Figure 16: BPMN 2.0 collaboration diagram vs. choreography diagram (source: visual paradigm)

2.4.3. Conclusion

In conclusion, redesigning the business process with DLT-based solutions is considered radical and transformational. The major impacts of DLT in business process redesign are: (a) change the view from intra- to the inter-organizational process by using a shared ledger; (b) use smart contracts as the data repositories and execute tasks, as well as serve as connectors of processes; (c) use DLT as means of data communication and (d) use tokens to manage digitally represented assets. The redesign heuristics are in line with and made use of the DLT capabilities analyzed in 2.2.7., therefore serve as a feasible framework for the considerations to be taken in the redesign.

This redesign of the mutual fund settlement process will be based on Milani and Garcia-Banuelos's heuristic of DLT as enabling technology in business process redesign, in combination with the ECB studies on tokenization in post-trade settlement scenarios. The modeling language will be BPMN 2.0 collaboration and choreography diagram. For the as-is process, the collaboration diagram will show the current activities and message flows owned by each participant, the choreography diagram will show the bilateral message exchanges of each choreography task. For the to-be process with DLT as enabling technology, a redesigned collaboration model will be presented.

It should be mentioned that, as the purpose of this study is the explore the high-level redesign of mutual fund settlement process, the business processes are not considered to be able to execute directly on DLT systems as is discussed by Falazi et al. (2019) and Lopez-Pintado (2019), but simply as a manifesto of the transition from the conventional settlement process to the DLT-enabled settlement process.

2.5. Chapter Conclusion

This chapter introduces the theoretical background for this research, constructed the knowledge base for the design science research, and answers research question 1. The concept of mutual fund and distributed ledger technology was introduced, the capabilities of DLT are studied, and the capabilities for mutual fund settlement have been analyzed. Further, the research framework of this thesis – business process redesign and the research methodology DSR have been studied. The study on the heuristics of business process redesign with DLT serves as the underlying redesign indicators, and BPMN 2.0 will be used as the modeling language for the as-is and to-be processes.

3. Mutual Fund Settlement Environment

This section introduces the environment for the design science research – the current mutual fund settlement process. The general model of how the mutual fund is distributed and settled in Europe is described in 3.1; A case study in an asset management company on the settlement of a mutual fund settlement process is studied in 3.2; The problems of the current process are analyzed in 3.3, and the chapter is concluded in 3.4. This section aims to answer research question 2: *What is the current mutual fund post-trade settlement landscape, and what are the problems?*

3.1. Mutual Fund Distribution and Settlement General Model

The value chain of fund distribution has been known as complex and challenging. The primary reason is the number of intermediaries and operational processes involved in the daily activities, including advising, identifying, instructing, acknowledging, processing, checking, confirming, monitoring, reconciling, reporting, regulating, auditing, etc. The value chain of European fund distribution consists of various commercial and operational intermediary institutions. The distribution model is mainly based on a B2B2C (business to business to customer) model (Accenture, 2020) via distributors such as banks, financial advisors, and insurance companies.

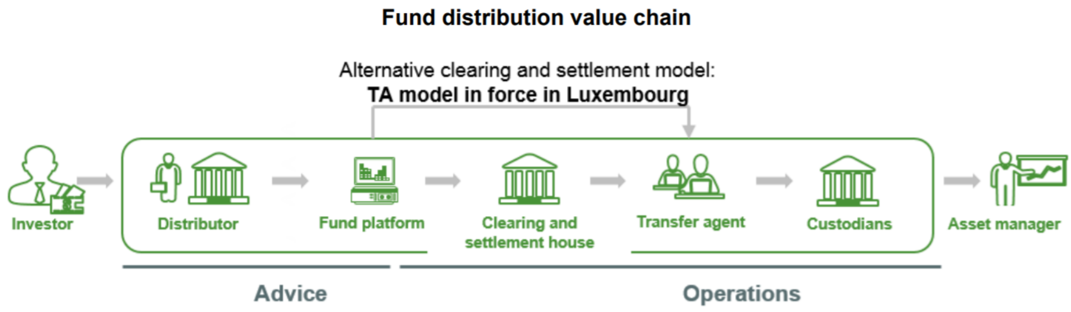


Figure 17: Fund distribution value chain (KPMG, 2018)

Intermediary institutions have different platforms performing order routing and commission computation as well as other compliance and operational services. The participating institutions might vary for different asset managers. The fund managers may not necessarily know that a broker has sold shares until the trades have moved through the trading system, been transmitted via transfer agents, and ultimately settled by the custodian banks or fund administrators. There is little transparency on the fund orders throughout the operations process. The fund managers know that clients ask to buy or sell, but not how much precisely during one trading date. Similarly, the fund's sponsor doesn't immediately know how much money people are investing. That piece of information would be beneficial to money market funds because the institutional traders are putting money in bulk for short-term liquidity and funding for their short-term liabilities (Sinha, 2020).

The European Fund and Asset Management Association (EFAMA) (2008) provides a general model for the European mutual fund order processing and settlement processes, reflecting the European fund's operating practices on a high level. This framework presents a recommendation for asset managers and related financial service infrastructures to improve efficiency in fund order processing. In this high-level model, one actor can perform more than one role, and one role can be performed by more than one actor. The actual configuration varies from asset managers to asset managers.

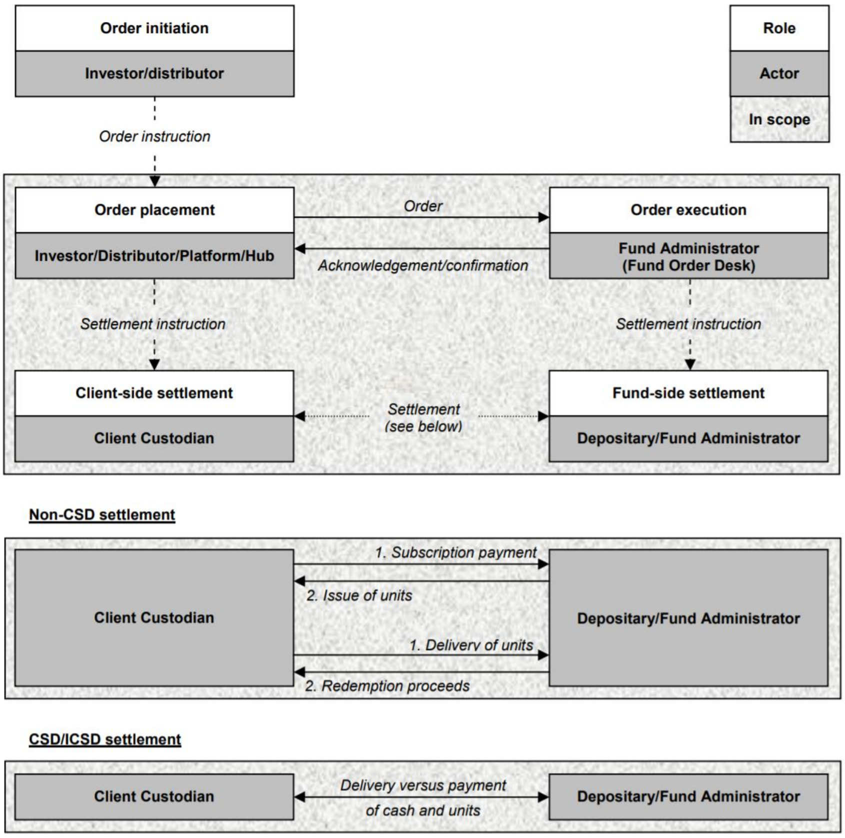


Figure 18: Fund order processing and settlement in Europe (source: EFAMA, 2008)

There are five essential processes in the fund order processing and settlement:

1. *Order initiation:* the initiation of the order by the end investor and communication through the placement stage, directly or through one or more intermediaries;
2. *Order placement:* communication of the order to the fund-side institution by the dealing function of the client-side institution and subsequent issue of the client-side settlement instructions;
3. *Order execution:* receipt, acceptance, and processing of the order by the fund-side institution as agent for the fund;
4. *Client-side settlement:* arranging for payment to be made for units purchased or for title to give up to units sold;
5. *Fund-side settlement:* making or arranging the settlement of transactions on behalf of the fund by issuing and buying back shares;

The order initiation and placement roles can be performed by the same actor or separate entities that either communicate directly or through one or more intermediaries. Where multiple entities are involved, they might use proprietary interfaces. To reduce duplications and errors in registered accounts, the current model suggests that client's accounts are maintained by the fund-side institution.

There are two main approaches towards the settlement of funds, as is shown in figure 18: the non-CSD settlement and CSD/ICSD settlement. The non-CSD settlement model, or direct model, is used by most of the European countries, including the Netherlands. With this approach, investors, intermediaries, and platforms go straight to the fund or its transfer agent to process the order and settlement of the fund. Payment or delivery is by the client-side custodian, on receipt of which the fund-side institution will complete the process. The CSD/ICSD settlement happens when the trading and settlement of funds occurs in the CSD or ICSD (International CSD) in the same way as an equity or bond trade would be cleared. The CSD model aims to build a settlement 'hub' for the use of transfer agents and aims to facilitate delivery-versus-payment (DvP)[1] in the mutual fund sectors, placing the mutual fund settlement on the same footing as securities settlement.

This model provides a high-level reference for asset managers to design their mutual fund settlement processes. However, it is not elaborate enough on the participating institutions and their activities in facilitating the settlement. A case study that follows a non-CSD settlement process with transfer agents and fund administrators perform order execution is conducted in a Dutch asset management company so as to provide the as-is process case for this thesis.

3.2. Mutual Fund Settlement Process Case

As the operation models for every asset manager can vary, a case on the settlement process of the mutual fund is studied in an international asset management company – NN Investment Partners (the AMC, hereinafter referred to as NNIP) via multiple interviews to understand the details of the as-is process of mutual fund settlement. The high-level process model was created based on the general model and literature research. Then the model was presented to the experts in business analysis and fund operations, who provided feedback on the actors and the process. The process model was then refined, and detailed collaboration and choreography models were created to demonstrate the process.

3.2.1. Primary Actors and Functions

The primary actors in the lifecycle of the settlement of mutual funds are generally trusted institutions that serve as intermediate operational institutions. They may play one or more critical roles in fostering the smooth functioning of the settlement system. The asset manager nominates

[1] Delivery-versus-Payment: A securities settlement process that requires the payment to be made before or at the same time as the delivery of the securities. The process is to reduce the risk that securities could be delivered without payment or payments could be made without the delivery of securities.

these institutions to perform operational activities representing the fund and pays specific service fees. The primary actors and their functions in the lifecycle of mutual fund settlement are introduced in table 7:

Table 7: Major participants' roles and functions in mutual fund settlement (source: NNIP & National Market Practice Group)

Actor	Quantity per Fund	Functions
Investor	Many	• Invest money in the mutual fund shares and benefit from the performance of such investments. • It can either be an individual or an institutional investor.
Regulator	One	• A state authority that lays down and monitors the rules for the financial market participants
Intermediary	Many	• An agent between the investors and the transfer agent. • Provides information on the investors' orders and the related amount. • Provide fund information to potential investors, accept orders on behalf of a fund and implement order transfer as well as the flow of information between the fund and investors. • It is remunerated in the form of commissions paid by the fund and/or the investors.
Transfer Agent	One	• Perform registrar functions to keep investor registers, keep the records of the investor securities account. • Appointed by the asset management company to update investors' accounts to reflect daily subscriptions, redemptions switches, and transfer transactions. • Provides tax information to the investors and its intermediaries. • Calculate, receive and set off commissions. • Prepare and send order confirmations and the resulting cash account statements to the investor or its intermediary.
Fund Administrator	One	• Perform back-office financial paperwork. • Process paperwork for trades and related activities, register and settle funds, converts cash to and from funds. • Perform fund accounting services, including the end-day calculation of NAV. • Report fund transactions to asset managers. • Assist with inquiries and provide information related to funds, portfolios, prices, dealing procedures, markets, and currencies. • Ensure financial and legal compliance of a fund.
Investor's Custodian	Many	• Accept money if an investor wants to deal directly with the fund or for investors holding registered mutual fund shares. It

		settles the investor's account with the fund's custodian by paying when the investor subscribes, and receives redemptions.
Fund's Custodian	One	• Makes and receives payment on behalf of the mutual fund. Keep track of mutual fund assets, sales and purchases, tracking and recording trades by investors to maintain accurate records. Maintain, monitor and track shareholder values. Disburse dividends and pays proceeds from unit redemption. • The custodian role is important in dividing the responsibilities of managing the mutual fund and eliminating asset managers' potential to acquire too much power.
Asset Management Company	One	• The company that launches the fund, determines the investment strategy, appoints service providers, and makes major decisions on behalf of the mutual fund. It is responsible for the distribution and marketing of the fund. • The asset managers within the company select securities of the portfolio in accordance with the fund objectives as reflected in the fund prospectus. They place to buy and sell orders for securities in accordance with the fund's net inflows and outflows. • The fund accountant within the company records the fund's assets and liabilities, calculates the trading prices and the funds' NAVs.

Compared to the EFAMA model of order processing, the investor performs the order initiation and order placement function via the intermediary or directly through the transfer agent. The order execution function is extended to activities including fund inflow/outflow calculation, fund NAV calculation, and settlement instruction and confirmation. These functions are performed by transfer agents and fund administrators nominated by the asset manager to provide services to the fund.

A transfer agent (TA) is a trusted institution that registers and maintains detailed records of investors' transactions for the convenience of the asset management company. The TA performs the order execution function in the EFAMA model, which, in the model, is performed by the fund order desk of the fund administrator. Transactions information like buying, exchanges, processing of mails and related information, changes in personal data, etc., occur frequently and need to be recorded and updated. Asset management companies usually outsource their transfer agent service to a trusted financial institution, and one mutual fund would be appointed to one transfer agent to process-related data. The intermediaries of one mutual fund, however, can be multiple and distributed. The investors can approach the mutual fund either by the intermediary or by the transfer agents. The transfer agent gathers all data of a mutual fund transaction on behalf of the asset management company and acts as a single-window of one mutual fund for the investors.

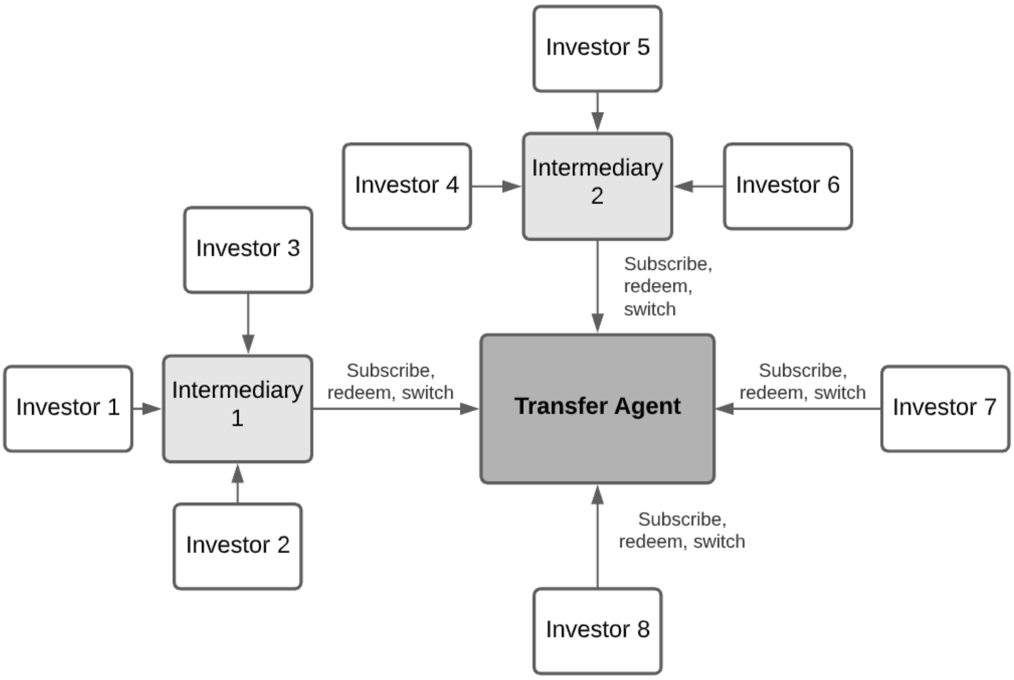


Figure 19: Transfer agent as a single-window of mutual fund for intermediaries and investors (source: NNIP)

The fund administrator (FA) performs the accounting operations on the daily cash flows of the mutual fund and reconciliations. It receives information both from the investor's side (through transfer agent, on the fund subscription, redemption, and switch) and from the investment side (through asset manager, on the fund assets and liabilities), and performs the accounting and calculation of NAV based on the two sides' information. Then instructs the investors' custodian banks to settle the orders and update the transfer agent and asset manager on the NAV and the settlement:

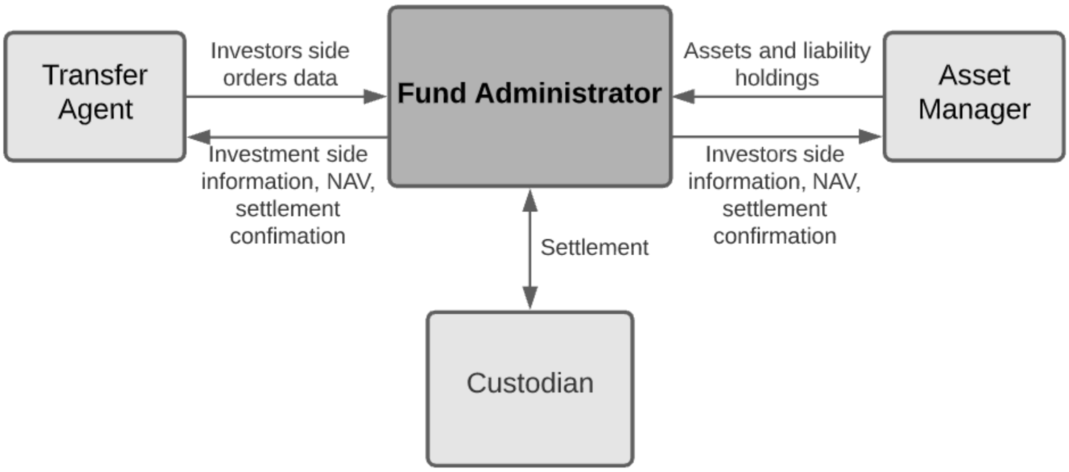


Figure 20: Fund administrator receives two side information and instructs settlement (source: NNIP)

The transaction data are passed through all the participants mentioned above, and each participating institution has its own ledger related to the transaction. The transaction data run through the distribution network and gathers to the asset managers. On one sides, the asset managers receive the aggregated fund inflow/outflow data from its service providers. On the other side, the asset managers make decisions on the assets trading with considerations on the inflow and outflow data of the mutual fund. The investment decisions result in the mutual fund's portfolio on the trading day and send back to the fund administrator, who does the accounting and calculates the NAV per share, as well as settles the transaction by converting cash and mutual fund shares. The confirmation and NAV data are then sent back to the transfer agents, where the digital fund certificates specifying the traded fund shares and investor’s rights are issued and sent back to the investors. Each institution in this process holds its own ledgers recording the transaction data. From the asset management company’s perspective, the ledgers can follow a hub and spoke structure abstracted to the following:

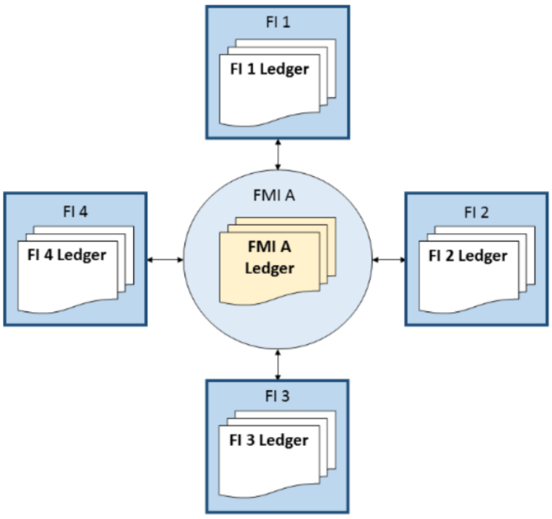


Figure 21: Hub and spoke structure with one FMI and FIs as participants (Mills et al., 2016)

3.2.2. Mutual Fund Settlement Process Models

As mentioned in the operation loop of mutual funds in 2.1.2, the operations include both on the investors' side and on the fund's side, with the asset manager in the middle. On the investors' side of the settlement, the process involves the investors, the intermediaries, the transfer agent, the fund administrator, the investor's custodian, and the asset manager. The aim is to receive orders from the investors, process the orders and convert the cash to units of shares in the mutual fund and issue fund certificates to the investors. On the assets' side of the settlement, the process involves the fund's custodian, and intermediary institutions who are not shown for simplicity reasons since the focus is on the other side. The aim is to execute the asset manager's investment decisions, to trade financial assets with the cash received from investors. The high-level operational process on both sides of the operations is shown in figure 22 to give an overview of the environment:

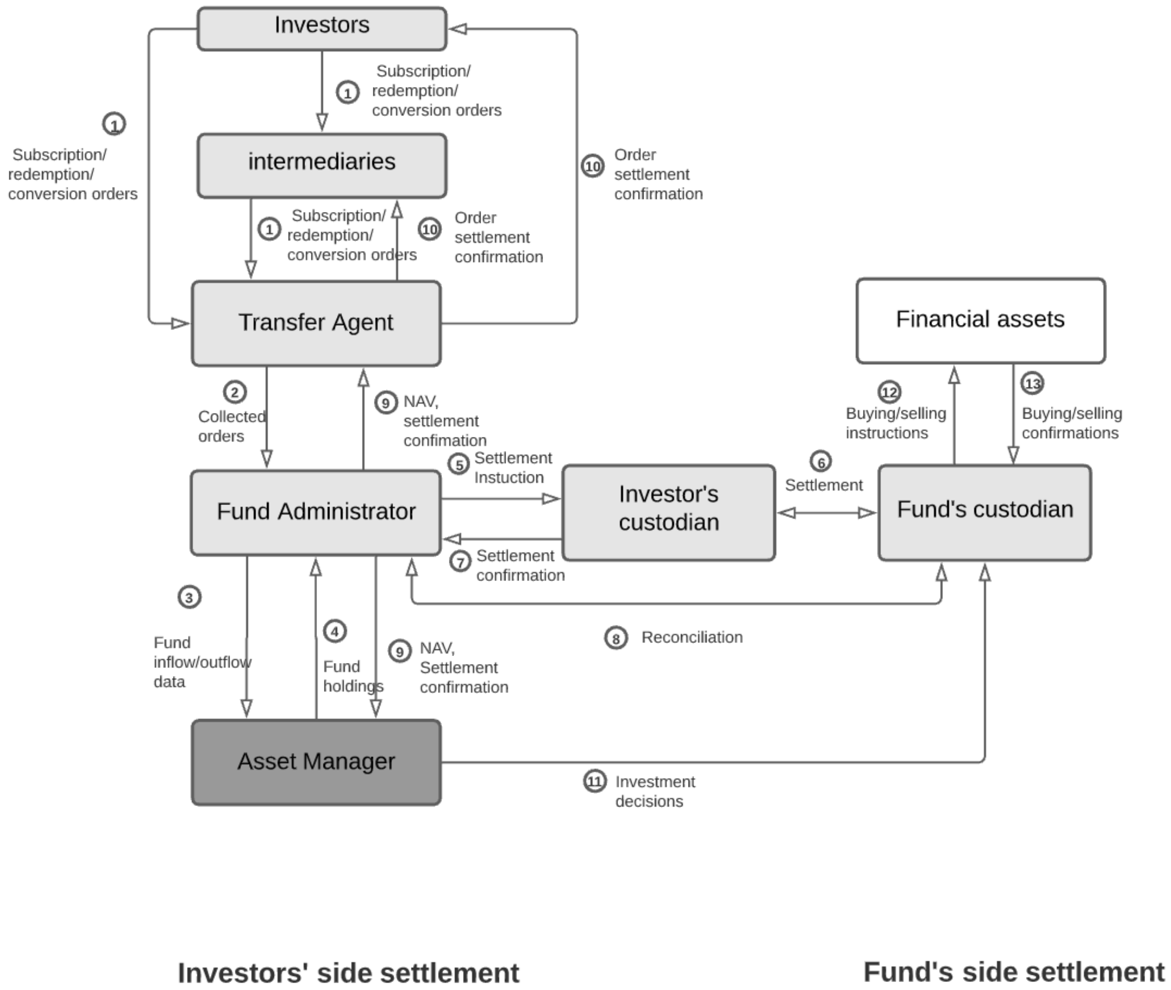


Figure 22: Mutual fund two sides settlement high-level process (source: NNIP)

The high-level process on the investors' side settlement includes nine steps:

Step 1: During the trading day, the investor wants to subscribe, redeem or switch certain shares of a mutual fund, the investor can use either approach to the intermediaries (brokers, banks, etc.) or a direct approach to the transfer agent to get the information of a mutual fund, and place the orders;

Step 2: The transfer agent collects all the orders from various investors and intermediaries of one trading day, and send the orders to the fund administrator of this mutual fund;

Step 3: The fund administrator aggregates the subscription, redemption and switch orders, and send the aggregated inflows & outflows of the fund shares to the asset manager;

Step 4: The asset manager gets the transaction information and makes investment decisions carried out on the right-hand side of figure 22. This will result in the settlement of fund holdings on the financial assets at the end of the trading day. The holdings data is then sent to the fund administrator to further calculate NAV per share.

Step 5: The fund administrator gathers the information on the fund in/outflows and the holdings of assets and performs the calculation of NAV per share. After the NAV per share is calculated, the fund administrator sends the settlement instruction to the investor's custodian, who follows the instruction and converts the investors' cash balance to the units of fund shares.

Step 6: The investor's custodian then settles money with the fund's custodian on the investor's account.

Step 7: After the settlement with fund's custodian, the investor's custodian sends back the settlement confirmation to the fund administrator.

Step 8: Then, the fund administrator sends the new NAV of the trading date and the confirmation of settlement to the asset manager and the transfer agent.

Step 9: The transfer agent sends the settlement confirmation (with a digital fund certificate) of the order back to the investors.

To understand the bilateral communications occur in this process, a BPMN 2.0 choreography process made from the process mentioned above is shown in figure 22 and 23:

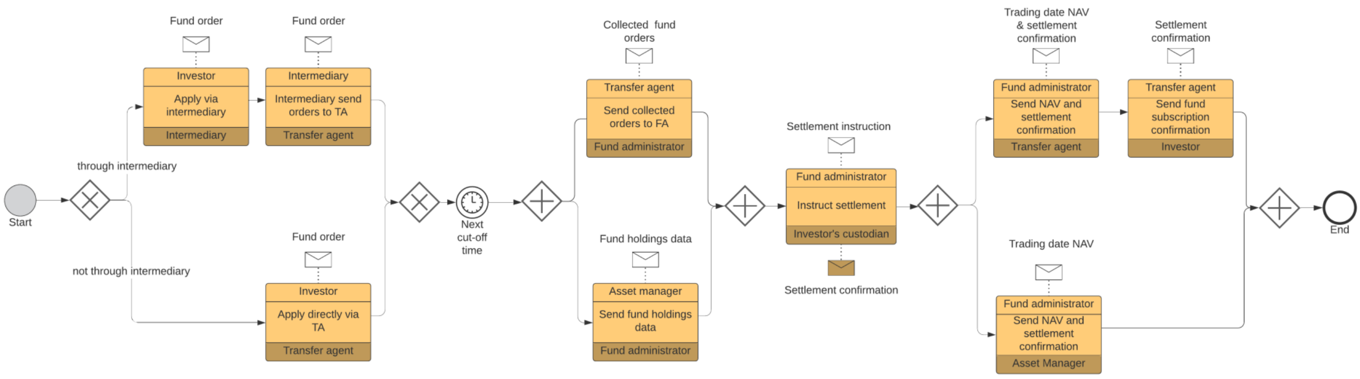


Figure 23: Message choreography process model of investors' side settlement

The following table shows the occurrence and communication of each data object in this choreography process:

Table 8: Data objects creating and receiving entities

Number	Data object	Create entity	Receive entity	Occurrence
1	Fund order (individual and aggregated)	Investor	Intermediary, transfer agent, fund administrator, asset manager	4

2	Fund holdings	Asset manager	Fund administrator	1
3	Settlement instruction	Fund administrator	Investor's custodian	1
4	Settlement confirmation	Investor's custodian	Fund administrator, transfer agent, investor	3
5	NAV per share	Fund administrator	Transfer agent, intermediary, investor, asset manager	4

An Entity-Relation Diagram (ERD) is made to better demonstrate the entities and data objects and their relations:

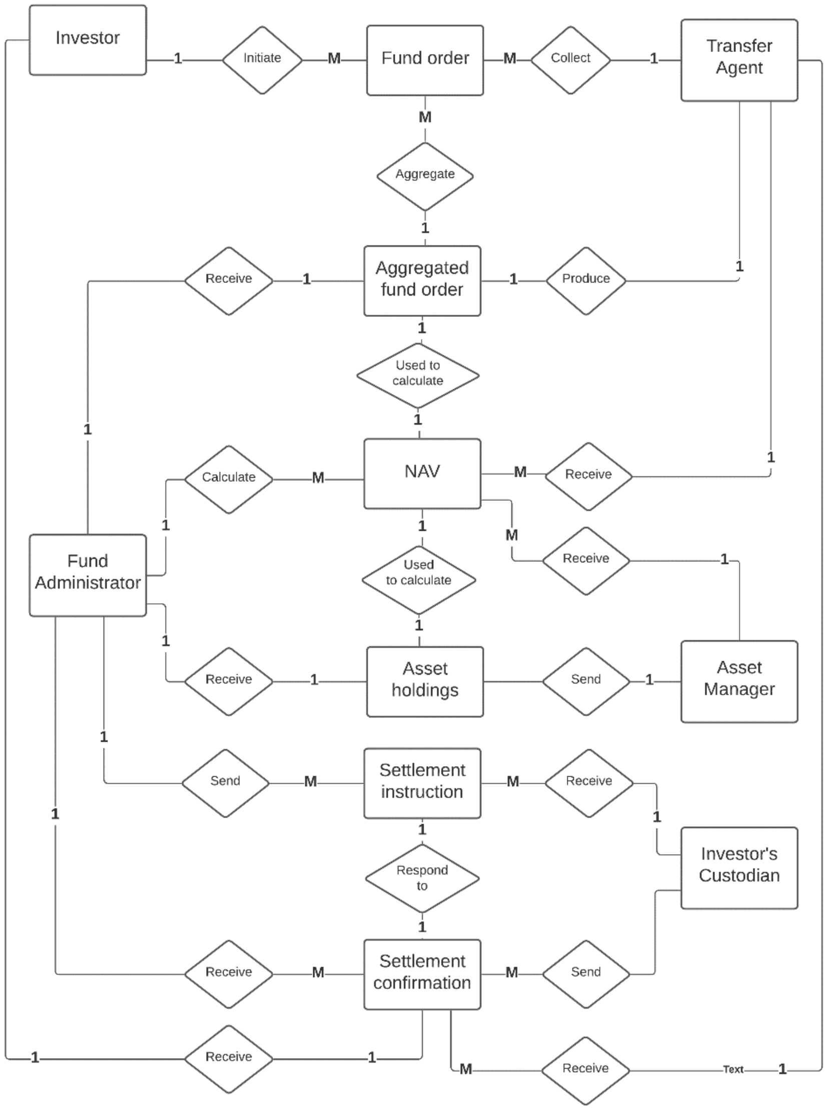


Figure 24: Entity-Relations Diagram showing the relations of participants and data objects

Based on the understood high-level process, a collaboration diagram using BPMN 2.0 is made and shown in figure 18:

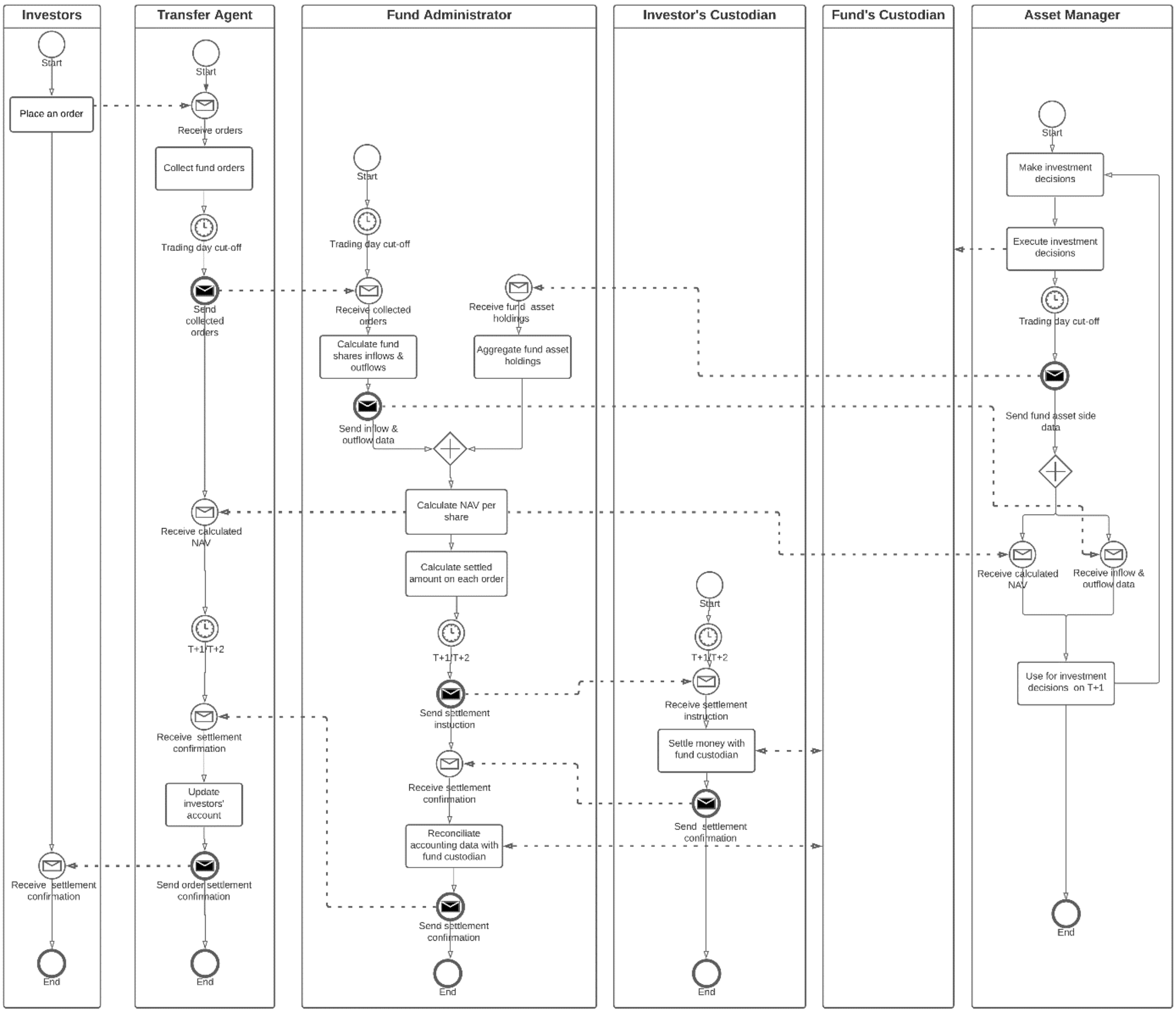


Figure 25: The as-is collaboration process model of investors' side settlement

In the collaboration process diagram, each pool contains and represents the process that is centrally controlled by one entity. The activities by each participant are illustrated in the table:

Table 9: Activities of the collaboration process

Number	Activity Owner	Activity Name
1	Investor	Place an order
2	Transfer agent	Collect fund orders
3	Fund administrator	Calculate aggregated inflow and outflow
4	Fund administrator	Calculate aggregated asset holdings
5	Fund administrator	Calculate NAV per share
6	Fund administrator	Calculated settled amount on each order
7	Investor’s custodian	Settle money with fund custodian
8	Fund administrator	Reconciliate accounting data with fund

		custodian
9	Transfer agent	Update investor's account
10	Asset manager	Make investment decisions
11	Asset manager	Execute investment decisions
12	Asset manager	Use data for investment decisions on T+1

3.3. Problem Analysis on Current Process

The choreography and collaboration process models of the mutual fund settlement processes show the cumbersome data communications for a settlement of investor's order. Since each party involving in this process holds a ledger that is unsynchronized with other ledgers, it hinders the efficiency and adds frictions to the settlement process by the communications and reconciliations on the ledgers. With a shared, synchronized ledger, this process will be largely simplified and improved. The current problems of the process are identified as follows:

1. *Bilateral communication and lacking data standard*

The same investor's order data passes through the intermediaries, aggregated in the transfer agent, and then sent to the fund administrator, who also shares the data with asset managers for investment decisions. The same data elements are communicated bilaterally among the participants. Each participant in this process has their own databases, which are distributed and unsynchronized. Data communications and confirmations are needed on a daily basis. The intermediated process and untransparent data hinder the efficiency of the operational process, resulting in an order to be settled in 1 to 3 days after placement.

The industry has developed its standard for communications of financial institutions using SWIFT messages and its network. SWIFT stands for Society for Worldwide Interbank Financial Telecommunication, which is a cooperative undertaking controlled by its participants to provide a secure messaging service for fund settlements among participants. SWIFT (2015) studied the levels of automation between financial counterparties. The communications between asset managers and custodians are highly automated, where standardized messages such as SWIFT are used for instructions and confirmations on the settlement. For example, SWIFT MT940/MT950[1] is used to send end-of-day bank statements that detail all entries booked to an account. SWIFT MT535 is used to reconcile the books of the account owner and the account servicer for the specified safekeeping account or sub-safekeeping account. However, the other information

[1] MT refers to Message Type, MT940 and MT950 are the format used by SWIFT to send and receive end-of-day bank account statements. MT535 is used to report at a specific moment in time the quantity and identification of financial instruments which the account servicer maintains for the account owner.

exchanges among asset managers, transfer agents, and fund administrators are less standardized, rely heavily on file transfers and fax, and have limited use cases for the available SWIFT message standards.

One asset manager can have multiple mutual funds with different transfer agents and fund administrators based on domiciles, and the institutions all have their own data standards. In the case of NNIP, over 300 fund products are managed, facing the Netherlands, Belgium, Luxemburg, Poland, and Japan markets. Each domicile has its own financial service providers providing transfer agency and fund administration services. For example, NNIP nominates Brown Brother Harriman (Luxembourg) S.C.A[1] to provide order processing to funds facing Luxembourg market and the Bank of New York Mellon Corporation[2] for Dutch and Belgium market. Different third-party agents have their own data format requirements. The lack of standard information set and format for these details can result in duplicate and incorrect investor account information, which adds workload for the reconciliation and dealing with errors. The industry has proposed to have a standard minimum set of account standing data, however with the complexity of intermediate institutions, the data standard still remains to be an issue.

2. *Intensive manual tasks lead to low efficiency and are prone to errors*

According to a survey by Calastone (2021) on 58 AMCs, distributors and fund platforms about the late settlement of mutual funds: 59% mentioned the manual processes are the main problems for the late cash settlement, with 38% specifying the manual data input errors, and 24% mentioning the trade data input and rekeying errors.

[1] Brown Brothers Harriman (BBH) is a privately-owned and managed American financial services company offers private banking and investment management services. Established in 1989, BBH Luxembourg offers asset servicing and data solutions across the middle and back office for fund managers and provides custody, data and infrastructure services to European private and national banks.

[2] The Bank of New York Mellon Corporation, commonly known as BNY Mellon, is an American investment banking services holding company headquartered in New York City. It is the world's largest custodian bank and asset servicing company.

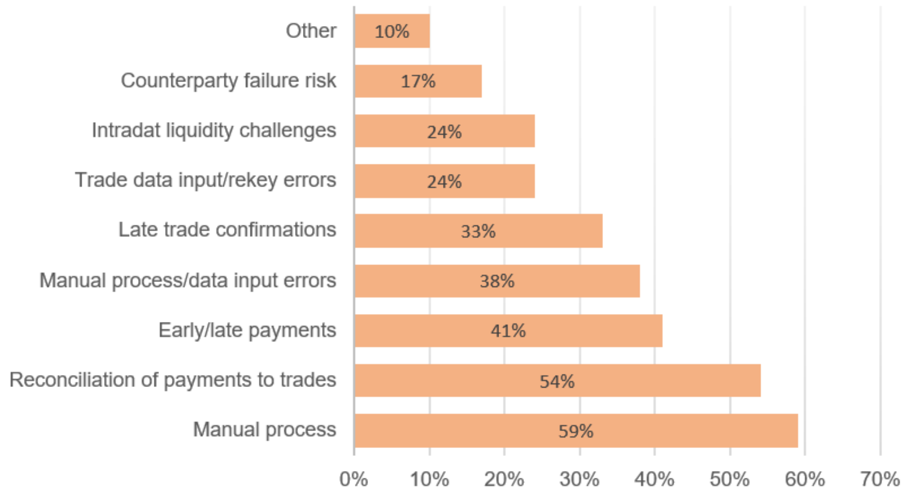


Figure 26: Problems causing late cash settlement of mutual funds (source: Calaston, 2021)

Updating trade register and settlement calculation are identified as the stages facing settlement problems most. On the order's placement, the orders are placed with the fund order desk by a variety of means, including post, telephone, fax, e-mail, and proprietary electronic messaging. With most of these methods, manual intervention and re-keying are required. On accounting and data communication, the accounting and communication of data rely heavily on excel. In many cases, the asset data are input into an excel sheet manually and sent to the counterparty, who then input the data into their platforms. The manual tasks are labor and time-intensive, which also leaves space for errors. A four-eye check is usually needed to ensure the data are input correctly, increasing complexity and reducing efficiency. The increase of transaction volumes and the settlement of multi-currency amplifies this problem.

3. *Dispersed and hard-to-access distribution data to asset managers*

The fund shares in-flow and out-flow data are aggregated from the transfer agent, sent to fund administrators, and then communicated to the asset managers. The asset managers only know the in-flow and out-flow data at the end of the trading day (unless extreme volatility happens), and the investment decision based on the data on the asset trading side is made on the next day. This causes a delay of information, making asset managers slow to the market. The delay in reaching investor's information can cause the asset managers to react slower to the market changes, especially in a volatile market situation, therefore impact the corresponding investment decisions.

4. *Late settlement confirmation and untransparent data*

The fund administration system generates confirmations at the end of the trading day on which the NAV is calculated and to be dispatched on the following day. This means the investor's side institutions cannot receive the formal confirmation and price of the transaction until the next day (or later if it is sent by post), even the settlement has been completed. The client service provided with the current approach, therefore, also suffers from inefficiency. The client's query on a previous day investment activity needs to be passed on through the network and may take 2 to 3 days to get the response (Van Verre, 2017). The late access to settlement information and untransparent settlement data can result in a delay of an investor's investment decision, therefore incur opportunity costs.

5. *Intermediary costs*

The transfer agents and fund administrators are nominated by the asset manager to perform the operational activities of the fund. Therefore, costs occur with the intermediary institutions offering services to the asset managers. The potential to disintermediate these participating institutions can reduce the costs for asset managers and focus the resources on improving service on the value-adding services to the investors.

3.4. Chapter Conclusion

This chapter studied the current mutual fund distribution value chain in Europe and showed the case study on a settlement process of the mutual fund of the fund in an asset management company. The participants in this process are identified, and their functions are explained. The as-is settlement process on the investor's side is illustrated with a BPMN 2.0 choreography and collaboration diagram, showing the activities of different participants and the bilateral communications of the data throughout the process. The problems of the current process are then analyzed. To generalize, the main problems are caused by the bilateral communications of fund orders throughout various intermediaries. These problems are used as the basis for the design of the to-be process.

4. Redesign Mutual Fund Settlement Process with DLT

This section aims to put into practice what has been studied in the theoretical framework in the combination of the mutual fund settlement environment and to answer research question 3: *How can the business process of mutual fund settlement be redesigned with DLT-based solutions?*

Following the theoretical frameworks studied in chapter 2, the redesign of the mutual fund settlement process mainly follows Garcia-Banuelos's 14 DLT-enabled business process redesign heuristics (2020) which are made into four categorizations. The four categorizations of heuristics are correspondent to the DLT capabilities on shared data storage, computation (smart contracts), data communication, and asset management. The first category – collaboration of entities – focuses on concentrating the inter-organizational process with a shared and synchronized data ledger; the second category – case management structure – focuses on eliminating and automating tasks using smart contracts; the third category – data management – deals with accessing on-chain and off-chain data involved in the inter-organizational process; and the fourth category – tokenization – discusses using digital tokens for asset management in the DLT system. The first four sections of this chapter discuss how the as-is mutual fund settlement process is redesigned based on the four categories of heuristics. The fifth section discusses the implications of the redesigned mutual fund settlement process.

4.1. Collaboration of Entities

The aim of the collaboration of entities is to centralize the inter-organization process with a shared ledger. The shared and synchronized ledger records data involved in the business process. Participants can read, write and commit the shared ledger with or without authorized permission (based on the permission model of the DLT system), therefore the need for bilateral communications on data between the participants is eliminated.

Following the heuristics, the first step is to consider that separate entities involved in this process are potentially connected to each other and can interact by means of a shared ledger (H1, table 6). Even though each entity participating in the as-is process has its own objective, it can be assumed that they all contribute to one virtual objective – to settle the mutual fund subscription/redemption/switch order initiated by the investor, with the correct NAV calculated on the trading date. The second step is to integrate the entities with the process running on the shared data ledger so that each participating entity can read and (partially) write data on the shared ledger, instead of communicating bilaterally and reviewing and reconciling (H2, table 6). With the first step, all participants in the inter-organizational process are connected to each other with a distributed shared ledger, which is shown in figure 27:

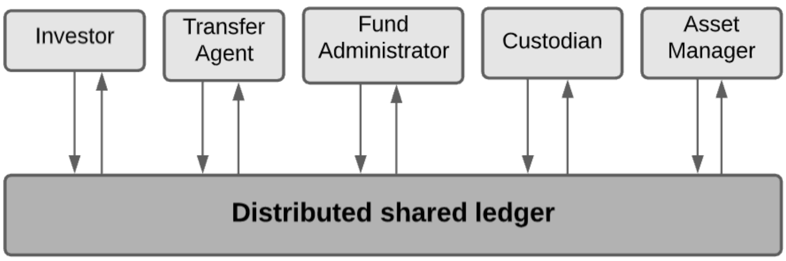


Figure 27: Collaboration of entities on the distributed ledger

The second step integrates the participating entities into the distributed ledger. In 2.2.6.2, two governance types are discussed: categorized by whether the intermediaries are kept or removed in the DLT solution, there are trusted bridging and trustless bridging. It will be further discussed in later sections, operational tasks can be automated by smart contracts (discussed in case management structure), and assets can be tokenized using digital tokens for smooth DLT operations (discussed in tokenization). The AMC no longer has the need to nominate third-party institutions to perform operational tasks. And as is discussed in the background, one of the main goals of adopting DLT in the mutual fund settlement process is to reduce settlement costs from disintermediation. With operational tasks automated, the role of the transfer agent, the fund administrator, and the custodians in the mutual fund settlement process under discussion, can be eliminated.

The actors involved in the to-be process of the settlement are then eliminated to investors and the asset manager. The investors are directly interacting with the DLT system, which is owned by the asset management company. The investors initiate subscription/redemption/switch orders on the DLT system, and the DLT system confirms the order and issues fund certificates. With the money pooled from the investors and safekept by the DLT system, the asset manager of the mutual fund buys and sells financial assets based on the investment strategy. The high-level to-be process is shown in figure 28.

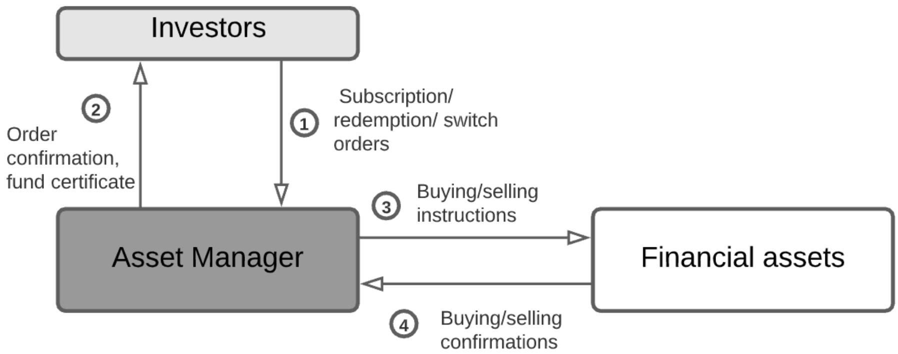


Figure 28: High-level to-be process

The investors need to go through an identity check (KYC/AML[1]) to becomes valid members to participate in the mutual fund transaction. The DLT solution requires all the participants in the settlement process to access a public and permissioned ledger. The asset manager gives permission

[1] Know-your-customer and anti-money-laundering, the procedures to assess customer's identity, financial activities, risk and legal requirement to comply with AML laws. The procedures are performed on new investor's opening the account on the fund, which is out of the scope of the discussion. The DLT is also discussed in the KYC/AML area with potential applications.

of writing and committing to the ledger upon the completion of the identity check. The process starts with the investor initiating a subscription/redemption/switch order of one mutual fund, similar to the as-is process. Instead of handing the order to the transfer agents, the investor directly initiates the order on the distributed ledger and pays the money (when subscribing) or fund tokens (when redeeming or switching) to the DLT system, where the order is then recorded on the ledger pending the calculation of the NAV on the next cut-off time. On the distributed ledger, fund units are kept as tokens and kept in custody by the distributed ledger. Upon the cut-off time, the NAV is calculated and the same as the to be settled amount on each ledger. The settlement (conversion of fund tokens and money) can then be executed, and the investor will receive settlement confirmation. The to-be choreography process (figure 29) can then be simplified to the communications of the investor and the AMC.

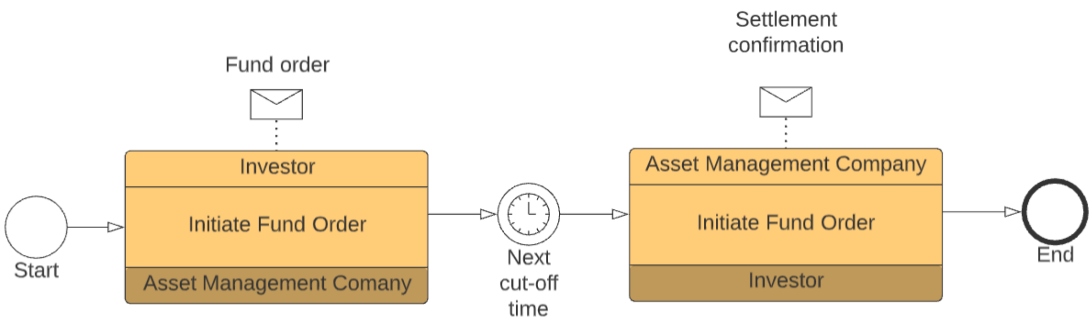


Figure 29: To-be mutual fund settlement choreography process

4.2. Case Management Structure

The aim of the case management structure is to eliminate tasks and automation activities with smart contracts, as well as the potential resequencing of the process. The first heuristic is to organize process activities around outcomes and use connected smart contracts to execute activities (H3 & H4, table 6). Then consider eliminating unnecessary tasks especially reduce manual interventions (H5 & H7, table 6). The sequence of activities can be adjusted as smart contracts can be executed in parallel (H6 & H8, table 6).

An example of how the settlement of payment can be realized with the smart contract is shown in figure 31, the pseudocode shows the inputs, triggers, activities, and outputs:

```
Algorithm 5: Settling Payment
Input : authorized caller, caller, BTcontract state, parent
        contract, main Contract, transportation fees,
        item price, buyer, seller
if BTcontract state = Successful Key Verification then
    Settle payment starting from the main contract.
    foreach contract ∈ chain do
        Set state of contract to Successful Key
          Verification.
        if contract is a BTcontract then
            Transfer item price to buyer.
            Transfer the contract balance to the seller.
            Set contract state to Settle Payment Success.
            Create a notification.
        end
        else
            if caller = authorized caller ∧ contract state
              = Successful Key Verification then
                payment ←
                  (2 ∗ item price) + transportationfees
                Transfer payment to contract's next
                  transporter.
                Transfer the contract balance to the child
                  contract.
                Create a notification.
            end
            else
                Revert contract state and show an error.
            end
        end
    end
end
```

Figure 30: Example of payment settlement smart contract (source: Hasan & Salah, 2018)

Based on the heuristics for case management structure, the to-be status of each activity in the as-is collaboration process (table 9) are analyzed as follows:

Activity 1 – Place an order: the outcome is the creation of fund order, which should be initiated by the investor by creating a subscribing/redeeming/switching fund order on the ledger;

Activity 2 – Collect fund orders: the outcome is collected fund orders during one trading day from all investors. As the orders are initiated on-chain, the collection of fund orders can be automated with a smart contract;

Activity 3 – Calculate aggregated inflow and outflow: the outcome is aggregated fund inflow and outflow data, which is later used for NAV per share calculation. The calculation can also be easily automated with a smart contract;

Activity 4 – Calculate aggregated asset holdings: the input is holdings on each asset from the asset manager, and the output is the aggregated asset holdings. The calculation can also be easily automated with a smart contract;

Activity 5 – Calculate NAV per share: the inputs are the outcomes from activities 3 and 4, and the output is the calculated NAV per share on the trading date. The calculation can also be easily automated with a smart contract;

Activity 6 – Calculated settled amount of each investor's order: the inputs are the outputs from activities 2 and 5, and the output is calculated settlement amount on each order. The calculation can also be easily automated with a smart contract;

Activity 7 – Settle money with fund custodian: the settlement previously by sending and receiving money between investors' and fund's custodian can be changed to transfer money and fund tokens on-chain with the help of asset tokenization. The execution can be automated with a smart contract;

Activity 8 – Reconciliate accounting data with fund custodian: the activity is to guarantee the orders are correctly settled. With a DLT-based solution, the reconciliation on the data becomes redundant, and data are kept on one single shared ledger;

Activity 9 – Update investor's account: the input is from activity 7 where the settlement is confirmed, and the outcome is the updated settlement status on each order. In the DLT-based solution, the settlement status of each order can be recorded on-chain, the update of status can be performed by smart contract after the successful settlement;

Activity 10 to Activity 12 are the fund's side operations, which will not be impacted under the scope of the thesis.

A comparison of the as-is and to-be activities is made in table 10:

Table 10: As-is and to-be activities

No.	As-is Owner	As-is Activity Name	Outcome	To-be Activity Name	To-be Owner
1	Investor	Place an order	Creation of a fund order	Place an order	Investor
2	Transfer agent	Collect fund orders	Collected fund orders of one trading day from all investors	Collect fund orders	Smart contract 1
3	Fund administrator	Calculate aggregated inflow and outflow	Aggregated fund inflow and outflow	Calculate aggregated fund inflow & outflow	Smart contract 1
4	Fund administrator	Calculate aggregated asset holdings	Aggregated asset holdings	Calculate aggregated asset holdings	Smart contract 2
5	Fund administrator	Calculate NAV per share	Calculated NAV per share on the trading date	Calculate NAV per share	Smart contract 3
6	Fund	Calculated	Calculated	Calculate settled	Smart contract 3

	administrator	settled amount on each order	settled amount of each investor's order	amount on each order	
7	Investor's custodian	Settle money with fund custodian	Settled fund order	Transfer money and fund tokens	Smart contract 4
8	Fund administrator	Reconcile accounting data with fund custodian	Correct settlement data on the fund	N/A	N/A
9	Transfer agent	Update investor's account	Updated settlement status on each order	Update settlement status	Smart contract 4
10	Asset manager	Make investment decisions	Investment decisions	Make investment decisions	Asset manager
11	Asset manager	Execute investment decisions	Investment portfolio	Execute investment decisions	Asset manager
12	Asset manager	Use data for investment decisions on T+1	Investment decisions for T+1	Use data for investment decisions on T+1	Asset manager

Based on the analysis in the case management structure, the to-be collaboration process diagram can be made. However, DLT systems as a nascent technology have rarely been studied in the business process modeling, therefore there hasn't been a standard on how the DLT can be better modeled. In the BPMN modeling language, a pool represents an organization, and a lane within a pool represents the sub-division of the pool, which is an 'activity-classifying mechanism' that is responsible for the activities delineated in the lane. As is discussed in 2.4.2 on using BPMN in modeling the DLT-based processes, as well as the study on Markovska's (2019) *Modelling Business Processes on a Blockchain Ecosystem (BPMN)* about the feasibility of BPMN in modeling blockchain ecosystem: 'Blockchain application can be modeled as one pool connected with all participating entities' pools via message exchange'. And 'as smart contracts are autonomous algorithms that automatically execute business rules and change the state of some object or trigger action, they can be depicted with expanded subprocesses, since based on logic, subprocess should have its own start and end event, and be autonomous'.

In the modeling considerations of the to-be process, instead of using a pool, the DLT system is represented with a lane under the pool of the AMC. This is based on two considerations: 1) the ultimate ownership of the DLT system is by the AMC, using a lane instead of a pool shows both internal and external interactions in the process; 2) using 'DLT system' as the lane name instead of functional department who are responsible for the DLT system, to show that the DLT system disintermediates the intermediaries by taking ownership of the operational activities. Smart contracts run on the DLT system in automating the tasks are modeled with expanded subprocesses, each has its own start (triggered by the end of the previous subprocess) and end event. A collaboration diagram including the abovementioned activities of the to-be process is illustrated in figure 31:

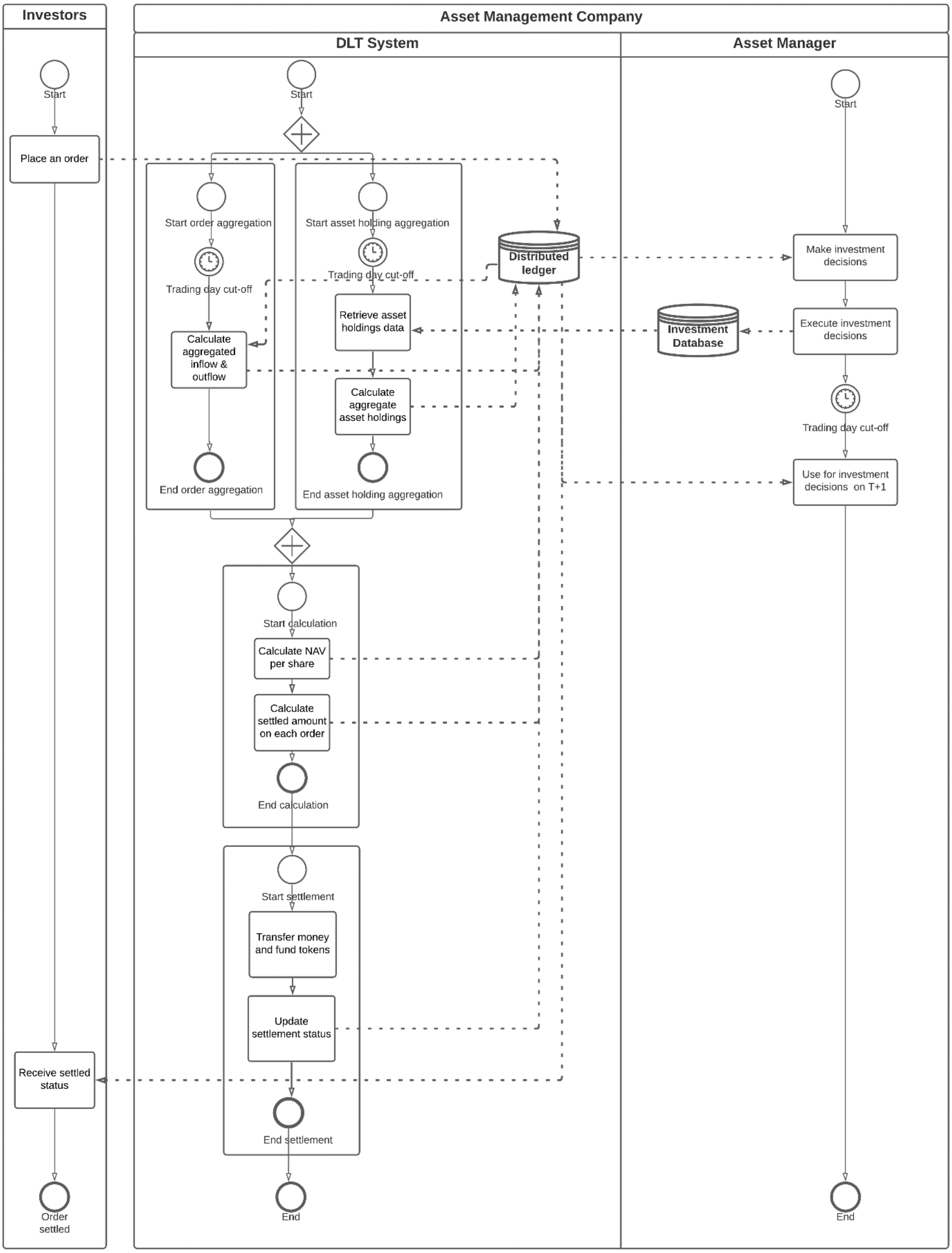


Figure 31: To-be mutual fund settlement collaboration process

4.3. Data Management

The purpose of data management is to manage the on-ledger and off-ledger data involved in the process. The first is to identify outcomes produced by both participating and external entities that is relevant to the process (H9, table 6). The data frequently used but with less frequent updates could be stored on the ledger and subscribed for updates (H12, table 6). Another idea is to capture the data from its source and record it on the shared ledger (H13, table 6), and move control close to the data entry to guarantee correct data input (H12, table 6).

The to-be collaboration diagram (figure 31) shows two ledgers/databases containing data that are relevant to the process. The distributed ledger captures the fund orders placed by the investors. Activity outcomes produced by smart contracts are also recorded on the distributed ledger. As illustrated in figure 31, arrows pointing to the 'Distributed ledger' indicate a write on the ledger, and pointing from the 'Distributed ledger' indicates a read on the ledger. The investment database is used by the asset managers to record the asset holdings of the mutual fund. Holdings on each financial asset cannot be shared with the investors on-demand as it involves investment strategies and might cause volatility problems in the market. The asset holdings data can be retrieved by the smart contract with an application programming interface (API)[1] to use for NAV calculation. The distributed ledger can be read by any potential investors. However, only investors who successfully passed KYC/AML check can participate in the transaction. The DLT system can therefore be public and permissioned, with the AMC giving authorizations to investors passed KYC/AML check.

CRUD refers to four actions on an object (typically on data entity): create (to create and store new data), read (to retrieve and read data), update (to change or modify then store the data), and delete (to delete or remove the data). A CRUD matrix is useful to capture and display activities and permissions within a system. The complete to-be settlement process contains activities both performed by smart contracts and conventional participants. On the data management of the DLT-based process, a similar matrix can better illustrate the actions of the data entities involved in this process. However, as studied in 2.2 that data stored DLT has an immutable feature, thus cannot be updated or deleted. In the discussions on the permission models in 2.2.2, there are three permission types of a DLT network: read (access the ledger and see transactions), write (generate transactions and send to the network), and commit (validate and update the state of the ledger). The actions can then be represented as:

---

[1] An application programming interface is a connection between computers or between computer programs. It is a type of software interface, offering a service to other pieces of software.

- C: create, generate transactions on the
- R: read, access the ledger, retrieve and read the transactions
- V: validate, validate and update the state of the ledger

Actions performed inside the DLT system will be represented with C, R, V, and actions performed outside the DLT system will use CRUD. The to-be process data management is then shown in table 13:

Table 11: To-be process data management

	Investors	Asset Manager
Place an order	CRV	RV
Collect fund orders	RV	RV
Calculate aggregated inflow & outflow	RV	RV
Calculate aggregated asset holdings	RV	RV
Calculate NAV per share	RV	RV
Calculate settled amount on each order	RV	RV
Transfer money and fund tokens	RV	RV
Update settlement status	RV	RV
Make investment decisions	None	CRUD
Execute investment decisions	None	CRUD
Use for investment decision on T+1	None	CRUD

4.4. Tokenization

The last heuristic involves using tokens to represent the asset or status (H14, table 6) digitally. The classification of digital tokens has been discussed in 2.2.5, and the tokenization scenarios have been discussed in 2.2.6.1.

As the mutual fund is a pool of investment in securities, the mutual fund units are conventionally represented in digital forms, which makes tokenization easier. For new mutual funds, fund tokens are created when the mutual fund is issued, which go through a security token offering. The mutual fund shares are subscribed/redeemed/switched on demand, therefore fund tokens should be non-minable.

On the tokenization of mutual funds, two cases need to be taken into consideration: tokenizing the existing mutual fund, and the issuance of a new mutual fund. The ECB model (2.2.6.1) discussed two tokenization models: model 1 illustrates securities directly issued on the distributed ledger, and model 2 is on the securities issued on conventional ledger then enabled in DLT environment. Model 2 further discussed 3 scenarios on the implementations. As discussed in

2.2.6.1, scenario 1 phases out the conventional ledger and concentrates the data on the distributed ledger, which is the preferred scenario for tokenizing existing mutual funds:

- Tokenization of existing mutual fund: With the development of the DLT system, custody and settlement of the securities initially held in the conventional system can be realized in the DLT system, with tokens made available and representing the securities. This scenario can be used for tokenizing the existing mutual fund, as the existing mutual funds are safekept by the conventional ledger. Existing mutual funds recorded on the conventional systems are represented with tokens on the distributed ledgers, the custodian of the mutual fund is on the distributed ledger and the conventional system can phase out. Mutual fund tokens then can be traded, cleared, and settled on the distributed ledger, with no need for the conventional ledgers. And the distributed ledger will become the single source of truth for the transactions.

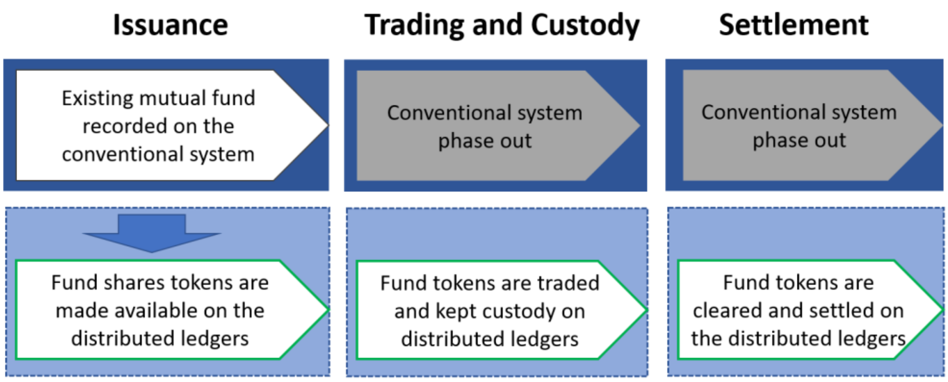


Figure 32: Tokenization on the existing mutual fund

- Issuance of new mutual fund: the issuance of the new mutual fund follows ECB model 1, where tokens are issued on the distributed ledger in the representation of the mutual fund. The mutual fund has no other representations outside the DLT network. In this case, the conventional system is completely phased out. Tokens are issued, kept custody, traded, and settled entirely on the distributed ledger.

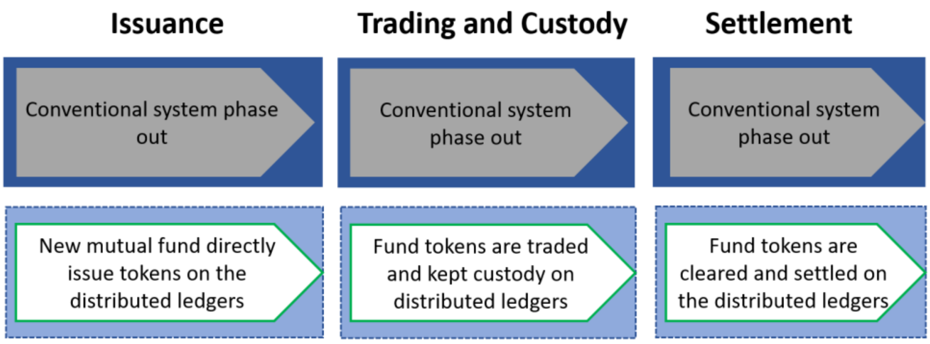


Figure 33: Tokenization on the new mutual fund

4.5. Implications of To-Be Process

1. Disintermediated intermediary institutions

It is concluded from the collaboration of entities, case management structure, data management, and tokenization into table 14, that the operational responsibilities of the transfer agents, the fund administrators, and the investor's custodians can be eliminated. The as-is mutual fund settlement process involves intermediary institutions including the transfer agent, the fund administrator, the investor's custodian, and the fund's custodian. In the to-be process model, the investors can directly communicate with the AMC, who owns the DLT system that automates tasks and keeps custody of the mutual fund. The disintermediation of the mutual fund settlement process give rise to the improvements of reduced data reconciliations, increase transparency, and faster settlement.

Table 12: Responsibilities of primary participants in to-be process

	Responsibility in to-be process	Changes from the as-is process
Investor	Initiate mutual fund subscription/redemption/switch orders	No change
Regulator	Oversight transaction data	No change
Transfer Agent	Operational function eliminated	1. Automated collection of fund orders; 2. Automated update settlement confirmations; 3. AMC owns the above activities
Fund Administrator	Operational function eliminated	1. Automated calculation of aggregated fund inflow and outflow; 2. Automated calculation of aggregated asset holdings; 3. Automated calculation of NAV per share; 4. Automated calculation of settled amount on each order; 5. AMC owns the above activities
Investor's	Operational function eliminated	1. Automated settlement of fund and money;

custodian		2. AMC owns the activities
Asset Management Company	1. Fully responsible for the DLT system 2. Make and execute investment strategies and decisions	Added ownership of activities

2. Reduced reconciliation and enhanced transparency

As mentioned in the problems in 3.3, the mutual fund settlement process is time-consuming and labor-intensive, as it involves reconciliations of information on siloed ledgers and the frictions of the different data standards stored in separate ledgers. The shared distributed ledger allows data to be recorded in one format and shared across participants, providing a single source of truth. Data discrepancy caused by different standards and human keying errors can be reduced. Reconciliation of the settlement data between the fund administrator and the fund custodian can be eliminated (table 10). Transaction data, as well as the calculated NAV per share, are open on the public ledger in real-time, which provides transparency to both investors and asset managers. The investors can access the calculated NAV faster, which helps make investment decisions on the mutual fund; The asset managers can get a real-time monitor on the investors' side data and better execute investment strategies accordingly.

3. Potential to achieve T-day settlement

As illustrated in the as-is collaboration process model, the actual settlement happens after 1 to 3 days from the order placement. The redesigned business process provides the opportunity to settle the mutual fund orders on the same day when the order is placed, which is indicated in the to-be collaboration process. Without the delay of communications and calculations of the intermediary institutions, and without the constraints of human working hours, settlement of the fund order can be achieved with the smart contracts immediately after the cut-off time. However, unlike the delivery-versus-payment settlement approach of stocks, it is not likely to achieve immediate settlement on the mutual funds, as NAV needs to be calculated when the asset side trading cuts off. The reduced settlement time is shown in figure 34 and figure 35:

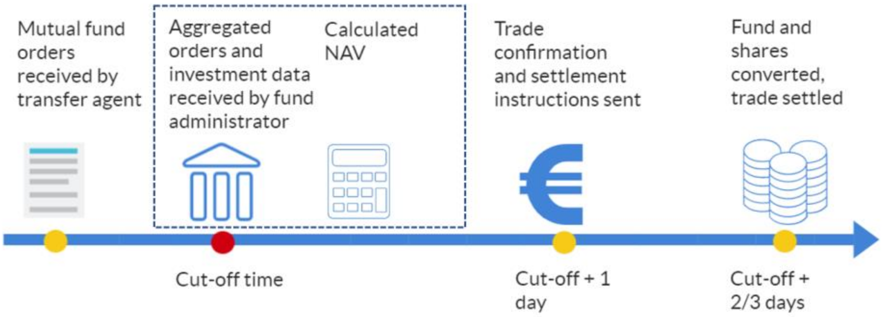


Figure 34: Current mutual fund settlement timeline (source: Author, with Viseme)

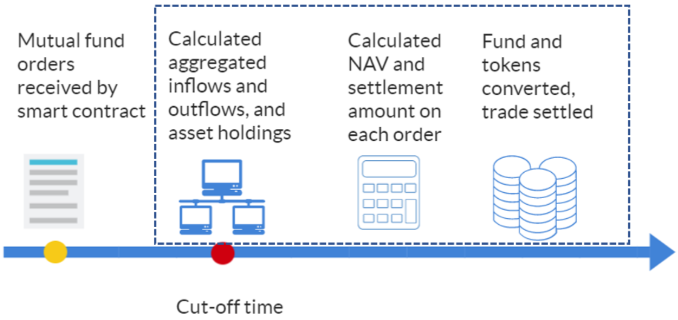


Figure 35: Redesigned mutual fund settlement timeline (source: Author, with Viseme)

4. Cost and complexity reduction

The operations services provided by transfer agents and fund administrators are bonded by the agreements and contracts between the service providers and the asset management companies, which results in management fees of the mutual fund. As the operational roles of these institutions are eliminated, both investors and asset managers can benefit from the reduction of management costs. Investors are fee-sensitive in that lower-fee funds and funds that reduce their fees grow faster. The single source of truth has the records on who owns what, which streamlines the distributions, compliance, and other corporate actions (Bech et al., 2020).

5. Risk consideration

There are two types of risks in the settlement process (Bech et al., 2020): replacement cost risk and principle risk. The replacement cost risk comes from the duration of trade executed but not yet settled. The principal risk comes from the settlement itself. The tokenization feature of the DLT solution shortens the cycle of settlement and lowers the exposure to replacement cost risks. A faster settlement allows investors to receive shares or funds more quickly, as settlement can be done on the same day when the transaction is initiated, and uncertainties on the +1 to +3 days can be reduced. However, in the short term, the technology could increase legal risks, as the legal basis of the digital tokens and the definition of settlement finality with digital tokens are still vague. Whether the net operational risks will be increased or reduced with the tokenization is uncertain.

4.6. Chapter Conclusion

This chapter outlined the redesigned solution in addressing the limitations of the intermediated and manual intensive current mutual fund settlement process. The redesign follows the frameworks of Milani and Garcia-Banuelos (2020) on DLT as the enabling technology for BPR, as well as the ECB DLT tokenization models. Considerations are made on the collaboration of entities with a shared ledger, automate the execution of tasks with smart contracts, re-sequence process with smart contracts, retrieving off-ledger data with API, and tokenizing the fund shares for on-ledger and off-ledger interoperability. The automation of the tasks allows the asset managers to focus their time and resource on the investment decisions that result in the portfolio of the asset, which benefits both the asset managers and the investors in the long run.

5. Discussions

5.1. Answering Research Question

The purpose of this master thesis is to get an insight into how the mutual fund settlement business process can be redesigned with DLT as an enabling technology, following a design science research methodology. The review of the literature provided the knowledge base on the DLT and the capability of the technology to be applied in the mutual fund sector. The thesis answers the research questions "*How can the distributed ledger technology (DLT) serve as an enabler to redesign the post-trade mutual fund settlement process?*" by answering the three sub-questions:

1. *What are the DLT's capabilities in the business process redesign for the mutual fund settlement?*

   The literature review on the mutual fund and the distributed ledger technology showed the capabilities of DLT with the potential to be applied in mutual fund settlement. The major capabilities discussed that impact the business processes of mutual fund settlements are a synchronized and shared ledger, self-running smart contracts, and asset tokenization. The shared record-keeping of a DLT system provides a "single-source-of-truth" on the mutual fund transaction data to reduce the redundant records among participating parties throughout the settlement process. Smart contracts reduce human interventions on trade orders and eliminate the need for intermediaries. The tokenization of mutual funds facilitates smooth settlement operations on DLT.

2. *What is the current mutual fund post-trade settlement landscape, and what are the problems?*

The identification of the current mutual fund post-trade settlement landscape serves as the environment of this design science research. Literature study and case study with interviews were conducted to get a view on the mutual fund distribution value chain and the as-is settlement processes among various participating institutions. The identified primary actors in this process are intermediaries, the transfer agent, the fund administrator, and the asset manager. Three process diagrams were created showing the different details of the settlement process. The high-level diagram shows the information flow among all the participants, including the settlements on both sides of the settlement and providing a complete and high-level view of the entire process. The choreography diagram shows the bilateral communications on the data objects throughout this process, and the collaboration diagram shows the relevant activities of participants in the settlement process.

The current process is crucial to this research as it lays the foundation for the identification of the problems and serves as the basis for the process redesign. The problems analyzed are: intensive bilateral communication and lack of data standard, intensive manual tasks lead to low efficiency and prone to errors, dispersed and hard-to-access distribution data to asset managers, late settlement confirmation and untransparent data to investors, and the intermediary costs for the asset managers.

3. *How can the business process of mutual fund settlement be redesigned with the identified DLT capabilities?*

The to-be process was designed based on the theoretical frameworks – knowledge base analyzed in chapter 2. Four major categories of heuristics – collaboration of entities, case management structure, data management and tokenization were considered, and the tokenization models were analyzed and adapted to the process redesign. As a result, the process prototype with a redesigned mutual fund settlement model was created, and the corresponding collaboration model is shown. With a shared data ledger on transaction data, smart contracts executing identified tasks, the role of transfer agent and fund administrator can be eliminated from the execution of the settlement process, and shorter settlement time, more transparency can be achieved.

5.2. Limitations

This thesis provides a business process artifact on the mutual fund settlement on the investor's side enabled by the distributed ledger technology. Literature research on DLT, BPR, and the intersection of DLT and BPR is used for the theoretical framework. A case study on the current mutual fund settlement environment serves as the environment for the design science research, and a redesigned model is then proposed.

Researches built on case studies are likely to be subject to validity threats (Markovska, 2019), including external validity and reliability validity. The external validity threat occurs when the subject and scope can limit the findings of one case study, therefore difficult to be generalized to a wider spectrum. The background of this case study – mutual fund settlement – has a relatively vast universe and has many variations from AMC to AMC. This thesis studied one type of general settlement framework and enriched the framework with a specific case study. The redesigned solution is on a high level, which has the potential to be extended and further studied on a wider spectrum. The reliability validity threat comes from the interdependency of the results and the researcher who produced them. The as-is process is modeled via study and analysis on the existing industry materials and internal documents and validated via interviews with experts. The to-be process cannot be easily validated, as the technology is new to the industry. While this research is an exploratory study focusing on understanding how DLT can redesign the settlement process, and exploratory research is conducted to better understand the existing problem, not to provide conclusive results.

Scope-wise, restricted by the timeline and the research scope, this thesis only discussed the settlement of open-ended mutual funds and only discussed the settlement process with a non-CSD model (via transfer agents and fund administrator). Other mutual fund products such as closed-ended funds and exchange-traded funds (ETFs), and other settlement models with CSD are not discussed. Settlement on the asset trading side is considered off-ledger data and not discussed in detail. Therefore, expanding the model to the entire AMC settlement ecosystem is suggested in future work. Regulations on digital tokens vary from country to country. As the technology is relatively new, regulations are not yet complete on the asset tokenizations and the deployments of smart contracts. This thesis takes less consideration on the friction of regulations on the financial market infrastructure but focuses on the technology and how the current infrastructure can be improved with the technology.

5.3. Future Work

5.3.1. Expand Model to the Complete AMC Settlement Ecosystem

This thesis discussed the mutual fund settlement on the investor's side with DLT, and as identified in the environment chapter. While the ecosystem of the mutual fund transactions also includes onboarding investors (KYC/AMC check) and settlement on the investment side. Assets traded on the investment side (by the asset managers) are considered off-ledger data in this thesis. As settlement of equities and debt securities has been mostly studied in this field, and how KYC/AML can be automated and optimized with DLT has also been studied (Parra-Moyano & Ross, 2017). It is also worth exploring if the whole ecosystem can be facilitated by DLT, whether interoperability can be facilitated among the different DLT systems, and how the related parties can benefit from the integrated DLT settlement.

5.3.2. DLT Adoption in Asset Management – The 'leapfrogging' phenomenon

There is an interesting phenomenon on the adoption of innovative technology named 'leapfrogging', which means areas that have poorly-developed technology bases can move themselves forward rapidly through the adoption of modern systems without going through the intermediary steps (Digital Strategies, 2021). An example is an analysis of Credit Suisse (2019) on India's market for mobile phone payments. Having been held back by legacy systems in payments, mobile payments are the most fast-growing in the past five years and have the potential to increase five-fold in the next five years. It is implied that DLT furthers this process, that investments in technology iterations such as ATMs and contactless credit cards will be skipped, and more seamless and cost-effective transacting will be adopted. The implication to the adoption of DLT in the mutual fund settlement is, even though the current infrastructure relies heavily on legacy systems and paperwork, it can be more cost-effective to skip iterative digitization and automation technologies and adopt DLT. With the trend of adopting the equities settlement feature and transfer from non-CSD settlement model (3.1) to CSD settlement model, as well as the centralized settlement initiative – Target2Securities[1], whether the mutual fund settlement technology can take a leapfrogging to distributed ledgers or it can be combined with the current trend can be further studied.

[1] Target2-Securities (T2S) is a European securities settlement engine that offers centralized delivery versus payment settlement in central bank funds across all European securities market. Instead of being a CSD, it is a platform that enables CSDs to increase their competitiveness.

6. Bibliography

(BCG), B. C. (2021). *In Capital Markets, DLT Is Moving from Experimentation to Commercialization*. Retrieved from CISION: https://www.prnewswire.com/news-releases/in-capital-markets-dlt-is-moving-from-experimentation-to-commercialization-301285218.html

(Italy), N. M. (2006). *Order and settlement of investment funds in Italy retail cross-border funds.*

Accenture. (2020, 09 09). *The future of fund distribution*. Retrieved from https://www.accenture.com/lu-en/blogs/belux/the-future-of-fund-distribution

Attanasio, S. (2021, 03 11). *The Spunta project – blockchain for Italian interbank reconciliation*. Retrieved from European Payments Council: https://www.europeanpaymentscouncil.eu/news-insights/insight/spunta-project-blockchain-italian-interbank-reconciliation

Bech, M. L., Hancock, J., Rice, T., & Wadworth, A. (2020). On the future of securities settlement. *BIS Quarterly Review*.

Benos, E., Garratt, R., & Gurrola-Perez, P. (2019). The economics of distributed ledger technology for securities settlement. *Ledger*, 121-156.

Bhardwaj, C. (2020, 08 29). *Blockchain vs DLT – An Explanatory Guide You Can't Miss On*. Retrieved from Appinventiv: https://appinventiv.com/blog/blockchain-vs-dlt-guide/

Brancheau, J. C., Janz, B. D., & Wetherbe, J. C. (1996). Key issues in information systems management: 1994-95 SIM Delphi results. *MIS Quarterly*, 225-242.

Broadbent, M., Weill, P., & Clair, D. S. (1999). The implications of information technology infrastructure for business process redesign. *MIS Quarterly*, 159-182.

Davenport, T. H. (1993). *Process innovation: reengineering work through information technology.* Harvard Business Press.

Deloitte. (2016, 08). *Blockchain - a new model for health information exchanges.* Retrieved from https://www2.deloitte.com/content/dam/Deloitte/us/Documents/public-sector/us-blockchain-opportunities-for-health-care.pdf

DTCC. (2019). *Guiding principles for the post-trade processing of tokenized securities - A white paper to the industry.* DTCC.

Dubovec, M., & Castellano, G. (2020). *Distributed ledger technology & secured transactions: legal, regulatory and technological perspectives - guidance notes series.* Federal

Department of Economic Affairs, Education and Research EAER.

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). *Fundamentals of Business Process Management.* Springer.

Economy, I. (2019, 03 27). *NITI Aayog: Digital Payments, Trends, Issues and Opportunities*. Retrieved from Drishti: https://www.drishtiias.com/summary-of-important-reports/niti-aayog-digital-payments-trends-issues-and-opportunities

Egelund-Müller, B., Elsman, M., Henglein, F., & Ross, O. (2017). Automated execution of financial contracts on blockchains. *Business & information systems engineering 59(6)*.

Falazi, G., Hahn, M., Breitenbücher, U., & Leymann, F. (2019). *Modeling and execution of blockchain-aware business processes.* Springer.

Florian, G. (2017). Pervasive Decentralisation of Digital Infrastructures: A Framework for Blockchain enabled System and Use Case Analysis. (p. 1543). Proceedings of the 50th Hawaii international conference on system sciences.

Glow, D. (2021, 02 08). *Monday Morning Memo: European Fund Market Review – 2020*. Retrieved from REFINITIV: https://lipperalpha.refinitiv.com/reports/2021/02/monday-morning-memo-european-fund-market-review-2020/

Gonzalez-Huerta, J., Boubaker, A., & Mili, H. (2017). A business process re-engineering approach to transform BPMN models to software artifacts. *Internation Conference on E-Technologies.*

Hammer, M. (1990). Reengineering work: Don't Automate, Obliterate. Harvard Business Review.

Hasan, H., & Salah, K. (2018). Blockchain-based proof of delivery of physical assets with single and multiple transporters. *IEEE*.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information System Research. *MIS Quarterly*, 75-105.

Hileman, G., & Rauchs, M. (2017). *Global blockchain benchmarking study.* Cambridge Centre for Alternative Finance.

Horváth, I. (2007). Comparison of three methodological approaches of design research. *DS 42: Proceedings of ICED 2007* (pp. 361-362). Paris, France: the 16th International Conference on Engineering Design.

Insight, L. (2018, 09 24). *Dubai government adopts blockchain for reconciliation*. Retrieved from Ledger Insights: https://www.ledgerinsights.com/government-dubai-blockchain-reconciliation/

James, M. (2020). *Straight Through Processing*. Retrieved from Investopedia: https://www.investopedia.com/terms/s/straightthroughprocessing.asp

Kugel, R. (2017). *Digital Process Reengineering Drives Business Change*. Retrieved from Ventana Research: https://blog.ventanaresearch.com/digital-process-reengineering-drives-business-change-1

Ladeif, J., Weske, M., & Weber, I. (2019). *Modeling and enforcing blockchain-based choreographies.*

Levi, S. D., & Lipton, A. B. (2018). *An introduction to smart contracts and their potential and inherent limitations.* Harvard Law School Forum on Corporate Governance.

Lind, M., Rudmark, D., & Seigerroth, U. (2014). Design Science Research for Business Process Design: Organizational Transition at Intersport Sweden. *IFIP Advances in Information and Communication Technology*, (pp. 159-176).

Lopez-Pintado, O., Dumas, M., Garc´ıa-Banuelos, L., & Weber, I. (2019). *Interpreted execution of business process models on blockchain.*

Lyons, G. (1995). Application of Information Technology in the Redesign and Implementation of Business Processes. *Science + Business Media Dordrecht*, 42-52.

Mainelli, M., & Milne, A. (2015). The impact and potential of blockchain on the securities transaction lifecycle. *SWIFT Institute Working Paper*.

Malhotra, Y. (1998). Business Process Redesign: An Overview. *IEEE Engineering Management Review*.

Manhaeve, C. (2019). *A qualitative analysis by case study approach for identifying the impact of smart contracts using the blockchain technology on customer relations within business models and service offering(s).*

Markovska, M., Milani, F. P., & Garcia-Banuelos, L. (2019). *Modelling business processes on a blockchain eco-system (BPMN).*

Marttiin, P., Lyytinen, K., Rossi, M., Tahvanaien, V.-P., & Smolander, K. (1992). Modeling requirements for future: issues and implementation considerations. *Thirteenth International Conference on Information Systems (ICIS), Proceedings*, (pp. 9-20). Dallas, Texas.

Mendling, J. (2018). Towards blockchain support for business process. *Business Modeling and*

Software Design, 243-248.

Milani, F., & Garcia-Banuelos, L. (2018). *Blockchain and Principles of Business Process Re-Engineering for Process Innovation.* Cornell University.

Milani, F., García-Bañuelos, L., Reijers, H. A., & Stepanyan, L. (2020). Business process redesign heuristics for blockchain solutions. *2020 IEEE 24th International Enterprise Distributed Object Computing Conference (EDOC)* (pp. 209-216). IEEE.

Mills, D., Wang, K., Malone, B., Ravi, A., Marquardt, J., Badev, A., . . . Barid, M. (2016). Distributed Ledger Technology in Payments, Clearing and Settlement. *FEDS Working Paper*, 36.

Moyano, J. P. (2017). KYC Optimization Using Distributed Ledger Technology. *Business & Information Systems Engineering*, 411-423.

Nakavachara, V., Potipiti, T., & Lertmongkolnam, T. (2019). *Should all blockchain-based digital assets be classified under the same asset class?*

OECD. (2020). *The tokenisation of assets and potential implications for finanical markets.* OECD Blockchain Policy Serier.

Parra-Moyano, J., & Ross, O. (2017). KYC optimization using distributed ledger technology. *SSRN Electronic Journal*.

Qiu, T. Z. (2019). Ripple vs. SWIFT: transforming cross-border remittance using blockchain technology. *Procedia Computer Science*, 428-343.

Rauchs, M., Glidden, A., Gordon, B., Pieters, G., Recanatini, M., Rostand, F., . . . Zhang, B. (2018). Distributed Ledger Technology Systems - A Conceptual Framework. *Cambridge Centre for Alternative Finance*.

Ross, O. &. (2019). Assets under Tokenization: Can Blockchain Technology Improve Post-Trade Processing. *Fortieth International Conference on Information Systems.* Munich.

Sachs, G. (2016). *Blockchain: Putting theory in practice*. Retrieved from Equity Research: https://github.com/bellaj/Blockchain/blob/master/Goldman-Sachs-Blockchain-Putting-Theory

Santo, A., Minowa, I., Hosaka, G., Hayakawa, S., Kondo, M., Ichiki, S., & Kaneko, Y. (2016). Applicability of distributed ledger technology to capital market infrastructure. *JPX Working Paper*.

SInha, S. (2020). *How blockchain is transforming fund servicing*. Retrieved from BNY Mellon:

https://www.bnymellon.com/us/en/insights/all-insights/how-blockchain-is-transforming-fund-servicing.html

Stoddard, D. B., & Jarvenpaa, S. L. (1995). Business process design: tactics for managing radical change. *Journal of Management Information Systems*, 81-107.

Strategies, D. (2021). *Leapfrogging*. Retrieved from Digital Strategies: https://leapfrog.cl/en/leapfrogging#:~:text=%22Leapfrogging%20is%20the%20notion%20that,without%20going%20through%20intermediary%20steps.%22

SWIFT. (2015). *SWIFT for Funds: Addressing Compliance and Automation - Insights from survey into operational challenges facing investment managers and fund participants.*

Van Verre, J. (2017). *Custody in 2025 - Game Changers.* HSBC.

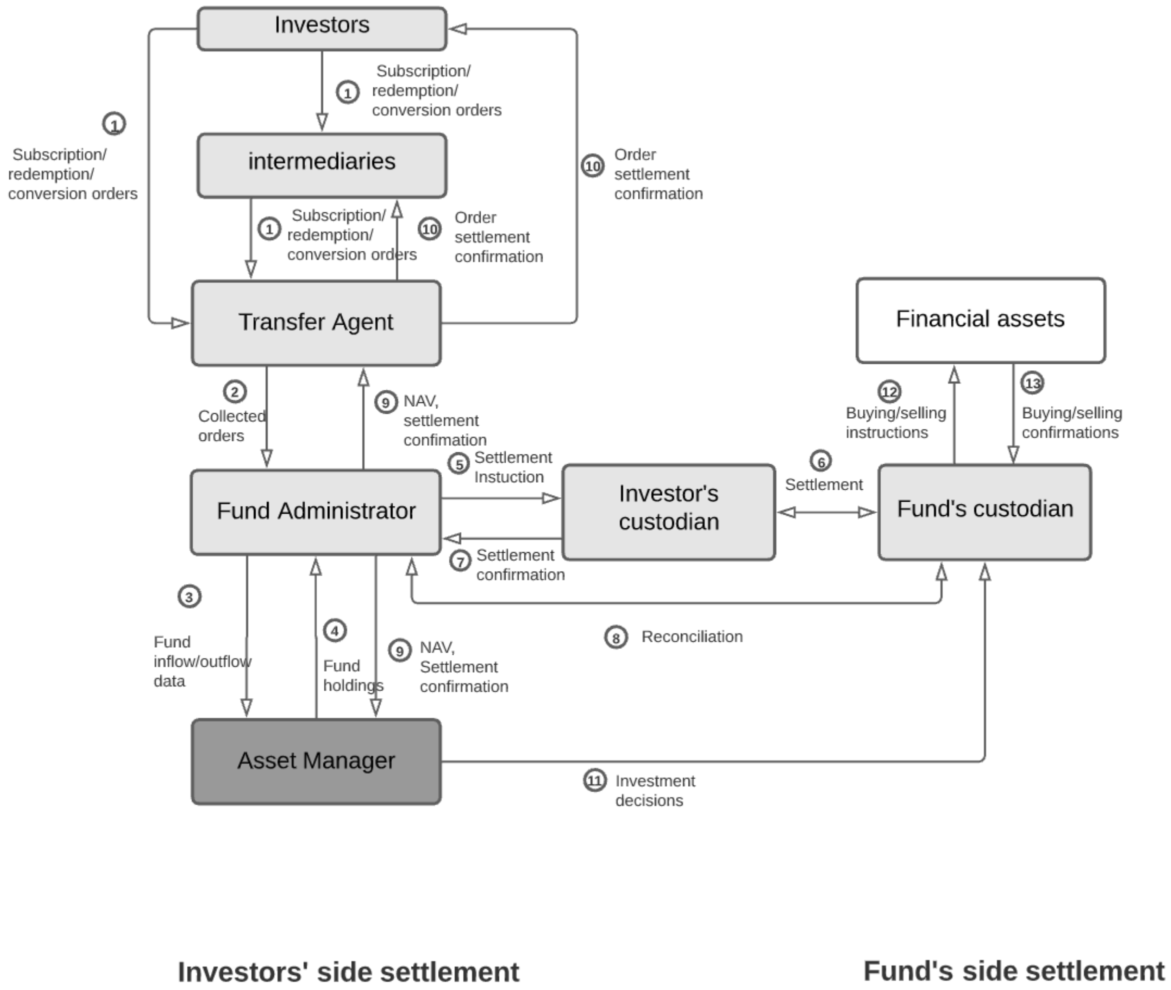
Walsh, J. (2021). *Mutual Fund Transactions: Process & Example*. Retrieved from Study: https://study.com/academy/lesson/mutual-fund-transactions-process-example.html

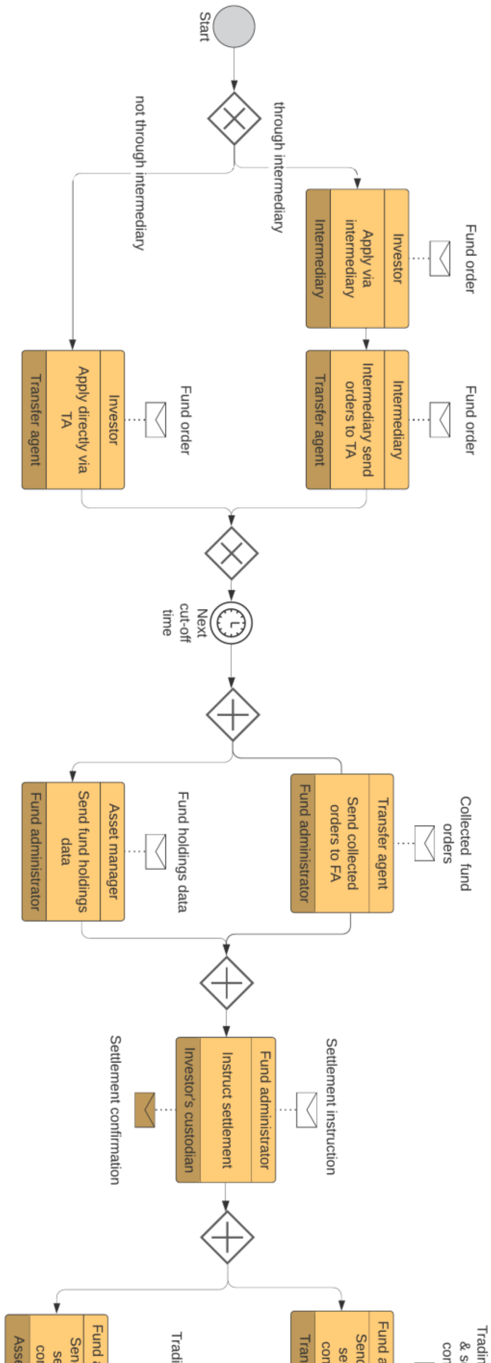
Xu, X., Zhu, L., Pautasso, C., & Lu, Q. (2018). A pattern collection for blockchain-based applications. *Proceedings of the 23rd European Conference on Pattern Languages of Programs.*

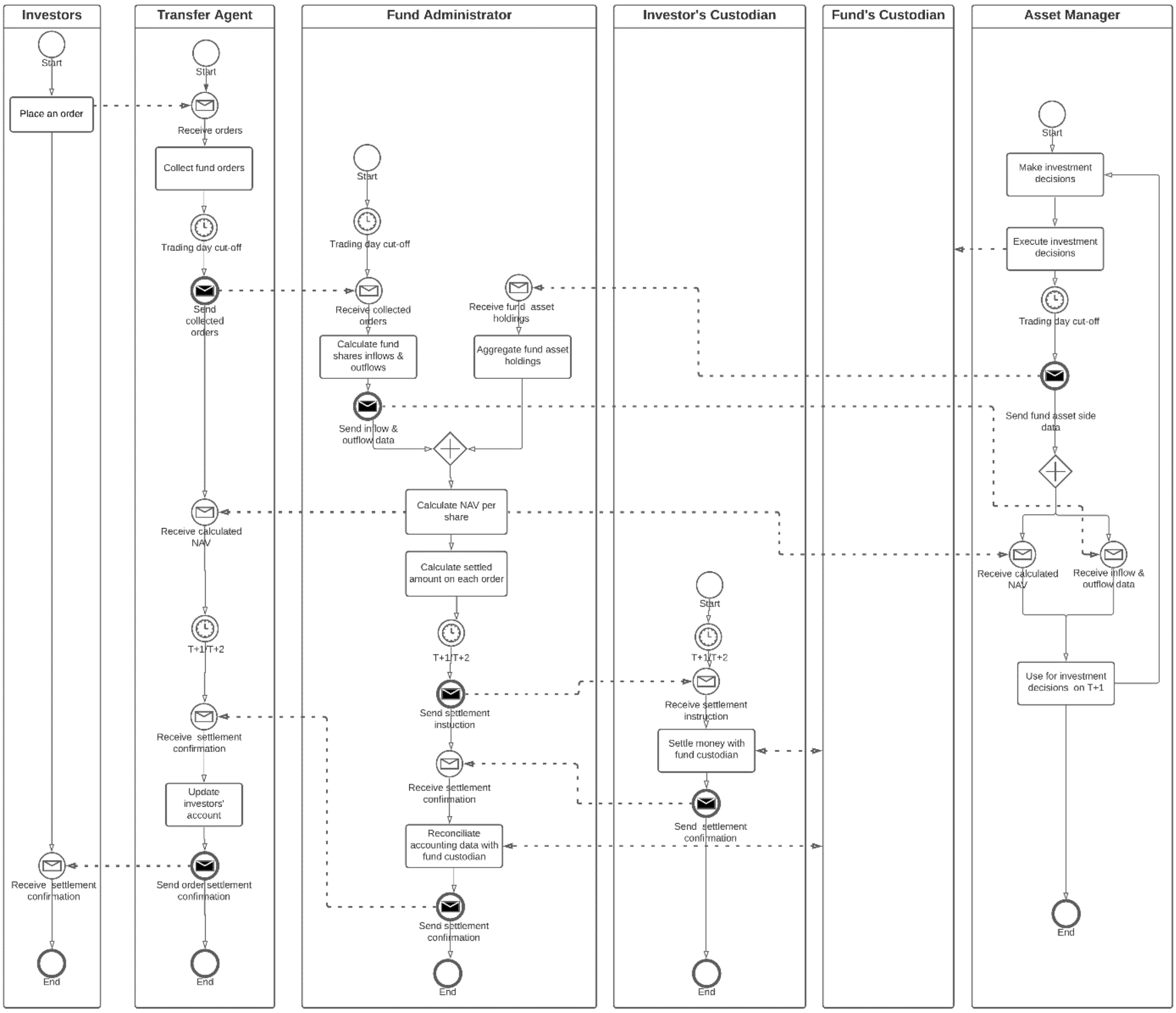
Zhang, P., Schmidt, D. C., White, J., & Dubey, A. (2019). Consensus mechanisms and information security technologies. *Advances in Computers*, 181-209.

Appendix

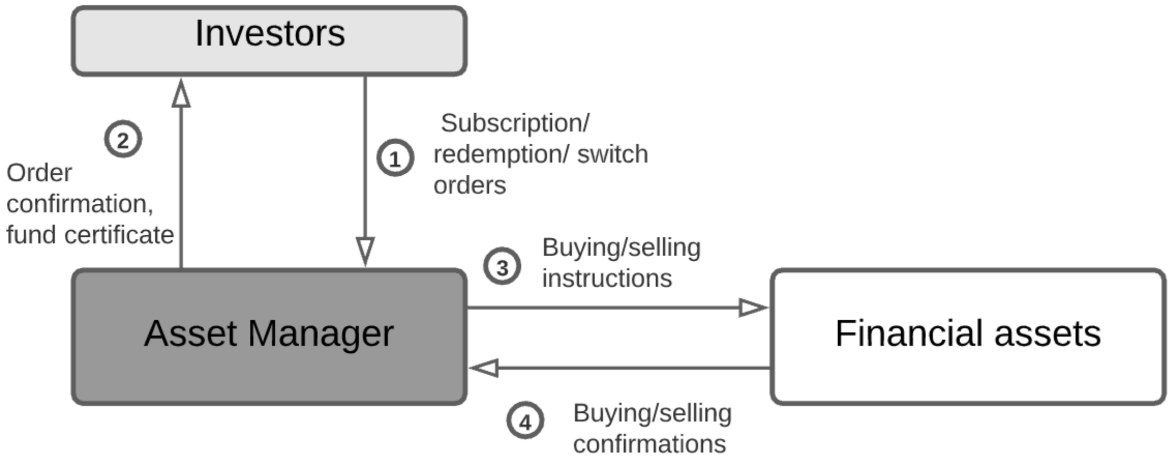
Appendix 1: As-is Processes of Mutual Fund Settlement

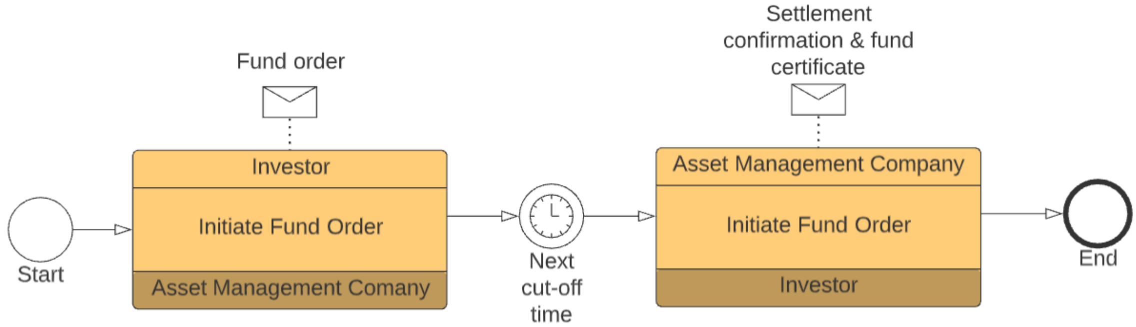


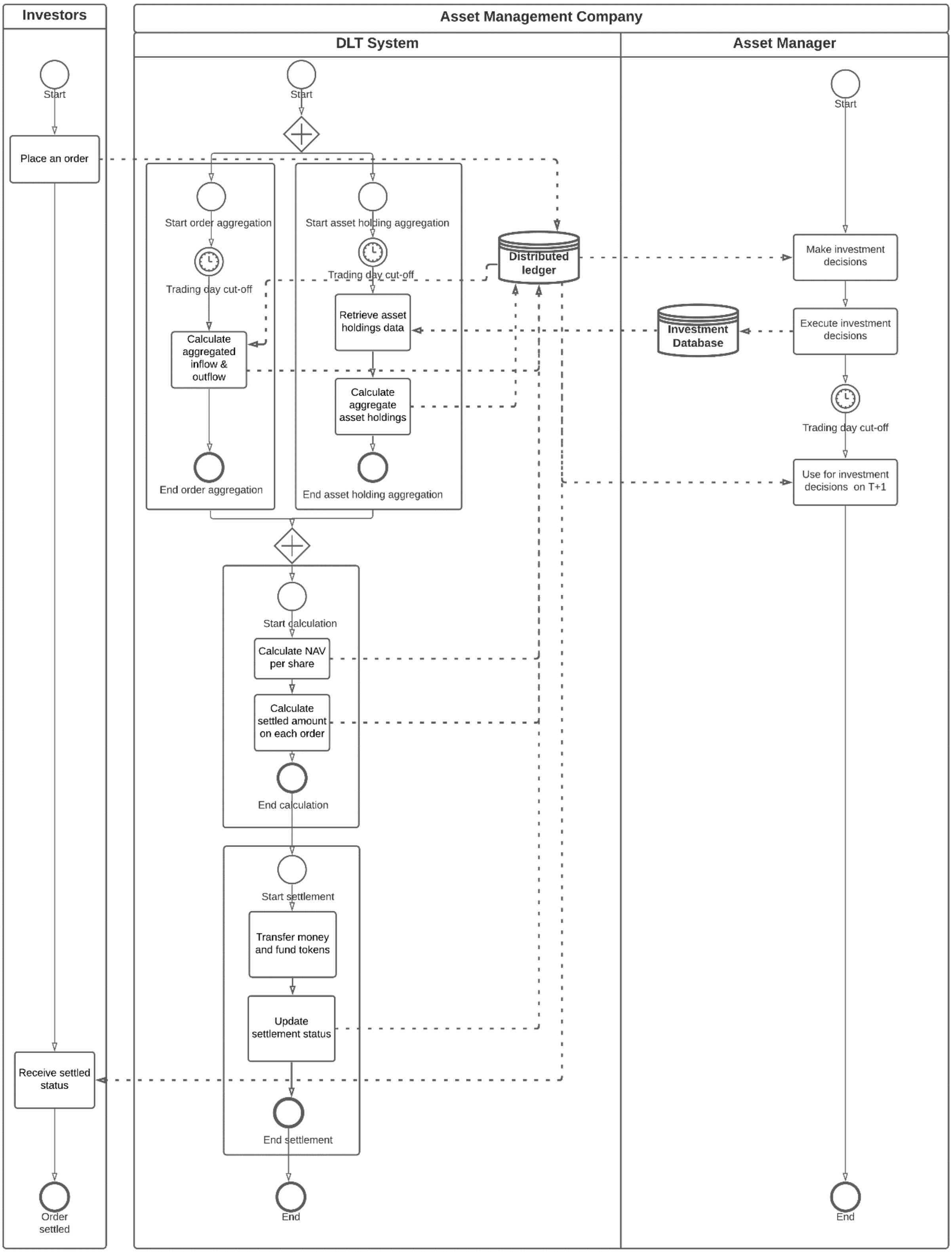

Start
through intermediary
not through intermediary
Investor
Apply via intermediary
Intermediary
Fund order
Intermediary
Intermediary send orders to TA
Transfer agent
Fund order
Investor
Apply directly via TA
Transfer agent
Fund order
Next cut-off time
Transfer agent
Send collected orders to FA
Fund administrator
Collected fund orders
Asset manager
Send fund holdings data
Fund administrator
Fund holdings data
Fund administrator
Instruct settlement
Investor's custodian
Settlement instruction
Settlement confirmation


Investors
Transfer Agent
Fund Administrator
Investor's Custodian
Fund's Custodian
Asset Manager
Start
Place an order
Receive orders
Collect fund orders
Trading day cut-off
Send collected orders
Receive collected orders
Calculate fund shares inflows & outflows
Send inflow & outflow data
Receive fund asset holdings
Aggregate fund asset holdings
Make investment decisions
Execute investment decisions
Send fund asset side data
Calculate NAV per share
Receive calculated NAV
Receive inflow & outflow data
Calculate settled amount on each order
T+1/T+2
Send settlement instruction
Receive settlement instruction
Settle money with fund custodian
Send settlement confirmation
Receive settlement confirmation
Use for investment decisions on T+1
Update investors' account
Send order settlement confirmation
Reconciliate accounting data with fund custodian
End

Appendix 2: To-be Process of Mutual Fund Settlement






Investors
Asset Management Company
DLT System
Asset Manager
Start
Place an order
Receive settled status
Order settled
Start
Start order aggregation
Trading day cut-off
Calculate aggregated inflow & outflow
End order aggregation
Start asset holding aggregation
Trading day cut-off
Retrieve asset holdings data
Calculate aggregate asset holdings
End asset holding aggregation
Distributed ledger
Start calculation
Calculate NAV per share
Calculate settled amount on each order
End calculation
Start settlement
Transfer money and fund tokens
Update settlement status
End settlement
End
Start
Make investment decisions
Investment Database
Execute investment decisions
Trading day cut-off
Use for investment decisions on T+1
End