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Funding Large Projects with a Blockchain Based Automated Fractional Reserve Currency

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***Abstract*—Public entities trying to raise funds are typically faced with, at best, two options: a *public-private partnership* or issuing municipal bonds. The former leaves the investee susceptible to value extraction or rent-seeking. The latter requires working through networks of intermediaries and the extensive infrastructure to support a municipal bond market. Moreover, current *initial coin offering* based blockchain fundraising methods do little to address the most significant issues with modern-day fundraising while adding complexity and risk. In this paper, we present a novel blockchain-based solution using a fractionally fiat-backed reserve currency using distributed ledger technology to increase transparency and democratization of investment while lowering fundraising costs. Our solution is an automated value engine letting investors hold a currency representative of their investment. At the same time, its supply is automatically burned or minted to algorithmically manage the ratio between funds raised and return on investment. When applied to a real-life bond issuance case, results show that our solution raises the required funds, provides a 0.25% higher return on investment, and yields an estimated reduction in direct costs of up to 19.27% through eliminating intermediary overhead.**

***Index Terms*—blockchain, distributed consensus, finance, fundraising, crowdfunding**

I. INTRODUCTION

The effective allocation and procurement of capital for infrastructure is a problem communities have struggled with for millennia. It is well established that growing economies, populations, and states need infrastructure to thrive over time [1]–[3]. Hence, the challenge lies in taking the promise of future benefits and using it to finance projects in the present day. Historical approaches to funding major infrastructure projects include the usage of taxes to purchase compulsory labor in ancient Rome [4], the privatization of water supplies in 15th century London [5], and modern-day municipal bonds [6].

Communities without absolute centralized authority, or access to significant capital reserves, are at the behest of the investors they manage to attract, making themselves vulnerable to exploitation by value extraction, i.e., the unproductive generation of income through price manipulation [7] and rent-seeking, i.e., the practice of increasing one's share of wealth without adding value [8]. Today's US municipal bonds attempt to mitigate these issues by democratizing investment and bridging the gap between the interests of capital and project leaders. However, high administrative expenses [9], and the requirement of an established bond market limit their viability. An ideal system would fulfill municipal bond systems' goals and minimize administrative expenses.

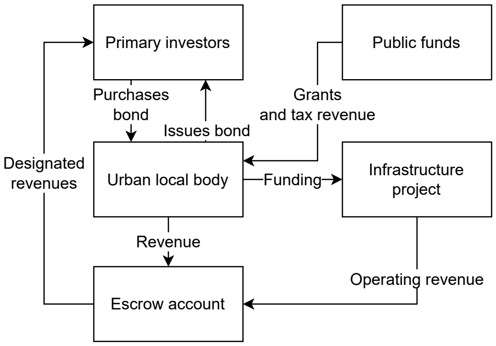


Fig. 1: Flow of funds under municipal bonds.

Distributed ledger technology (DLT) [10] has already been considered as a fundraising mechanism for the private sector [11], [12], using *initial coin offerings* (ICOs), in which tokens representing some form of real-life value, e.g., equity, fiat currency, a product, etc., are sold to investors. However, ICO tokens are not algorithmically linked to the value they provide; token holders must trust that the token issuer is able and willing to uphold any promised token value. Furthermore, ICO tokens do not inherently provide a solution for sale and distribution, contributing to over 40% of total municipal bond issuance costs [9].

In this paper, we propose a system using automated fractionally backed reserve currencies based on DLT as a funding method for public transportation infrastructure projects and compare it to existing examples of public-private partnerships and municipal bonds. In addition, we explore to what extent an automated fractionally backed reserve currency improves upon the cost, transparency, and investment democratization of existing models for functioning public transport infrastructure. To assess investment democratization, we compare each model's barrier of entry and centralization of investor power, i.e., what proportion of the funding is controlled by a singular entity. We then compare the total cost breakdowns associated with implementing and maintaining each model and their respective transparency. The performance of each system is also considered.

The remainder of this paper is organized as follows: Section II discusses related work. Section III provides an overview of DLT, and existing funding models. Section IV outlines our system and its general architecture. Section V describes design choices, the evaluation criteria, and the effect that certain system hyper-parameters have on overall system behavior. In Section VI we evaluate the performance of our system against existing models. Section VII describes the implications, as well as the impact they have on both current and future research and models. Finally, Section VIII concludes the paper.

II. Related Work

Ahluwalia et al. [12] evaluated blockchain as a fundraising method in corporate startup environments using transaction cost economic theory. They concluded that DLT enables crowdfunding-like investment with reduced risks of opportunism or rent-seeking. Startups face challenges such as giving up equity to VCs/angel investors or dealing with crowdfunding difficulties. Ahluwalia et al. proposed ICOs as a solution, where blockchain tokens are sold through an ICO, representing ownership/participation. ICOs differ from our reserve-based model, relying on a promise of value rather than an automated value engine. Their applications differ from our case, as startup fundraising entails higher risk than municipal infrastructure funding.

Rrustemi and Tuchschmid [11] highlighted the limitations of ICO fundraising using the example of LakeDiamond, a Swiss synthetic diamond company. LakeDiamond's ICO, which aimed to involve token holders in funding and profit sharing, fell short due to timing, complex incentives, limited decision-making power for token holders, and regional constraints. The authors proposed solutions like security token offerings (STOs) backed by tangible assets and initial exchange offerings (IEOs) on accredited exchanges to ensure project quality. These alternatives, while addressing fundraising challenges and leveraging DLT, differ fundamentally from our reserve-based model, relying on human-based contracts or promises rather than a protocol-based approach.

Rosenfeld [13] presents the mathematical formulas underlying the Bancor protocol, the first reserve-backed DLT-based token system. Hertzog et al. [14] propose a contract-based reserve currency protocol, highlighting crowdfunding as a potential use case similar to ours. The formulas for determining currency price based on reserve and supply values resemble our consensus layer in section IV. However, the Bancor protocol relies on smart contracts, which are Turing complete applications prone to the halting problem. Additionally, Bancor smart contracts operate on the Ethereum network, incurring costly processing on the Ethereum virtual machine.

Davis and Cartwright [15] assess investment-based crowdfunding for public sector fundraising, introducing the concept of a "community municipal bond." They conducted case studies across sectors to evaluate this new investment structure on crowdfunding platforms. Community bonds sell project equity directly to the municipal community, eliminating bureaucratic processes. Crowdfunding shows potential as a cost-effective alternative to traditional models, but requires addressing public awareness, education, and administrative costs. Direct bond sales foster community involvement in local projects. Similar to our paper, Davis and Cartwright aim to democratize investment, decentralize power, and lower barriers. However, their reliance on third-party crowdfunding introduces drawbacks similar to traditional public-private partnerships (PPPs) [16].

III. Background

Modern taxonomies of infrastructure funding can be categorized based on the requirements for initial investment. The Organisation for Economic Co-operation and Development (OECD) identifies three categories: fixed income, equity, and mixed [17]. Fixed income involves the investee guaranteeing steady repayment of investment in the future, while equity involves the exchange of infrastructure ownership for capital. Mixed models combine elements of both. In order to compare our DLT-based model to existing systems, we focus on two specific models: equity-based public-private partnerships and fixed income-based municipal bonds.

A. Public-Private Partnerships

While there are different definitions of PPPs [18], for the purpose of comparing it to DLT-based capital procurement in public transportation infrastructure, we adopt the definition by Webb and Pulle [19]: "partnerships between the public and private sectors for designing, planning, financing, constructing, and/or operating projects traditionally handled by the public sector, such as roads and bridges." Private partners often downplay risks initially to appear cost-efficient, but later exploit their position to demand guarantees for the price difference between assumed and actual risk [20].

PPPs lack inherent guaranteed transparency, and frameworks for information dissemination must be implemented to ensure information disclosure. Private parties often avoid releasing potentially proprietary information due to resource constraints and their own interests [21]. Even when legal requirements mandate a minimum level of transparency, private partners frequently fail to disclose mandatory information [22].

B. Municipal Bonds

Municipal bonds are a public method of infrastructure finance reserved for regions with administrative abilities to facilitate the sale of debt-backed bonds [23]. Intermediaries play a role in coordinating the issuance of bonds sold at a fixed price to accredited investors [9], [24]. Municipal bonds guarantee the return of principal and fixed annual interest [24]. The model illustrated in Fig. 1 encompasses the general concepts of municipal bonds used for public transportation infrastructure funding [24].

Municipal bonds offer increased decentralized investor power compared to PPPs. By guaranteeing repayment and fixed returns for each bond, and allowing issuance to any

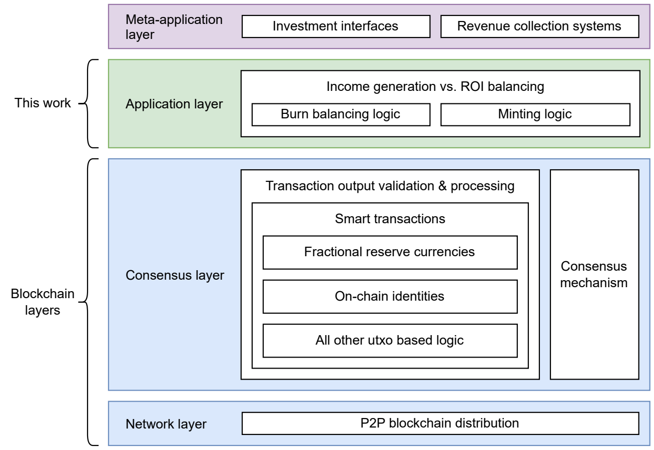


Fig. 2: System architecture layers.

accredited investor [25], the bond issuer reduces the influence of individual investors on the project. However, the issuance and distribution of municipal bonds entail substantial initial and ongoing accounting costs, which are directly related to the total value of bonds issued. The estimated median cost is 1.71% of the bond value [9]. The underwriter's discount represents the highest percentage of total cost for bond issuance, reaching 46.03% in the analysis. Underwriters play a crucial role by purchasing or facilitating the purchase of all bonds during an issuance, ensuring the required funds are raised. They earn a profit by charging a premium to bond owners. Additionally, underwriters simplify the bond issuance process for public entities, handling complex accounting and organizational tasks.

IV. ARCHITECTURE

In this section, we introduce our system architecture and describe the flow of funds. Figure 2 illustrates the system built upon two layers constituting the blockchain protocol: the network layer and the consensus layer. Our core fundraising software operates within the application layer. Above the application layer lies the meta-application layer, consisting of user interfaces and applications facilitating fund flow into and out of our system. Here, we primarily focus on the application layer. We develop an offline model [26] representing the key interfaces of the main consensus layer, based on the equations described in section IV-A.

A. Blockchain Protocol

We propose a DLT-based model for infrastructure finance, where an infrastructure project is represented as a reserve currency. This currency is fractionally backed by an on-chain representation of fiat, enabling automatic conversion between the project currency and fiat. Investors can hold the project currency as equity, and the investee can adjust the currency supply to reflect project expenses and revenues. Our choice to employ blockchain technology for infrastructure finance is validated by the model presented in [27], which evaluates the suitable application of DLT.

Automated fractional reserve currencies can be implemented either on a standalone blockchain or as a token on a parent chain. Consider a hypothetical fractional currency with a single reserve currency as an example to illustrate these mechanisms. Initially, the currency is created with a predetermined supply s allocated to users and a reserve of funds, denoted as total reserves v. The blockchain protocol can spend these reserves to users who convert the fractional currency. Additionally, a reserve ratio r is set, satisfying $0 < r \leq 1$. Throughout the currency's existence, the reserve ratio r can be adjusted independently of the reserves v by modifying the supply s, either through minting (increasing) or burning (decreasing) s while keeping v unchanged.

Users can convert their reserve currency to the fractional currency by adding it to v and receiving newly minted s. Similarly, they can convert their fractional currency back to the reserve currency by burning a fraction of s and receiving a corresponding fraction of v. The protocol governs the conversion amounts, determined by equations derived from the Verus automated reserve currency protocol [28], similar to those used in the Bancor protocol [13] and the Balancer protocol [29].

$$v_{out} = v\left(1 - \left(1 - \frac{s_{in}}{s}\right)^{1/r}\right) \tag{1}$$

$$s_{out} = s\left(\left(\frac{v_{in}}{v} + 1\right)^{r} - 1\right) \tag{2}$$

where v = total currency reserves, s = total currency supply, v_{out} = total reserve currency to leave the reserve, s_{out} = total currency supply to mint, v_{in} = total reserve currency entering the reserve, s_{in} = total currency supply to burn, and r = the currency reserve ratio. The Eqs. 1 and 2 are calculated every time a block is added to the blockchain that hosts the fractional reserve currency, based on the totalled value of all incoming and outgoing currency conversions, where s_{out} and v_{out} are distributed proportionally among users converting. Note that converting does not change r, as s and v are modified together, keeping the reserve ratio the same.

The protocol's instantaneous price p of a currency can be represented by the relationship between s and v, given by $p = \frac{1}{sv}$. If the total value of conversions from reserve currency to fractional currency exceeds the total value of conversions from fractional currency to reserve currency, p and the value of s in its reserve currency increase. Conversely, if total value leaving the system exceeds total value incoming, the value of s in its reserve currency decreases. The volatility of p in response to conversions is determined by r, with lower r values leading to more significant changes in p.

Within the context of this work, the term *fractional reserve ratio* denotes the ratio of the currency reserves to the currency supply in value. Conceptually, the definition of r can thus be likened to the definition of *fractional reserve ratio* or *reserve requirement* in the financial sector [30]. The lower r value a currency has, the higher risk it has of rapid changes in value, thus a high r denotes currency stability. The effect of r

on fractional currency volatility can be illustrated by Fig. 4a, depicting the relationship between s and v for 10 currencies, each launched with $s = 1000$, $v = 1000$, and differing values of r.

Anyone with permission to mint new funds on a currency has access to three interfaces they can use to either extract or inject currency value: minting, burning for weight, or burning for price. Minting new currency generates new currency supply s, adds it to a specified recipient, and then modifies r such that $r_{new} = \frac{rs}{s_{new}}$. Burning for weight does the inverse of minting new currency, where a holder of a fraction of s forfeits their fraction, subtracting it from s, and then calculating a new value for r using the previous equation. Burning for price also involves the forfeit and subtraction of some fraction of s from s, but does not modify r afterwards, causing the price p of the currency to increase. Using the DLT based fundraising model described, combining the use of these interfaces is how municipalities convert their incoming funds, either through initial investment, government grants, or revenue streams, into spendable currency.

Direct costs that aggregate during continued system operation include transaction and conversion fees. We assume transaction fees to be the average cost per transaction l. A conversion fee k is charged for every conversion made between v and s, such that the cost of a conversion c in reserve currency can be calculated by $c = v_{in} \times k$ for conversions into s, and $c = v\left(1 - \left(1 - \frac{s_{in} \times k}{s}\right)^{1/r}\right)$ for conversions into v. The currency creator can set a minimum conversion cost value m such that if $c < m$ for any given conversion, $c = m$ for that conversion. Half of c is paid to chain validators and the remaining half is added to v.

B. Application Layer

The application layer uses the consensus layer described in Section IV-A to regulate the ways in which incoming revenues are burned and new funds are minted, such that a balance is achieved between return on investment, and ability to mint new funds as income. Both components of the application layer in Fig. 2 are part of balancing income vs. return on investment.

Income is generated through two methods: direct allocation of reserve funds and accumulation of reserve currency via minting and conversion of fractional currency. A fixed percentage of the currency held in the reserve is given to the currency controller during the initial investment round, known as a *pre-launch carve-out*. This changes the reserve ratio r but does not affect the currency price. Project funds are categorized as immediate or gradual, with immediate funds required for urgent expenses such as outstanding debt. The pre-launch carve-out method covers immediate expenses.

For generating gradual income over longer periods of time, target reserve ratio r_t, and a target reserve ratio threshold t are defined, such that enough currency is never minted to bring the reserve ratio r below $r_t - t$. With this solution, it follows that the maximum amount of currency mintable s_m at any point is a function of the currency reserve ratio r, supply s, t, and r_t such that

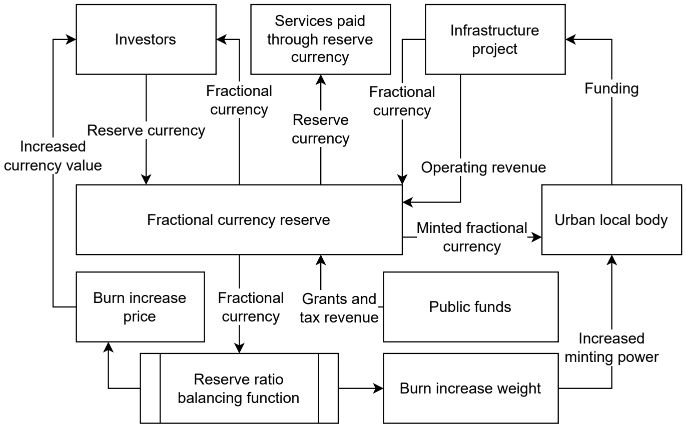


Fig. 3: Flow of funds under a fractional reserve currency based funding model.

$$s_m = \begin{cases} \dfrac{rs}{r_t - t} - s, & \text{if } \dfrac{rs}{r_t - t} - s > 0 \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

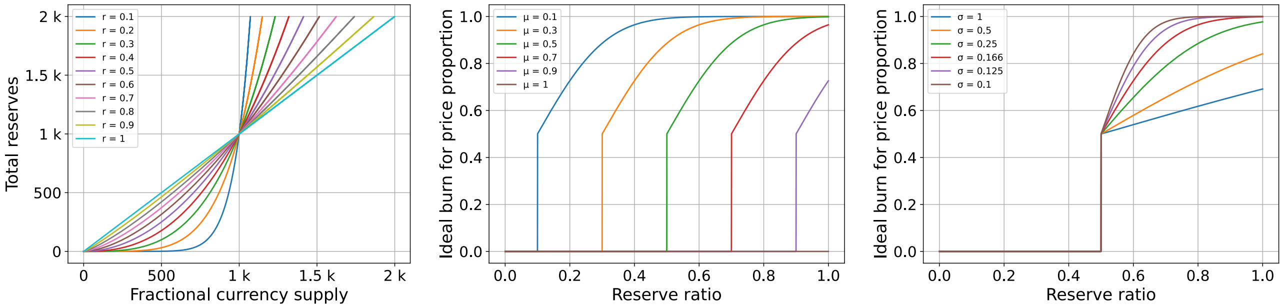
Furthermore, although s_m depends on the amount of revenue flowing into the project, the ratio of how incoming funds increase minting power through burn for weight vs how they increase return on investment through burn for price can be manipulated. The following function is used to calculate the proportion of funds to burn for price b_p

$$b_p = \begin{cases} F(r; r_t, \sigma), & \text{if } r_t \leq r \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

Where F represents the cumulative distribution function of a normally distributed random variable X, such that $F(r; r_t, \sigma) = P(X \leq r)$, r_t is the mean of the distribution, and the pre-determined system parameter σ is its standard deviation.

The Fig. 4b and 4c illustrate the effect that modifying the σ and r_t (represented by μ) system parameters has on the proportion of incoming revenue burned for price b_p at different values of reserve ratio r. The condition making $b_p = 0$ when $r < r_t$ is clearly visible. If return on investment was considered equally or more important than meeting fundraising goals, different methods could be used to determine b_p; this is discussed more in Section V.

Finally, a minting strategy must be determined. Thus, the budget deficit b_d is introduced, to keep track of the quantity of funds that still need to be minted to meet the current income needs of the infrastructure project. If r falls such that $s_m = 0$, b_d will increase every block that funds are requested from the system by the municipality, until $s_m > 0$, at which point fractional funds are minted, converted into the reserve currency, and the result of this conversion is subtracted from b_d. The amount of fractional funds minted is the minimum of s_m and the budget deficit divided by p, as an attempt to estimate the amount of funds required to bring the deficit to



(a) The effect of r on reserves vs. supply.

(b) The effect of μ on b_p.

(c) The effect of σ on b_p.

Fig. 4: The effect of system parameters on fractional reserve currency behavior.

0. If the deficit is less than 0, a surplus is achieved, and funds requested are subtracted from that surplus without the need to mint new currency. Different minting strategies are possible and are discussed further in Section V.

C. Flow of Funds

Fig. 3 illustrates the flow of funds in a DLT based fundraising model, using the same components referenced in Fig. 1 for comparative purposes. The entire network operates around the blockchain layer fractional currency reserve, which is fed reserve currency by investments and revenue, and used to convert fractional currency to reserve currency for providing return on investment and covering project expenses/services. The Eq. 4 maintains a steady balance between funds used for minting power and price. In Fig. 3, all services required for the infrastructure project are paid for by the reserve currency, assumed to be fiat, but it is also feasible to use the fractional currency as payment in certain cases, in a conceptually similar manner to how companies may issue equity to their employees.

V. DESIGN AND IMPLEMENTATION

In this Section, we outline these the configurable aspects of our DLT based fundraising system, and the effect that they have on currency behavior.

A. Burn Balancing

Incoming system revenue is burned to increase currency value. The proportion of this revenue that is burned to change the price b_p vs. burned to change the reserve ratio $b_w = 1 - b_p$ will directly affect how much impact it has on both the funds raised for the infrastructure project, and the funds put towards providing a return on investment. Sending revenue directly in the reserve currency to the municipality wallet is also possible, and would allow for currencies to be created without the ability to mint or burn given to anyone, thus increasing decentralization. However, this decreases the control project coordinators have over currency issuance, and presents a more complex accounting model due to lack of automation. To decrease unnecessary conversion fees, the implementation described in this paper adds burned revenues to v, as opposed to achieving the same effect by converting revenues to s, raising v in the process, and then decreasing s. The effect of burn balancing standard deviation, or σ on the burn balancing function is shown in Fig. 4c.

Although there are numerous ways to determine b_p, Eq. 4 allows for configurable risk to fundraising ability. Whenever r falls such that $r < r_t$, $b_p = 0$ until $r > r_t$, at which point b_p begins to increase, but will only reach 1 if r reaches its maximum value of 1. If either return on investment or raising project funds were considered more important than one another, but not as explicitly shown so far, r_t and σ could be configured to smoothly shift the balance between the two. Furthermore, if return on investment was considered much more important than the probability of successfully raising enough funds, the above case could be inverted such that as long as $r \geq r_t$, $b_w = 0$. Finally, there is no requirement to use any smooth cumulative distribution at all, and hard limits could be set for different values of b_p at certain values of r. The implementation in this paper sets $\sigma = \frac{1}{6}$.

B. Locking Funds

Debt-backed financing instruments are often issued with a date of maturity [17], determining the point at which they can be redeemed for their original value. To simulate this bond behavior in a distributed ledger based system, funds can be locked to prevent invested reserve currency from being redeemed for a fixed period of time after it has been invested.

C. Minting Strategy

Minting funds consists of, for every block, accumulating a deficit based on the income asked from the system during that block, and then, if the deficit exceeds 0, minting the lesser value between maximum mintable currency s_m and $\frac{d}{p}$, where p is the price calculated with values determined from the latest block. The minted value is then converted from fractional currency to the reserve currency and subtracted from the deficit. This strategy effectively generates the required project funds, and provides a return on investment. Minting less than s_m, risks failing to sufficiently reduce the budget deficit, due to the fact that all conversions into and out of the fractional currency are converted at once every block. This risk of increasing budget deficit can be mitigated at the cost of investor return if desired, by always minting s_m when $s_m > 0$,

TABLE I: Achievement of baseline targets for fractionally backed currency fundraising (USD).

	Our Model	Municipal Bonds
Funds Raised	295,015,943.92	295,015,915.20
Incoming Revenue	408,875,596.70	408,875,596.64
Total Investor Return	364,781,888.10	363,884,681.44

with no concern for whether or not the minted amount will provide a budget surplus.

D. Target Reserve Ratio and Threshold

The target reserve ratio r_t and threshold t affect the burn balancing and mint scheduling functions described in Section IV. The higher r_t is, the less incoming revenue will be burned to increase the price. Thus, $r > 1 - r_t$ defines the only domain in which $b_p > 0$. Furthermore, $r > r_t - t$ defines the only domain in which any currency will be minted, thus $r_t > r > t$ is where both currency can be minted, and $b_p = 0$, meaning this is where all incoming revenue can be translated into income. The size of $r_t > r > t$ therefore directly translates to how important guaranteeing income generation is.

Following an initial funding period, $r_t = 0.65$ and $t = 0.2$, to provide enough project funding and a sizeable return on investment. Although these values were selected manually, further research could and should be done to find an optimization function for r_t and t given a particular project case.

The initial currency values for reserve ratio, supply, and reserves have an impact on the early behavior of the currency, before much minting, burning and converting occur. Initially, it is ideal to set $r = r_t$ or $r > r_t$, so burning entirely for weight is not immediately necessary. The reserve to supply ratio should reflect the initial value of r to prevent any large changes once currency behavior normalizes, so initial supply is set such that $s = \frac{v}{r_t}$, where v is the initial reserve value. Setting v initially requires some amount of capital in the reserve currency, which should both be considered a deposit for the currency funding system, and reflect a small percentage of the total funds the municipality is aiming to raise.

VI. EVALUATION

Here, we examine the contemporary example of municipal bond issuance for a light rail project in Honolulu [31], use the same overall values for funds borrowed and repaid, and emulate a DLT based system being applied to the project. The design choices of our system for this simulation are configured as described in section IV. Every block, all incoming funds are burned according to Eq. 4, and maximum mintable amounts are calculated according to Eq. 3. If budget deficit $b_p > 0$ and mintable amount $s_m > 0$, funds are minted and withdrawn as USD to decrease or eliminate the deficit. Funds are assumed locked on-chain and unspendable until they mature, to emulate bond maturity. The mapping of locked funds to bonds in our bond issuance example is explained in further detail in Section VI-A.

The Honolulu trail transit project is a large-scale aboveground light rail system on Oahu island [32]. While the total planned cost of the project is 9.5 billion USD [33], we compare it to a series of general obligation bonds issued in 2019, totaling 250,025,000 USD. These bonds mature at different dates, with varying amounts, such as 775,000 USD maturing in 2019 and 2,585,000 USD maturing in 2043.

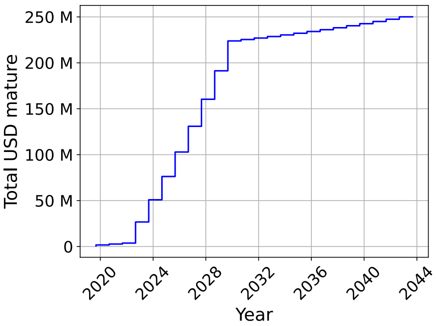


Fig. 5: Bonds maturation schedule.

The issued bonds have a total value exceeding 250 million USD, but their initial purchase cost is typically higher due to projected earnings based on interest rates and maturity dates. The city and council of Honolulu determined that the total issuance premiums for this bond series amount to 44,990,915.20 USD, resulting in a total raised amount of 295,015,915.20 USD. These funds are allocated to three categories: 150,010,399.01 USD for the Bond Improvement Fund, which supports the Honolulu Rail Transit Project; 144,000,000.00 USD for refunding commercial paper; and 1,005,516.19 USD for covering bond issuance costs. While all funds are theoretically available after bond issuance on January 31, 2019, it is assumed that the refunding of commercial paper occurs immediately, while the bond improvement fund is spent gradually as project expenses arise.

Bonds are repaid through interest payments and the full repayment of the principal amount. Each bond generates fixed yearly interest until its maturity date, when the bondholder receives the full principal amount. Throughout the issuance period, a total of 250,025,000 USD in principal and 113,859,681.44 USD in interest are repaid, resulting in a total repayment of 363,884,681.44 USD. The maturity dates of the bond amounts are not evenly distributed, with a majority of bonds maturing between 2023 and 2030. After that period, the total mature value gradually increases until reaching the total bond principal of 250,025,000 USD (see Fig. 5).

A. Mapping Data to a Fractional Reserve Backed Currency

By applying the values of borrowed and repaid funds to a DLT-based system, we achieve improved performance in terms of cost, transparency, and the potential for democratization of investor power. We map the values from a system similar to Fig. 1 to a system resembling Fig. 3, enabling us to create a fractionally backed reserve currency with USD as the reserve currency. Regarding protocol costs, we assume an average cost per transaction $l = 0.00025$ USD, a conversion fee of $k = 0.00025$, or 0.025% of every conversion made, charged in the source currency, and a minimum conversion cost $m = 0.0002$. The minimum conversion cost is paid in USD, and set to ensure that small conversions cannot pay less than a minimum fee value. The average transaction fee is also priced in USD, and has been calculated using the current default fees present on the VerusCoin blockchain today [28].

In the current municipal bond system, funds are generated by selling bonds for their principal and premium on January 31, 2019. To replicate this bond behavior, we introduce a "pre-launch" period where investors can convert their US dollars into USD-backed fractional currency. During this period, funds are locked, and investors can invest in 25 different time-locked batches with varying maximum amounts. The pre-launch period runs from January 1 to January 31, 2019. Bond premiums are charged based on the amounts specified by the city and council of Honolulu, distributed among investments maturing more than 10 years after bond issuance. It is assumed that all batches are fully invested in by the end of the pre-launch period. Any investments in a time-locked batch of funds cannot be converted from fractional currency into reserve currency until the time-lock expires. Furthermore, it is assumed that all unlocked funds are redeemed for USD as soon as possible.

Income from invested funds is received as USD through a pre-launch carve-out or a minting schedule. The 144 million USD for commercial paper refunding is taken directly from reserves, while other expenses are gradually minted from 2019 to 2029. The total raised amount of 295,015,915.20 USD is assumed to be spent by 2030. In the DLT fundraising model, investor return is the difference between USD spent to convert into fractional currency and USD earned upon conversion back. Fixed interest income and redemption earnings contribute to the return. To maintain an increasing currency value, burn balancing is used. Bond premiums, principal, and interest contribute to the revenue burned. The source of these funds is not considered for simulation purposes, as long as the values provided in the issuance report are used.Revenue from bond principal accrues gradually each year, aligning with the maturity of bonds. Similarly, revenue from bond interest accumulates gradually, corresponding to the interest payments due on June 30th of each year. Bond premium revenue is added gradually during the pre-launch period as investments are made.

VII. RESULTS

Our USD-backed fractional reserve currency successfully raises funds to cover all listed expenses by the city and county of Honolulu. The total return on investment is approximately 0.25% higher, even under worst-case investor behavior. Overhead costs using our model are estimated to be 19.27% lower to 0.72% higher. Fig. 6a illustrates the expected fund generation. Initially, 144,000,000 USD is raised to refund commercial paper, with the remaining amount gradually converted from fractional currency to USD over 10 years.

Fig. 6a shows the distribution of funds redeemed by investors converting their fractional currency to USD. The step-wise nature of most plot lines is due to the assumption that all funds are sold at maturity. The *USD redeemed* line resembles Fig. 5, with the majority of funds maturing between 2023 and 2030. Fig. 6c displays cumulative direct protocol fees over the funding period. Fees increase in larger steps during high-value conversions, while smaller, gradual increases occur as revenue is accumulated, converted, and burned. The total protocol fees at the last recorded block amount to 208,382.13 USD, approximately 0.08% of the total bond value.

As shown in Fig. 6a, the reserve ratio stays above the lowest set threshold of 0.45, with a minimum value of 0.51. Furthermore, the reserve ratio trends upwards as revenue flows into the system and gets burned, indicating that if the currency were to be in use past the current final maturity date, more funds could be minted to pay expenses as needed.

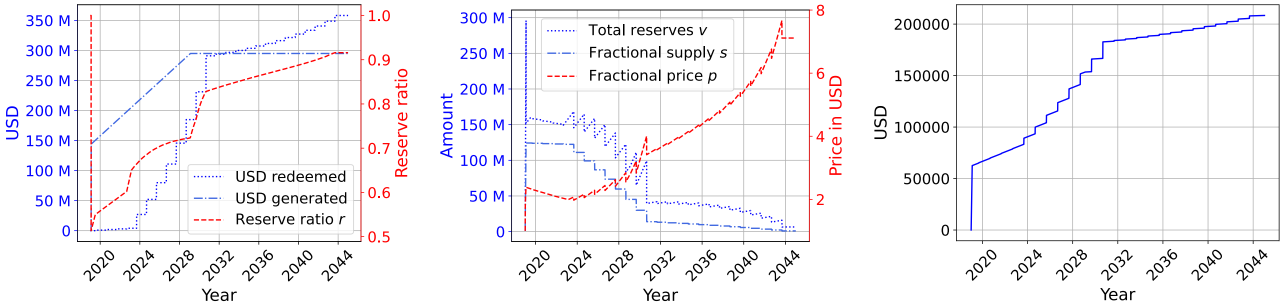
In Fig. 6b, the fractional currency supply and USD reserves behave as expected. Both reach their maximum after the initial investment period, followed by a drop in reserves due to the pre-launch carve-out. Reserves gradually increase between maturity dates through incoming revenue and decrease as investors redeem fractional currency. At the final block, 6,529,863.77 USD remains in reserves, assumed to be distributed as dividends to investors. Repayment mechanisms for leftover funds are not discussed here, but investor details can be accessed or dividend vouchers issued during investment.

The fractional currency price generally increases over time, with a slight drop when time-locks expire (Fig. 6b). The DLT-based model described in this paper achieves a cost reduction of approximately 42.69% compared to traditional methods (Section III). By halving underwriters' discounts and general counsel fees, and incorporating DLT protocol fees, the total cost is 0.98% of the bond issuance amount. If an underwriter is not needed and enough individual investments are attracted, costs could drop by up to 58.48%, reaching 0.71% of the issuance amount. This model's cost savings are significant compared to third-party crowdfunding platforms (5-9% of funds raised) [16]. Model limitations, as well as more details regarding the consensus layer, are further discussed in the extended version of this work [34].

VIII. CONCLUSION

In this paper, we introduce a new model for financing public infrastructure, built upon DLT with a fractionally backed reserve currency protocol. In addition, we introduced automated application layer fund management functions. We evaluate our model by taking an existing case of municipal bond issuance for the Honolulu rail transit project, and find that benchmarks such as investor return, revenue, and funds raised are all either equivalent to or higher than their municipal bond counterparts. Furthermore, our model introduced a cost reduction between 42.69% and 58.48%, when compared to contemporary median bond issuance costs while intrinsically providing democratization of investment and increased transparency.

Although the paper focuses on public transportation finance, the configurable aspect of our risk to income/return on investment algorithms makes our solution fairly versatile, and able



(a) USD redeemed and generated. (b) Currency price, supply and reserves. (c) Protocol fees paid.

Fig. 6: Performance of a DLT based fractional reserve fundraising model over the 26 year bond issuance period.

to be implemented in environments with varying degrees of acceptable risk to investors and investees.

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