Pev Model: A Tokenized Model for Trading Cities

By

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Abstract

Despite the fact that cities are long-lived assets and highly valuable to billions of people, there exist no securities and no formal financial markets to trade cities (city stocks). We provide a solution to this problem that model cities as “sovereign firms,” collects data on cities’ asset portfolios, and computes “composite valuations” of cities. We design a city-token-economy by using blockchain technology to issue city security tokens (Pev Token) and city utility coins (CitiQuants Coins) that are traded on a proposed decentralized exchange (CitiQuants Exchange) network. Better public policy emerges from ‘citizen investment voting” and new city revenue instruments are issued through the exchange. In addition, city investors (City Guardians and Participants) get access to new financial instruments; reap efficiencies from funds disbursements, and better monitor the impact of funding using cities’ asset performance data.

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I. INTRODUCTION

Cities are highly valuable to billions of people; it's where they were born, relocated to, work, live, and die. Today, 80% of people in the developed world and 50% in the developing world are city dwellers. Cities account for over 80% of global GDP and are projected to provide over 80% of future GDP growth, up to 2030. [1] Despite cities being highly valuable, there exist no financial assets and markets that allow people to purchase and trade city (valuations) stocks. Municipal bond markets exist, but they allow people to trade city debt, backed by general tax revenues or project revenues. Basically, they are trading projected city revenue valuations. There are also real estate investment trusts (REITs), but these only allow people to trade valuations of specific segments of cities' real estate.

Increases in the value of living in the city, that flows from public policy, are not captured and traded in formal markets. However, people implicitly make calculations of the value of living in cities and trade them every day. When people and firms make relocation decisions to other cities they are trading cities. When people quit jobs in San Francisco, because of the high cost of housing, and move to Miami or Tucson, they are trading the value of living in one city for another. In the case of existing "site-selection markets," their focus is on valuing the performance of selective city assets for enterprises to trade cities. However, no tradeable financial instruments or markets have been created to trade the resulting valuations, primarily due to inefficiencies, and the hidden, backroom, and oligopolistic nature of these markets.

What is needed is a method to compute the valuation of cities, issue securities, and establish markets to trade the securities. In this paper, we propose a method that models cities as "sovereign firms" with portfolios of tangible and intangible assets. We design a system to collect cities' data and measure the returns (valuations) on the city's portfolio of assets. The design includes asset performance classes, a digital platform, a site-selection engine, and City Oracles. To trade the expected returns, we use blockchain technology to issue city security tokens (Pev Tokens) and city utility coins (CitiQuants Coins), on a proposed decentralized exchange network. The exchange network gives rise to policy feedback loops that engender "citizen investment voting." The emergent city-token-economy provides new and cheaper sources of funds, and more efficient city payment systems, for city governments. City Guardians and Participants (investors who are city dwellers and non-dwellers) access new financial instruments and more efficient funding mechanisms.

NOTES:

[1] See, World Cities Report, wcr.unhabitat.org/main-report/ 2016.

II. THE CITY-ASSETS FRAMEWORK

a. Sovereign Firm

We start with the basic notion that cities are analogous to firms that use factor inputs (land, labor, physical and human capital, entrepreneurs) to produce goods and services (value creation) to maximize profits. Firms may pursue alternatives to profit maximization, such as sales revenue or managerial utility (from salary, security, power etc.) maximization, however, all of these alternatives vanish if the firm makes zero profits and shuts down. [1, 2] Cities are "sovereign firms" that use factor inputs and a political process (governance model) to generate public goods and services to sustain and improve the quality of city life.

City dwellers require a range of goods and services that include transportation, public safety, utilities, a sustainable environment, public assistance, education, recreation, housing, and economic development to live in their particular city. This requires city managers (mayors and city officials) to make policy, managerial, and planning decisions, like firms, to marshal resources to provide the range of goods and services city dwellers need. City managers are modeled as maximizing a city-social-welfare function in which individual utilities are defined on the city goods and services provided. [3] The choice of the social welfare function is determined by the city electoral process or the existing governance model, which may be non-democratic.

City managers formulate, adopt, and implement policies that facilitate the transformation of resources into public goods and services to maximize the city-social-welfare function. But, like firm management, city managers may pursue alternative objectives, such as power, prestige, rent-seeking (bribery and corruption), and regulatory capture, through collusion with firms and entities that city managers depend on for knowledge of specific markets. The end result is a shift away from social welfare maximization that shows up in the form of declining city services, economic dislocation, falling property values, and out-migration from the city. In the limit, city bankruptcy, depopulation, and abandonment imply that the pursuits of alternative objectives are self-defeating.

b. Portfolio of Assets

To provide public goods and services, for city dwellers, city managers formulate, adopt, and implement policies that create a portfolio of tangible and intangible city assets. These city-assets encompass physical structures (roads, pavements, bridges, residential and commercial buildings), vehicles and equipment, sustainable environment, human capital, stock-of-trees, competitiveness, fiscal balances, transparency, personal safety, diversity, culture, and openness. The performance of these stocks of assets determines the quantity and quality of the public goods and services created by the city. And it's through the consumption of public goods and services that city dwellers maximize their individual utilities. The city-social-welfare function is then an aggregate representation of these individual utilities or preferences. The stocks of city-assets are valued by city dwellers because they provide the stream of utilities that make the city the place they choose to live and die.

We represent a city as a portfolio of assets (city-assets) that provide a stream of utilities for city dwellers. City-assets are long-lived assets that last for very long periods of time. Evidence for this is provided by the existence of cities such as Athens that has been continuously inhabited for at least 7,000 years and today remains a sprawling metropolis, and Sidon, Lebanon, that has been inhabited for at least the last 6,000 years and today is the home for about 200,000 people. [4] The central variable explaining these characteristics of cities is the performance of city-assets. The relevant question then is how to analytical capture and represent the performance of city-assets?

Analytically, we propose to capture the performance of city-assets by identifying four asset performance classes, as follows: *Livability Assets, Workability Assets, Sustainability Assets* and *Governability Assets*. These asset performance classes capture the use values created by city-assets, for city dwellers, through a set of *asset performance variables*, see Table I. The Livability Assets capture the cost of living and well-being of city dwellers' lives, as it represents the quality of city life. Workability Assets capture the city's economic competitiveness and the cost of business operations, in the city, which represent city dwellers economic opportunities and survivability. Sustainability Assets capture the need to live in a clean and healthy natural environment, which anchors the fact that cities are long-lived and maybe be continuously populated. Finally, the Governability Assets capture the fiscal and financial management that ensure the financial viability of the city, and the extent to which city managers pursue alternatives to maximizing the city's social-welfare-function; in simple terms, it measures the extent of political accountability. In addition, it captures the social fairness of public safety institutions. Using this analytic approach, involving four asset performance classes, is not only parsimonious but also data and computationally efficient.

c. Portfolio Returns and Trading Cities Dynamics

City-assets create use values for city dwellers that are captured by the asset performance classes and measured by the asset performance variables. It's the use values that provide individual city dwellers with utilities that are maximized individually.

But, in practice, the use values are equivalent to the returns generated by the city-assets. Recognizing this fact leads to questions about the determinants of the rates of return or performance of city-assets? The answer though is quite simple; it's the rate of technological innovation across the city. Technological innovation improves the performance of city-assets which then increases the utility city dwellers get from living in the city. Given information flows, knowledge about improvements in city living generates population inflows that further deepens the density and diversity of the city. [5] This generates more disruptive innovations, better performance of city-assets, and improvements in the value of city living. Persistent information flows, about the quality of city living, sparks additional population inflows which further deepens density and diversity. The results are more disruptive innovations! What emerges is a self-sustaining process of disruptive innovations, driven by population dynamics, as the determinants of city-assets' returns. However, this process is not independent of city managers' policies that can accelerate, slow down or kill off the rate of innovation, and the returns on city-assets. It suggests that consistently bad public policies can lead to secular stagnation and decline of cities.

We've established that technological innovations drive the returns generated by city-assets. The returns, in practice, are equivalent to the use values that provide utility to individual city dwellers. These individuals maximized their utilities, from living in the city, by solving a city-utility-maximization problem using preferences defined on cities' use values. This means that population flows to cities can be viewed as the outcome of individuals solving city-utility-maximization problems. The individual computes the expected maximized city utility for a range of cities and then selects the city with the highest maximized utility. The solution incorporates a budget constraint that assigns prices to use values. In cases where use values are traded in formal markets, like housing markets, the prices are explicit. If there are no formal markets, as in the case of a sense of belonging ("A New Yorker"), the city dweller assigns a shadow (implicit) price for use values in the budget constraint. As a consequence, the individual's city location decisions can basically be viewed as one of computing valuations for cities and then trading cities based on those valuations. The individuals are valuing cities because cities are viewed as portfolios of assets. Similar valuations are made by firms using expected future profits.

d. Summary

Cities are viewed as portfolios of assets and their performances or returns can be captured by four asset performance classes. The returns or use values generated by the assets can be measured by using asset performance variables. When individuals (and firms) execute city location and relocation decisions they are essentially computing valuations of cities and trading cities. These are, however, private valuations and trading decisions. The issue is to make them public by creating formal financial markets for trading cities

Notes:

1. For early work on the theory of the firm, see Coase, Ronald H. (1937). "The Nature of the Firm." *Economica*. **4** (16): 386–405.

2. Some alternative explanations of firm behavior are provided in, Jensen, Michael C.; Meckling, William H. (1976). "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure". *Journal of Financial Economics*. **3** (4): 305–360.

3. The earliest formulation of the social welfare function is provided by, Abram Bergson (Burk),"A Reformulation of Certain Aspects of Welfare Economics," *Quarterly Journal of Economics*, 52(2), February 1938, 310-34.

4. See, for example, Nelson, Bryan. 12 oldest continuously inhabited cities: these ancient cities have seen human civilization evolve, Mother Nature Network, August 4, 2015, https://www.mnn.com/lifestyle/eco-tourism/stories/12-oldest-continuously-inhabited-cities.

5. For evidence on the relationship between innovation and unconventional innovation, population density, and diversity see findings by Enrico Burke's and Ruben Gaetani, The Geography of Unconventional Innovation, June 21, 2017, sites.northwestern.edu.

III. CITY-ASSETS VALUATION

a. Data Capture Strategies - The CitiQuants Platform

The asset performance variables are measurement proxies that capture the use values or returns that city-assets produce. These we interpret as measures of the city's intrinsic or fundamental values that city dwellers compute to make their city trading or location decisions. To compute cities' valuations we pursue three strategies. First, we identify a set of asset performance variables that capture most (70% on average) of the use values produced by each asset performance class, see Table I. Second, we build a platform, the *CitiQuants Platform*, linked by a set of APIs to *City Oracles* that provide continuous measurement data to the platform. The *City Oracles* are the research institutes, government organizations, foundations, university research institutes, international organizations, enterprises, and startups that collect, produce, and disseminate city data. Third, we build a city location engine, the *eKlekos Engine*, which is the algorithm the platform used to manage the data and compute the cities' valuations. The valuations are the critical information that fuels the formal financial markets that are created. See the flowchart in Figure 1.

b. Data Measurements and Assets Valuation - eKleKos Engine

A set of data measurement (problems) issues has to be resolved in order to implement our data capture strategy. There is the issue of data *standardization* which means that the data being captured must measure the same performance variables across all cities. This requires the use of common definitions to capture the measurement data underpinning Data-Driven City Development (DDCD). In the case of data-driven economic development (DDeD), for example, wages should be the fully loaded wages that firms use to compute the cost-of-operations in the city. Our data-driven economic development (DDeD) publisher standardizes the cities' economic data that are needed to measure the workability asset performance variables. The DDeD publisher is one component of our DDCD publisher that standardized the data for all the asset performance classes.

Data *aggregation* is another issue that involves combining the standardized data from the various City Oracles. The eKleKos Engine's data aggregation rules combine the data and apply data quality rules to ensure the quality and integrity of the data. It also generates from the aggregate data the decisional data that firms need to make firm location decisions; city managers need to formulate city policy, and institutions and organizations need to make city centered decisions. There is also the issue of data being *fresh* or *real-time*. The platform links the City Oracles through a set of APIs that enables

Table I

TANGIBLE & INTANGIBLE ASSETS STOCK	ASSET PERFORMANCE CLASSES	ASSET PERFORMANCE VARIABLES
Social Infrastructure	**Livability Assets**	
Health	Health and Wellness	Average Health Insurance Premium Plus Co Payments
Housing	Safety	Crime Rate/ Social Services Expenditure
Civic	Cost of Living	Median Housing Cost/2 BR Apt Rental/CPI Inflation Rates
Utilities	Inclusiveness & Diversity	Population Shares by Race and Ethnicity
Transportation		
Education		
Arts & Culture		
Economic Infrastructure	**Workability Assets**	
Commercial Structures	Talent	Population /STEAM Stock
Businesses	Cost of Operations	Daily Wages/Commercial Real Estate cost/Telecom Cost
Startups	Transit	Commute Time
Accelerators	Competitiveness	Median Household (Family) Income
Incubators		
Commercial Structures		
Data Infrastructure		
Small Data	**Sustainability Assets**	
Big Data	Quality of Air	CO2/Methane, Nitrous Oxide, Fluorinated Gases/Emission
Platforms	Green Spaces	Green Space Per Person
Public Safety Infrastructure	Building Efficiency	Energy Usage Index Ratings
Police		
Prisons		
Disaster Management & Preparedness		
Human Resources	**Governability**	
Population	Transparency	Transparency Expenditure (Public Meetings, Reporting Platforms etc.)
Natural Resources	Financial Management	Budget Surplus-Deficit /Credit Rating
Land, Water, and Air	Police Fairness	Police Oversite Boards/Internal Affairs/Complaints Unit
City Brand	Corruption	Cost of Corruption (Legal Cost, Bribes, Tax Evasion, Employee Fraud)
Location		
History		
Managerial and Leadership Capabilities		
Managerial Capacity		
Political Leadership Skills		
Research & Development		
Social Infrastructure		
Health		
Housing		
Civic		
Social Infrastructure		
Health		
Housing		

continuous real-time data updates to the platform. This guarantees access to the most recent and up-to-date data generated by the City Oracles on the asset performance variables.

Customization and *visualization* are the last two issues. The standardized data must be accessible in forms that fit the needs of city dwellers. They must be able to tailor the data to meet their unique interests and needs. This includes accessing the data in pictorial and graphical forms that makes it easy to view, see analytics, identify patterns, and drill down for details. Such visualization must cover comparative city visualization which involves easily comparing different cities' data in graphical forms. *eKlekos Engine* integrates leading-edge advanced visualization capabilities into the platform to enable advanced visualization.

The solutions for the data *standardization, aggregation, freshness, customization,* and *visualization* problems then enable us to generate data using a select set of asset performance variables, for each asset performance class. This set-up was explained previously and shown in *Table 1*. The asset performance classes provide measurement categories that summarize the use values that city dwellers get from living in the city. It allows for the identification of asset performance variables, for each asset performance class, that captures 70% and more of the total use values generated by each asset performance class. [1] By extension, we are capturing on average 70% or more of the returns (use values) generated by the city's tangible and intangible assets, listed in *Table 1*. This approach provides a simple, parsimonious, and flexible solution to the city asset valuation problem.

The asset performance variables can be updated and modified to incorporate the effects of changes in technology and preferences over time. For example, assets performance variables that capture asset returns during the 3rd technological (industrial revolution) revolution are inadequate for the 4th technological revolution that requires new variables like population and STEAM (science, technology, engineering, arts, and mathematics) density. Technological and preference conditions can cause the value of a single asset performance variable to dominate city dwellers trading decisions. Such a variable is called a Super Performance Variable (SPV). [2] The *eKlekos Engine* generates numerical values for the asset performance variables that are interpreted as fundamental or intrinsic valuations of city assets. When these numerical values (with differing units) are reported jointly they constitute a *composite price* or *composite valuation* of the city. It is this composite price that city dwellers internalize when making their city trades or location decisions.

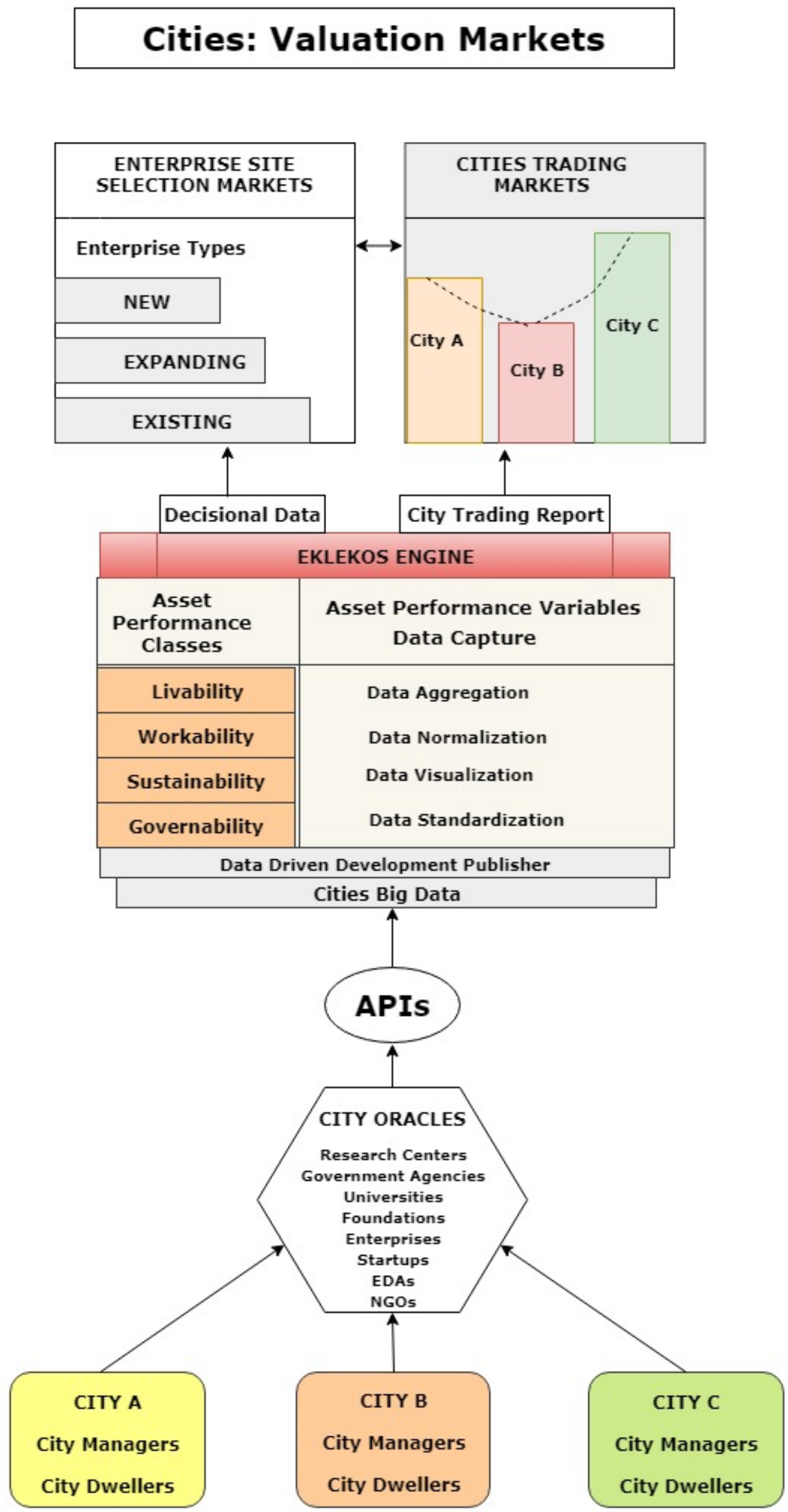

Cities: Valuation Markets
ENTERPRISE SITE SELECTION MARKETS
Enterprise Types
NEW
EXPANDING
EXISTING
CITIES TRADING MARKETS
City A
City B
City C
Decisional Data
City Trading Report
EKLEKOS ENGINE
Asset Performance Classes
Asset Performance Variables Data Capture
Livability
Workability
Sustainability
Governability
Data Aggregation
Data Normalization
Data Visualization
Data Standardization
Data Driven Development Publisher
Cities Big Data
APIs
CITY ORACLES
Research Centers
Government Agencies
Universities
Foundations
Enterprises
Startups
EDAs
NGOs
CITY A
City Managers
City Dwellers
CITY B
City Managers
City Dwellers
CITY C
City Managers
City Dwellers

Figure 1

A city's composite valuation is reported in a *City Trading Report* (CTR). We present CTR for Boston and New York Cities using Table 1 and available data. The asset performance variables and their measurement units are shown in columns 3 and 4. The selection of the asset performance variables is determined by a number of factors. First, the location benching-marking and decisional-data used by enterprises in our site location analysis work. Second, the need for proxy variables to capture the effects of different sub-variables within an asset performance class. Third, the extent to which data is being systematically collected across cities and, finally, the degree of standardization of the data. These factors determine the asset performance variables used to create the CTRs.

The flow diagram, Figure 1, shows that the *eKlekos Engine* generates the decisional data for cities valuation-markets. Decisional data flows into the enterprise site selection market and CTRs or composite valuations fuels the cities trading market (exchanges). Formalization of cities trading markets emerges with the systematic and composite valuations of cities. City dwellers can explicitly make city trading decisions with the emergence of formal financial markets.

c. Policy Feedback Loop

The emergence of financial markets, for trading cities, open-up positive policy feedback loops through the trading activities of investors (city dwellers). How this works is that when investors trade cities' stocks, on cities-trading exchanges, an individual city's stock price then exercise an independent influence on the city managers' public policy decisions. A number of channels can be identified through which this occurs in the context of functioning information markets. There is an immediate *competition effect* that occurs as cities' stock prices show divergent performances. A relatively bad city stock price performance exposes the particular city managers to public disapproval that pushes them to compete on city stock prices. This implies the generation of better CTRs that can only result from better public policy. As a consequence, city managers would be constrained to pursue social welfare maximization objectives rather than alternatives like prestige, bribery, and corruption.

Better performing city stocks also give rise to a *demonstration effect* on public policy. The cities with poorly performing stock prices would have exposure to the CTRs and public policies of high performing cities. The public policies of high performing cities can provide a catalyst for the implementation of similar type policies in lower performing cities. This can give rise to similar or better policies being adopted by the low performing cities. There is also a policy *learning effect* that's closely related to the demonstration effect. The learning effect occurs as cities may want to develop and implement next steps for various city policies. City managers with easy access to available cities trading information can examine the CTRs of high performing cities. They can then study the policies associated with the high returns asset performance variables to determine future policy steps.

d. Citizen Investment Voting

The existence of channels of influence, from cities' stock prices to public policy, give rise to *citizen investment voting.* That is, city dwellers are able to directly influence and force changes, in their city's public policies, through their stock investment decisions. They can purchase their city's stock when asset performance variables reflect good public policies as shown in its CTR, and they can sell city stocks if asset performance variables reflect bad policies. The resulting increases and decreases in the city's stock prices will trigger better policymaking responses from city managers. The stock price changes would impact policy by causing policy reviews, better implementation or adoption of new policies whose effects would show up in the CTR. The CTR provides the city's composite prices that drive the investment decisions of city dwellers.

e. Summary

We developed a platform (CitiQuants Platform) to collect real-time data on cities through a set of APIs that connects the City Oracles generating the data measurements. A set of data measurement problems are solved to facilitate the collection of standardized data. We then select asset performance variables and compute their numerical values using our algorithmic engine (*eKlekos Engine*). The joint representation of these numerical values defines a composite price or composite valuation of a city which is compiled in a City Trading Report (CTR). These reports underpin the information basis of financial markets for trading cities and are a necessary condition for their emergence. These markets give rise to positive policy feedback loops and citizen investment voting through the trading of city stocks.

Notes:

[1] Our substantive analysis of the workability asset performance class, for numerous enterprise site selection decisions, revealed that talent variables (demographic and STEAM densities and disruptiveness/Startups) and operating costs (wages, telecom cost, real estate, travel and cost of utilities) drives the use values. In the case of technology companies, talent drives 70% of corporate expansion decisions and 65%-70% of their total operating cost. These variables become candidate asset performance variables.

[2] The relevance of the SPV concept can be understood in the context of discussions about high housing cost in San Francisco. Peter Theil, recently, commented that the majority of the capital he gives startups goes to landlords (commercial real estate and apartment rentals). He further explained that a

one bedroom apartment rental of $1k in Austin versus $4K per month in San Francisco forces the geographic (location) question and distorts the network effect (there is a tipping point). The cost of housing in San Francisco is an example of an SPV. See, https://www.econclubny.org/page/2018thiel.

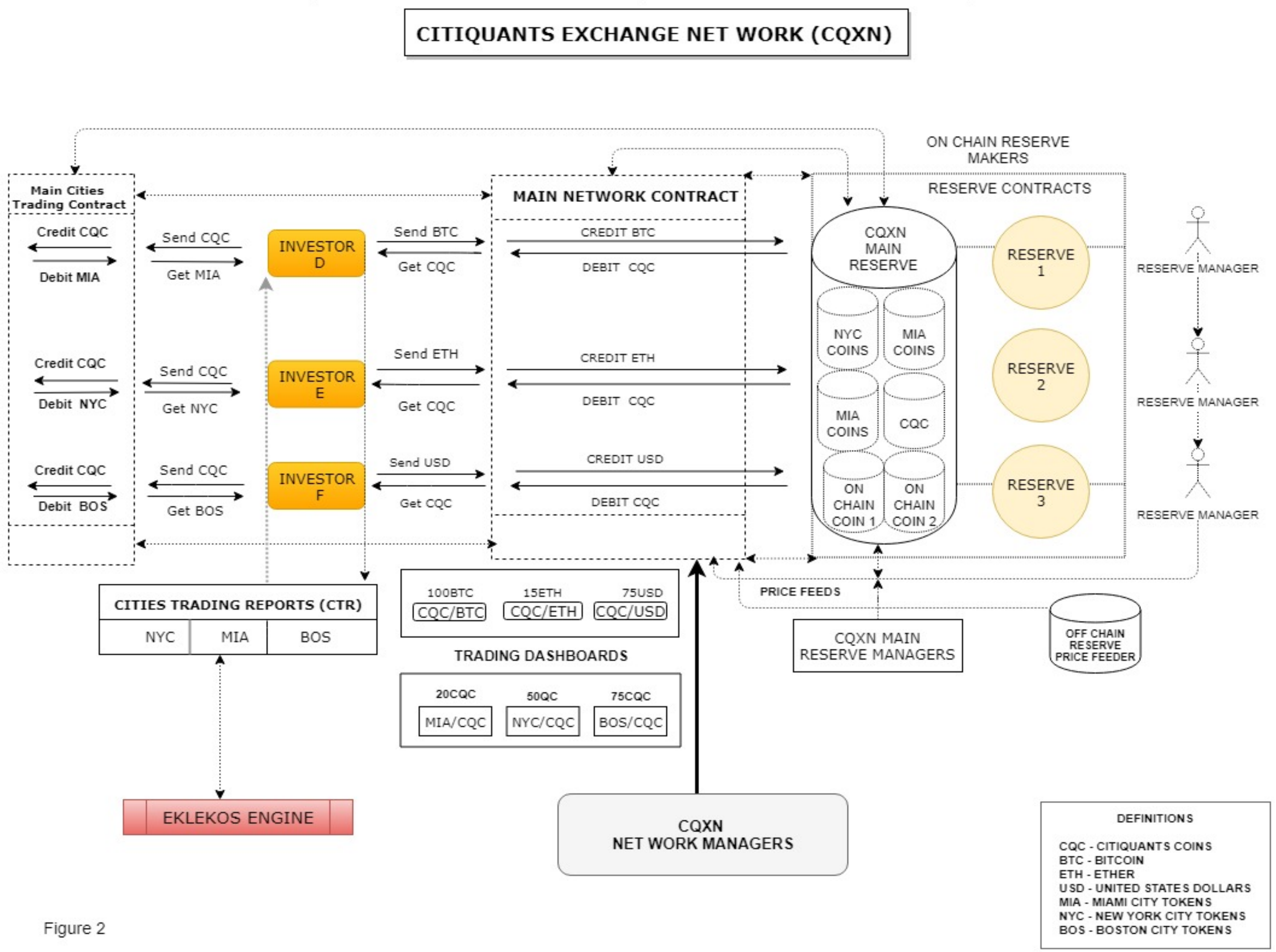
IV. City- Assets Trading

a. City-Assets Trading Exchange - CitiQuants Exchange Network (CQXN)

The CitiQuants Exchange Network (CQXN) is a decentralized exchange on the blockchain that aims to facilitate peer-to-peer trading of cities. To achieve this aim, the CQXN is expected to satisfy the following set of criteria. The network should be secure, user-friendly, offer low trading cost, provide liquidity, and allow instant trades. Existing decentralized exchanges like ShapeShift, Ox protocol, EtherDelta, Kyber Network, and Switcheo Network satisfy varying subsets of these criteria. [1] This means that CQXN will have features that are common as well as dissimilar to these exchanges.

The CQXN is designed to trade city security tokens or city tokens (Pev Tokens) and a City Utility Coin, the CitiQuants Coin or CQC. The CQXN will issue security token for cities, but to purchase and trade security tokens, investors or *City Guardians* (individuals, enterprises, foundations, NGOs, financial firms, and Startups) will need to use CitiQuants Coins. [2] The trading price of the city tokens will be expressed in units of CQC. To exit a particular city token, the investor will receive the equivalent amount of CQC at the trading rate. The investor can then exchange it for crypto or fiat currencies on existing exchanges, where it will be listed. In addition, with emergent adoption across cities, the individual would be able to directly purchase city services using CQC. An important issue is how the different city tokens will be tracked and identified; a unique symbology called *Universal Crypto Asset International Number* (uCAIN) will be used to identify and track city tokens. What uCAIN does is that it assigns a unique alpha-numeric signifier that distinguishes and identifies each city's token on the CQXN. [3]

The basic design (see Figure 2) architecture for the CQXN involves the use of a main network contract, main cities-trading contract, and reserve makers' contracts. There is no global order book, like in other decentralized exchanges, and there is a set of reserve makers who hold inventories of city tokens, CQC, and other cryptocurrencies. The reserve makers maintain exchange liquidity and enable the CQXN to facilitate instantaneous trading. The main network contract controls the reserve makers' contracts and interacts with the cities-trading contract to facilitate investors' trading requests. The main network contract collects prices at repeat intervals (1-3 seconds) from all the reserve makers, for the various City Token/CQC, CQC/BTC, and CQC/Alt Coins exchange



CITIQUANTS EXCHANGE NET WORK (CQXN)
Main Cities Trading Contract
Credit CQC
Debit MIA
Credit CQC
Debit NYC
Credit CQC
Debit BOS
Send CQC
Get MIA
Send CQC
Get NYC
Send CQC
Get BOS
INVESTOR D
INVESTOR E
INVESTOR F
Send BTC
Get CQC
Send ETH
Get CQC
Send USD
Get CQC
MAIN NETWORK CONTRACT
CREDIT BTC
DEBIT CQC
CREDIT ETH
DEBIT CQC
CREDIT USD
DEBIT CQC
ON CHAIN RESERVE MAKERS
RESERVE CONTRACTS
CQXN MAIN RESERVE
NYC COINS
MIA COINS
MIA COINS
CQC
ON CHAIN COIN 1
ON CHAIN COIN 2
RESERVE 1
RESERVE 2
RESERVE 3
RESERVE MANAGER
RESERVE MANAGER
RESERVE MANAGER
CITIES TRADING REPORTS (CTR)
NYC
MIA
BOS
100BTC
CQC/BTC
15ETH
CQC/ETH
75USD
CQC/USD
TRADING DASHBOARDS
20CQC
MIA/CQC
50QC
NYC/CQC
75CQC
BOS/CQC
PRICE FEEDS
CQXN MAIN RESERVE MANAGERS
OFF CHAIN RESERVE PRICE FEEDER
EKLEKOS ENGINE
CQXN NET WORK MANAGERS
DEFINITIONS
CQC - CITIQUANTS COINS
BTC - BITCOIN
ETH - ETHER
USD - UNITED STATES DOLLARS
MIA - MIAMI CITY TOKENS
NYC - NEW YORK CITY TOKENS
BOS - BOSTON CITY TOKENS

Figure 2

pairs, to create a continuously updated *trading-price list* from which the cities-trading contract fetches prices.

When an investor (investor D) initiates a purchase request to convert CQC to MIA (Miami City Token), the cities-trading contract first selects the best trading-price from the trading-price list. Upon execution of the order, it checks to determine if the required amount of CQC has been credited to the contract and then sends a corresponding amount of MIA to the address provided by the investor. To complete the order, the contract sends the credited amount of CQC to the reserve maker whose price was selected and reserve debited. A network fee is deducted from the amount of CQC sent to the reserve maker. Similarly, if an investor (investor E) initiates a purchase request for CQC in exchange for cryptocurrencies (ETH), the main network contract checks for the best trading price from the trading price list. Upon execution of the order, it checks to determine that the amount of ETH was credited to the contract and sends the corresponding amount of CQC to the address provided by the investor. To complete the order, the contract sends the credited amount of ETH to the reserve maker, whose price was selected and reserve debited. The network fee is deducted from the amount of ETH sent to the reserve maker. The trades in both cases are atomic and the CQXN does not hold the tokens/coins of the investor or the reserve maker.

b. Network Roles

The following roles are performed on the CQXN:

- *Investors*
- *Reserve makers*
- *Reserve managers*
- *Network managers*
- *City Trading Report maker*

The investors (City Guardians and City Participants) trade city tokens on the exchange by purchasing CQC using cryptocurrencies, such as BTC, ETH, and Zcash, as well as fiat currency. They make buy/sell decisions based on cities trading reports, which provide current updates of cities' composite prices, and market-driven trading sentiments.

Reserve makers are private funds (individuals), mutual-funds, central exchanges, and CQXN-funds that hold inventories of city tokens, CQC, and cryptocurrencies that provide liquidity to the CitiQuants Exchange Network. Individuals with large holdings of city tokens, CQC, and cryptocurrencies supply the reserve contracts and determine their profits based on the spreads. Mutual-funds are reserve makers that solicit and pool contributions from other investors to supply the reserve contracts. The profits generated by the mutual-fund are shared among the member contributors, and as multiple reserve makers emerge overtime a competitive market in the provision of reserves will develop and this will ensure competitive trading prices. The reserve makers will be both on-chain and off-chain reserve providers.

The reserve managers are the persons who manage the reserve contract by supplying reserves to maintain the reserve balances. They determine the trading prices for the tokens and currencies in the reserve contract and feed the exchange prices to the trading-price list. In the case of mutual funds, the manager solicits contributions from fund members and shares the profits with them.

Network Managers are the CQXN managers who operate the exchange and ensure its smooth functioning. They are responsible for the addition and removal of reserve makers from the exchange, thereby managing the listing and delisting of tokens and currencies on the exchange. Network managers monitor the trading price list; they can change network parameters and suspend trading in response to security threats, and other emergencies.

City Trading Reports are generated by the CitiQuants Platform through its *eKlekos Engine*. The trading reports contain the current composite prices or composite valuations of cities, which are the fundamental prices used by investors, on the exchange, to make their trading decisions. The engine feeds the CTRs to the exchange trading dashboard.

d. System Architecture Components

The exchange architecture will include the following main system components:

- *Smart Contracts*
- *PEV Wallet*
- *Reserve Manager Portal*
- *Network Manager Dashboard*
- *Trading Dashboard*
- *Network APIs*
- *eKlekos Engine*

The CQXN trading operations are executed by smart contracts that reside on the blockchain. There is the main network contract, *CQXNetwork,* which is the main gateway to the system for investors, other users, and reserve managers. The cities trading contract, *CQXNCitiTrading,* controls the buying, selling, and depositing of PEV Tokens. While, the reserve contracts are the on-chain reserve contract, *CQXNReserve,* and the off-chain reserve contract, *CQXNBridgeReserve,* which maintain and control the reserves in both cases, respectively. The reserve contracts are operationally circumscribed by the main network contract. Finally, there is the contract wallet, *PEVWallet*, which provides easy user access to all features that CQXN supports. The contracts will be built with extensibility focus and modularity to accommodate future tokens and coins.

PEV Wallet is the CitiQuants web-wallet application with an enhanced user interface to support investors and users. It's where investors and users interact directly with the exchange when they wish to buy and sell Pev Tokens. The wallet will be integrated with existing user wallets like Metamask, Status, MyEtherWallet, Trezer, Ledger Nano, and other popular wallets to facilitate easy investor and user adoption of the exchange.

The Reserve Manager Portal provides reserve managers with dashboards that provide network performance statistics, reserve balances, and algorithms to manage reserves balancing and targeting, and pricing strategies. Managers will conduct all their interactions with the network through this dashboard.

Network Manager Dashboard is where the exchange network managers monitor, manage and controls the entire exchange system. It's here they would add and remove reserve makers, add and delist tokens and cryptocurrencies, and change network parameters.

The Trading Dashboard is the dashboard investors will encounter when they log in using Pev Wallet and other wallets. It will display the Pev Token/CQC, CQC/Alt Coins, and CQC/BTC exchange rates together with trading charts. The CTR reports with their visualization and comparative cities charts will also be displayed. In addition, investors and users will be able to access personal transaction history, check wallet balances, execute trades, and perform other activities.

The system includes different APIs for investors, reserve contributors, reserve managers, and network managers. There's also provision for the retrieval and presentation of data about orders and transaction, which would be required by external auditors and regulators.

An external component of the system is the *eKlekos Engine* which is located on the CitiQuants Platform. Its function is to provide the Composite Valuations of cities to the exchange for investors to make cities trading decisions. The interactions between the components of the system are provided in Figure 2.

e. Price Determination

The fundamental price of the city is generated by the *eKlekos Engine*. This price is the composite price or composite valuation reported in the City Trading Reports. The price reflects the performance of city-assets with the drivers being the quality of city managers' policy decisions and technological innovation. These decisions are the public investments that improve the quality, performance, and stock of tangible and intangible city assets. Policy decisions also drive city innovation and measures that give rise to low costs startup co-working spaces are good examples.

The fundamental price exerts a determinate influence on token trading prices on the exchange. It will drive investors' demand for Pev Tokens, as city guardians and city participants correlate composite valuations with their spending on Pev Tokens. Improvements in Livability, Sustainability, Governability, and Workability Assets which represent real improvements in cities' use values will be reflected in Pev Token prices; that is, how much they are willing to pay for a Pev Token. Operationally, on the CQXN, reserve managers will be feeding their price of Pev Tokens to the *trading-price list* at the given intervals. The Cities Trading Contract will select the best price from the set of prices provided by all the reserve managers; the lowest price for a buyer and the highest price for a seller. Initially, CitiQuants Reserve Managers will set the Pev Token prices (monopoly pricing), but as the exchange grows and new reserve makers register, there will be multiple (competitive pricing) prices.

Another critical influence on the trading price is market sentiments. These sentiments will reflect speculative impulses, as city participants and guardians bet on expansion in City A relative to City B's composite valuation. They will encapsulate policy pronouncements by city managers on the one hand and policy rumors on the other hand. While the general euphoria and excitement together with disappointment and dejection over city developments will have an impact. A city's Pev Token Value (PTV) function can then be written as:

$$\text{PTV} = f(Trading\ Price, Composite\ Valuation, Market\ Sentiments\ ) \qquad (1)$$

Given equation (1), the CitiQuants Coin (CQC) value function can be expressed as follows:

$$\text{CQC Value Function} = \sum_{i=1}^{N} PTV + \sum_{i=1}^{N} \beta_i V_i + \sum_{j=1}^{M} S_j \qquad (2)$$

$$i = 1, \ldots\ldots, N$$
$$j = 1, \ldots\ldots., M$$

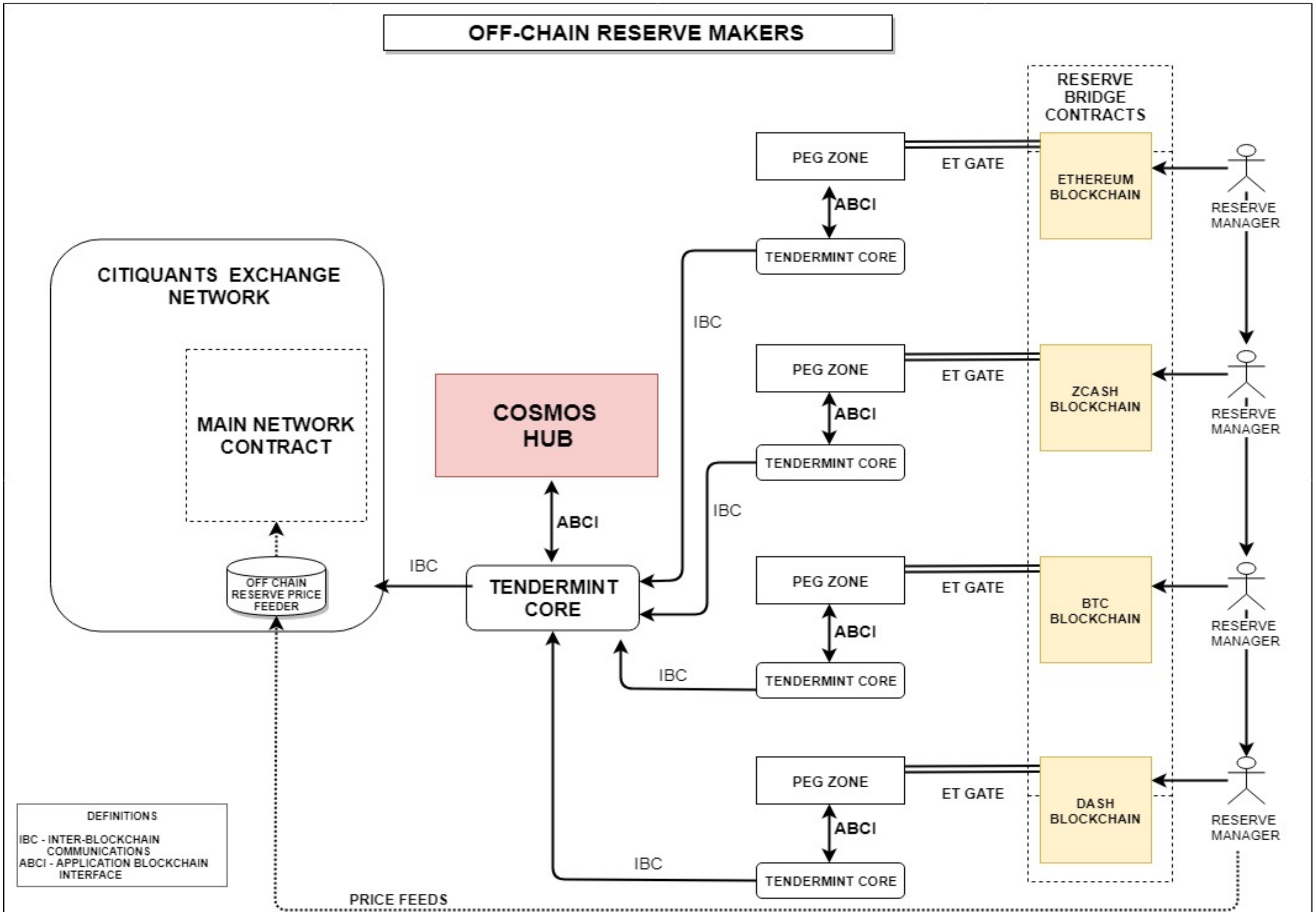
Where N is the number of cities, M is the number of exchanges listing CQC, and β is the speed of adoption coefficient for CQC. Equation (2) says that the value of CQC is the sum of PTV across all traded cities, the sum of values (V) due to the speed of adoption of CQC as a means of payment by city departments, and the sum of values generated by speculative (S) trading on exchanges that list CQC. Clearly, equation (1) and (2), show that the value of CQC is a global measure of value, which CQXN quantifies into a price.

f. Off-Chain Reserve Architecture

The Reserve Makers guarantee liquidity on the exchange network. The Off-Chain Reserve Makers play a central role in this process. But, a major challenge exists with integrating the off-chain reserves because they live on alternative blockchains. Progress has been made in facilitating cross-chain trading through such technologies as *blockchain relays* (BTC-Relay, ZCash-Relay) and cross-chain protocols (Polkadot, Cosmos, Interledger). To ensure liquidity of Alt Coins on the CQXN reserves of Alt Coins will be enabled through the Cosmos Hub. The architecture is represented in Figure 3. Using the Peg Zones created on the Cosmos Hub that creates bridges between different Blockchains through ET Gates, Reserve Bridge Contracts will be created. [4] The Off-Chain Reserve Maker will supply the Reserve-Bridge Contract with the particular Alt Coin and the reserve manager will feed the prices to the main network contract. The CQXN will communicate with the Alt Coin's blockchain through the inter-blockchain communications (IBC) protocol. The benefit of Cosmos is that it allows for full developer flexibility in developing individual blockchains. What Cosmos does is standardize the transfer of values between different blockchains.

g. Pev Token Economics

The Pev Token economy consists of City Tokens or Pev Tokens (Security Tokens) and a City Utility Coin, the CitiQuants Coin (CQC). In the case of Pev Tokens, three types of tokens will be issued and traded on the exchange: Initial Pev Offerings (IPO), Revenue Pev Offerings (RPO), and Initial Pev Distributions (IPD). The Initial Pev Offerings are Pev Tokens issued in collaboration with city managers (city governments) and the funds generated from the issue of the tokens will go to the city managers, and, in exchange, the city will adopt and implement the use of CQC as means of payment for services provided by city departments. Revenue Pev Offerings, however, are issued on behalf of city managers and are backed by general tax obligations or specific city (project) revenue streams. In contrast, Initial Pev Distributions are issued independently of the city managers to satisfy City Guardians and City Participants pure intrinsic interests in the city's development, and the desire for financial assets based on its valuation. See Figure 4, which show tokens and coin flows for the typical city.



OFF-CHAIN RESERVE MAKERS
RESERVE BRIDGE CONTRACTS
PEG ZONE
ET GATE
ETHEREUM BLOCKCHAIN
RESERVE MANAGER
ABCI
TENDERMINT CORE
CITIQUANTS EXCHANGE NETWORK
IBC
ZCASH BLOCKCHAIN
MAIN NETWORK CONTRACT
COSMOS HUB
BTC BLOCKCHAIN
OFF CHAIN RESERVE PRICE FEEDER
DASH BLOCKCHAIN
DEFINITIONS
IBC - INTER-BLOCKCHAIN COMMUNICATIONS
ABCI - APPLICATION BLOCKCHAIN INTERFACE
PRICE FEEDS

Figure 3

The IPO and RPO provide a number of benefits for city managers, city guardians, and city participants. They offer an efficient solution to the problem city managers face of finding alternative sources of revenue. The cost of municipal bonds issuance is of major concern to them because these costs average $3 to $4 billion USD annually. For small municipalities, the cost can hit as high as 9% of the face value; for example, USD 80 million face value can cost USD 7.2 million. [5] RPOs can substitute for some of this funding and reduce substantially the issuance costs (fees for: underwriters, bond counsel, disclosure counsel, underwriter counsel, rating agency, bond insurance (premium), CUSIP, verification agent, trustee, printing fees, and contingency), which are funds that cities need. Both IPO and RPO are purchased with CQC that are transferred (CQC payments and transfers, see Figure 4) to the city managers. By adopting and using CQC as means-of-payment (CQC expenditure and revenue payments, see Figure 4) cities will reduce transactions costs associated with current cities' payment systems (payment gateways and processors' fees). And as cities move all records, services, and transactions to the blockchain (vehicle management system, building records, commercial registry, land registry, licenses, and permits, etc.) CQC will be easily integrated.

Initial Pev Distributions are made independent of city managers. Pev Tokens will be distributed to City Oracles as payment for capturing and providing data to the CitiQuants Platform. Distributions will also be made to city managers to incentivize the adoption of CQC as payments for city department services. City Guardians and Participants (Foundations - private, family, charities, and international) will be encouraged to purchase Pev Tokens with grants and program funding. The Pev Tokens can then be used to provide Token Grants and Token Program Funding to their chosen activities and groups in the city. By using tokens, foundations will be able to eliminate or substantially lower the transactions costs associated with moving funds through the traditional financial system. Foundations will receive direct feedback on the impact of their funding over time through the CTR. They will be better able to target specific areas and cities using the report. For example, the charts for Sustainability Assets (building efficiency/CO2 emissions) may show better performance of City A compared to City B. An environmental foundation, on the basis of this data, can provide Token Grants to NGOs in City A to install solar panels and other energy-saving devices, in public and charter schools.

City guardians and participants can influence the city's asset performance (returns) by investing in Pev Tokens. This investment voting, through the policy feedback loop, improves the quality of public policy (see, Price-Policy Effects in Figure 4) decisions. They also get a new financial earning asset that captures a city's expected valuation and a utility coin to convert the value into city services. For example, City Dweller Alice may liquidate 500 Pev Tokens (IPO) on CQXN and receives 15,000 CQC in return, she then

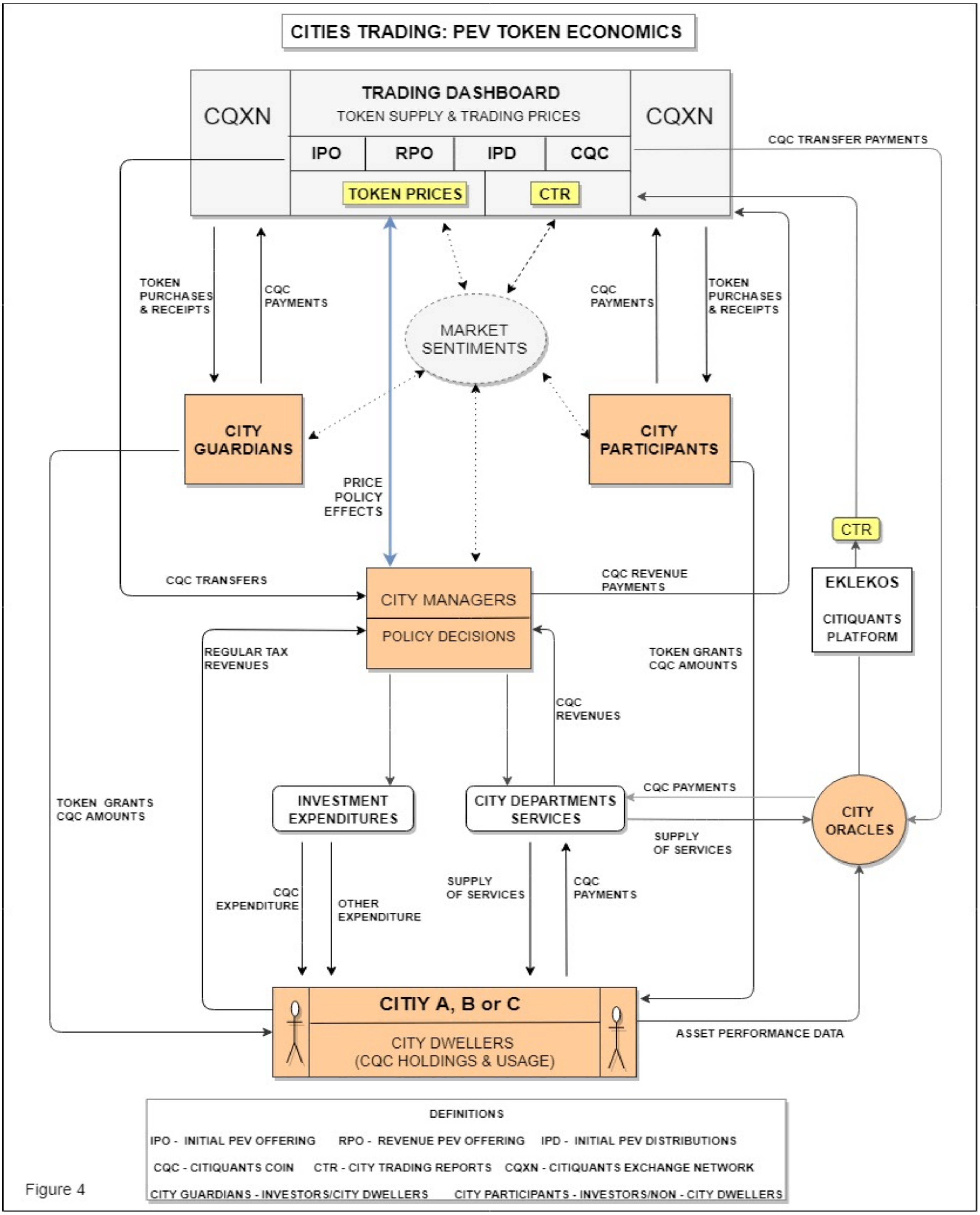

CITIES TRADING: PEV TOKEN ECONOMICS
CQXN
TRADING DASHBOARD
TOKEN SUPPLY & TRADING PRICES
CQXN
IPO
RPO
IPD
CQC
TOKEN PRICES
CTR
CQC TRANSFER PAYMENTS
TOKEN PURCHASES & RECEIPTS
CQC PAYMENTS
MARKET SENTIMENTS
CQC PAYMENTS
TOKEN PURCHASES & RECEIPTS
CITY GUARDIANS
CITY PARTICIPANTS
PRICE POLICY EFFECTS
CTR
CQC TRANSFERS
CITY MANAGERS
POLICY DECISIONS
CQC REVENUE PAYMENTS
EKLEKOS
CITIQUANTS PLATFORM
REGULAR TAX REVENUES
TOKEN GRANTS CQC AMOUNTS
CQC REVENUES
TOKEN GRANTS CQC AMOUNTS
INVESTMENT EXPENDITURES
CITY DEPARTMENTS SERVICES
CQC PAYMENTS
SUPPLY OF SERVICES
CITY ORACLES
CQC EXPENDITURE
OTHER EXPENDITURE
SUPPLY OF SERVICES
CQC PAYMENTS
CITIY A, B or C
CITY DWELLERS (CQC HOLDINGS & USAGE)
ASSET PERFORMANCE DATA
DEFINITIONS
IPO - INITIAL PEV OFFERING
RPO - REVENUE PEV OFFERING
IPD - INITIAL PEV DISTRIBUTIONS
CQC - CITIQUANTS COIN
CTR - CITY TRADING REPORTS
CQXN - CITIQUANTS EXCHANGE NETWORK
CITY GUARDIANS - INVESTORS/CITY DWELLERS
CITY PARTICIPANTS - INVESTORS/NON - CITY DWELLERS

Figure 4

uses it to pay property taxes and licenses. In addition, city dwellers will be able to efficiently finance special city projects through special purpose RPOs. This is due to the simplification of issuing RPOs that emerges with the exchange and blockchain.

The supply of CQC will be determined by the city's GDP and velocity of money. It will expand to accommodate the needs of new cities starting to trade for the first time. The amount of CQC created per city is set to (City Nominal GDP/Velocity of Money). [6] The velocity measures the number of transactions each unit of the currency finances on average, for a given time period. It's used to approximate the amount of city-payment transactions each city dweller undertakes on average. Clearly, it will overestimate the amount of city-payment transactions, but this will enable CQC to satisfy other functions, such as a store of value. The City GDP is a scale variable that proxies for the city's fundamental valuation. CQC will be provided to city dwellers, city managers, city guardians, and city participants through various incentive mechanisms (Air Drops, Faucets, and Service Grants) to jump-start the Pev-Token-Economy.

Pev Token supply will depend on the type of tokens issued, which is determined by the extent of city managers collaboration. The IPD token supply per city is set by the formula: [(City Per Capita Income x City Labor Force x Personal Saving Rate x Crypto Savings Factor) x Participation Factor /Initial Token Price]. The Crypto Savings Factor is an estimate of the fraction of the personal savings rate that city dwellers desire to hold in crypto assets. The percentage of city dwellers eager to hold crypto-assets is what the Participation Factor estimates, for example, with polling data. [7] The Initial Token Price is an estimate of the initial trading price, and the remaining variables are standard economic variables. This formula seeks to match the supply of Pev Tokens with a measure of desired demand.

The issuance of IPOs and RPOs are dependent on collaboration with city managers. IPO supply will be based on the supply formula, but the Participation Factor can then adjusts for market conditions and investor sentiments, driven by city collaboration. In the case of RPOs, the (project) funding requirements, market conditions, investors' sentiments, asset performance, and project returns will substantially influence amounts supplied. The supply formula may be used initially, but over time these factors will dominate.

h. Security Considerations

There are security issues that must be addressed to ensure users' tokens and coins are not stolen or lost when using the network. The CQXN is based on smart contracts that will live on the blockchain to facilitate the exchange of tokens and coins. Smart contracts are susceptible to bugs due to coding errors and shortcomings that bad actors can exploit. To prevent such errors, we will invest in vigorous bug-bounty programs to identify and eliminate coding bugs. We will also engage in rigorous external code audits to ensure that the smart contract code is well written and of the best quality.

Another set of security threats surround reserve contract security. This relates to protecting against reserve managers who are bad actors. Reserve managers may devise multiple strategies to drain the reserve contract of tokens and coins. Such bad reserve managers may use pricing strategies, for example, they may quote bad prices and trade with themselves using multiple trading addresses to drain coins from the reserve. They may feed false and unreliable exchange rates to the *price-trading list* that could benefit associates. In the case of private funds and centralized exchanges, which are reserve makers, the problem may be one of who has access to the reserve contract? The problem can be contained by restrictions and careful scrutiny of who is appointed reserve managers by these private entities.

For the case of mutual funds, the fund members contribute to the reserve contract and have access, which makes the problem more severe. Control over fund withdrawal from the reserve contract can be established by restricting withdrawal to addresses on the main network contract that can be monitored by network managers. For the case of bad reserve managers, who may use pricing strategies to drain tokens and coins from the reserve, background monitoring will be built into the system architecture. The network managers can suspend and stop trading, on the reserve contract, if irregular prices and trading volumes are observed. System design can also allow fund members to observe and see all trading activities that the reserve manager undertakes. This fund member monitoring provides social pressure that can further constrain reserve managers from being bad actors.

Notes:

[1] See: https://shapeshift.io/#/coins
https://0xproject.com/
https://etherdelta.com/#PPT-ETH
https://kyber.network/
https://switcheo.network/

[2]. City Guardians are all the investors who are City Dwellers. They ensure good city public policies through their investments in city tokens. Good policies arise from the city token trading prices through the policy feedback loop. City Guardians include individuals, Startups, Enterprises, NGOs, Foundations, City Managers, and Financial Firms. While, City Participants are investors who are non-City Dwellers and include: individuals, Financial Firms, Enterprises, Startups, Supranational Organization, and Foundations.

[3]. A total of 375 cities, with an innovative and smart technology focus, spanning 75 countries, that we have identified, will be issued uCAIN numbers. Over time, the 50,000 cities across the globe, with a base population of 100,000, will all be issued with uCAIN on the CQXN. Smaller towns, cantons, and micro-states will eventually be issued their own uCAIN numbers.

[4]. The average cost of bond issuance is estimated at 1.02% of bonds' principal amounts and varies to as high as 9%. See Joffre, Marc. "Doubly bound: the cost of issuing municipal bonds," Haas Institute, UC Berkeley, 2015.

[5]. The velocity of money measure used is M1. Given its fluctuation and decline over time, the average rate for the period 2000 - 2018 was computed and is 8.214, using FRED data, St. Louis Federal Reserve. For example, the amount of CQC that will be issued for the City of Boston is (422.660 million/8.214), which equals 51,456 million CQC. The GDP is the 2017 measure for the Boston Metropolitan Area. This works out to be 11 CQC per person given the population of 4.732 million people.

[6]. An example is the Bank of Korea polling data that show 40% of young adults are eager to possess cryptocurrency. See The Korea Times, May 26, 2018, "40% of young adults eager to possess cryptocurrencies," By Park Si-soo. Let's consider, the City of Boston with a per capita income of $70,157; Labor force of 2,747,549, and US current personal savings rate of 2.4%. Assuming, a Crypto Savings Factor of 3%, Participation Factor of 5%, and Initial Price of $2 (or 1.5 CQC). The IPD = (70, 157x 2,747,549 x 0.024 x 0.03 x 0.05)/2 = 3.124 million Pev Tokens.

V. CONCLUSION

We have proposed a model for valuing and trading cities. The model re-defines cities as sovereign firms with a portfolio of long-lived tangible and intangible assets. To measure the asset performance (returns) we identify four asset performance (Livability, Workability, Sustainability, and Governability) classes and a set of asset performance variables. Using a platform (CitiQuants Platform), data-driven development publishers, and City Oracles data for the performance variables are compiled from the cities. A site selection engine (*eKlekos Engine*) is used to compute numerical measurements, and they joint representation defines a composite valuation (or composite price) for the city. This composite valuation provides a measure of the city's fundamental price.

To trade city valuations, a blockchain solution is proposed to provide city security tokens (Pev Tokens) and city utility coins (CQC). A decentralized exchange network (CQXN) is proposed for city guardians, city participants, and city managers to trade security tokens, using the city's fundamental price. This tokenized financial market delivers new benefits. City managers get new sources of revenue, more efficient city payment systems, and lower securities issuance cost. City guardians and participants can directly influence policy through investment voting; get access to new investment assets; provide social funding at lower costs, and access performance data to better assess the citywide impact. These incentives that are built into the city-token-economy serve to broaden democratic participation in cities' development.