Blockchain-based smart contracts as new governance tools for the sharing economy.

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Abstract

Examples of sharing economy platforms are proliferating, generating new concerns on the exploitation of local resources, ethical and intellectual properties. Necessary changes are required to the regulatory frameworks of our cities. This paper proposes an application of blockchain technology for planning governance purposes. This new cutting-edge technology, currently under-exploited in applications for smart cities planning. may represent a fundamental building block for the digitalization of the sector. We propose blockchain-based management systems (BMSs) as new governance tools to improve traceability, transparency, and decentralization of transactions in the sharing economy. We build a BMS prototype for the management of co-working spaces (CWSs). In particular, we show how a blockchain can be used to track transactions between users (e.g., rent payments), and to advertise or store information about a given space (e.g., building specifications, IP conceived within the space). A large amount of data will be permanently and securely stored on ledger and made available to both institutions and corporations, providing a wide range of new governance tools and services to local authorities of the future. Similar BMSs can be developed for different types of buildings or public services purposes.

Keywords

Co-working spaces, urban governance, blockchain, smart cities, sharing economy

1. Introduction

The last financial downturn has imposed severe changes in the labour market causing the disappearance of some traditional jobs and social securities. Among the diverse effects induced by those recent modifications to the socio-economic fabric, we have witnessed the emergence of the sharing economy or access-based consumption, which has then led to the rise of companies like Airbnb or Uber. More recent incarnations of the same phenomenon are co-working spaces, essentially shared office spaces**,** offering a more flexible solution than traditional workspaces.

These new ‘shared’ services have emerged as bottom-up, affordable reactions to the crisis, but soon enough they have started raising concerns on their ethical and economic implications, stimulating intense debates in different fields. Above all, the sharing economy has been identified by many scholars as a case of disruptive innovation. The ethical dilemmas mainly question who is really profiting from such sharing solutions and the impact they may have on the surrounding environment. In the case of Airbnb or Uber, the bottom-up ideology and principles that originally fostered the emergence of the sharing economy, have ultimately led to the creation of large multinational companies. Those companies produce profits and pay taxes in countries that do not coincide—in most cases—with the geographical locations where the resources are consumed or held. Indeed, some startups have already faced regulatory and legal problems with governments, local councils, and lobbies fighting to stop their proliferation and growth (Cannon and Summers, 2012; Libert et al., 2014; Rogers, 2016). In the case of co-working spaces, the discussion is centred around whether they represent a positive social experiment (i.e., the local and/or publicly led ones) or a sheer commercial real estate product (i.e., WeWork).

The debate on the ideological and sociological dynamics and the governance of the sharing economy is also relevant to the field of computer science where new decentralised technological solutions have started to appear. As a by-product of the financial crisis and instability, blockchain technologies and digital assets have emerged as a solution to curb the risks and costs associated with standard mechanisms for value transfer and to eliminate the need for multiple intermediaries.

Blockchain technology dates back to 2008 when the cryptocurrency Bitcoin first appeared. In this new system, transaction validation and currency issuance do not need a central trusted authority to be performed. All transactions once validated are *immutably* stored and made *publicly* available on the blockchain ledger. Bitcoin's idea has paved the way for the exploitation of the appealing ledger's properties for the most diverse applications. The sectors that most actively embraced the new technology range from finance to the travel industry, from healthcare to real estate management. As for the earlier debate, ethical concerns have been raised on the legal aspects associated with the use of this technology and on its disruptive innovative features. The rise of cryptocurrencies—as in the case of service platforms like Airbnb or Uber— elicited concerns in the tax and regulation departments of many governments, which felt that using digital currencies for legal transactions would cause an overall loss of control over these activities and a shift towards decentralized economies globally. Despite the new ethical and legal issues raised by cryptocurrencies, blockchain technology turned out to be particularly useful to address centralisation problems, where transactions are controlled by a single authority, to reduce transaction costs paid to intermediaries and increase transparency as all transactions can be made publicly available. Similarly to the case of sharing economy and the explosion of co-working spaces, the blockchain hype caught the attention of both the research community and the press, which started questioning whether this technology was made to last or rapidly disappear (Aste et al., 2017; Michelman, 2017; Pisa and Juden, 2017).

In this paper, we discuss the application of Blockchain Management Systems (BMSs) for planning purposes. We propose a cross-sectorial overview of the two so far disjoint innovations, namely blockchain technologies and co-working spaces. We will discuss the benefits for the co-working space business by building a prototype of an *ad hoc* blockchain platform dedicated to the administration of their services. Our solution may be devised on an existing public blockchain, as well as on a completely new system associated with a new token used to transfer value or permission to rent. In our case, the prototype is built using the open-source *Digital Asset* platform (*https://digitalasset.com*). We will discuss details of the architecture and functionalities of the BMS, bearing in mind that in a real-life implementation the BMS can be accessed in a more user-friendly way, and with the same functionalities as standard search engines.

The use of the blockchain in the processes of sharing economy could solve ethical and managerial issues, starting from making rent transactions traceable and transparent, therefore eliminating any sort of cronyism or fraud risks. Moreover, the proposed platform may represent a valuable resource to maximise revenues for both private stakeholders and local public authorities. This result can be achieved by eliminating intermediaries and creating a more efficient and users' self-regulated network of facilities. The possibility of a decentralised platform accessible to a wider number of stakeholders could be useful to limit the rental increases or the process of gentrification (Wachsmuth and Weisler, 2018a).

The next three sections provide an overview of the existing literature: first, we approach the topic of sharing economy and CWSs from a social science perspective and then we offer an overview of blockchain technologies and existing applications in the planning sector. In the second part of this paper, we discuss the features of our prototype. Finally, we explore challenges and wider implications for planning and policymaking, providing further examples of compatible uses. We claim that BMS and planning could go hand-in-hand to generate new governance tools to tackle the challenges brought to our cities by the sharing economy (i.e., security, transparency, and tax regulations) on the verge of a possible bureaucratic and economic restructuring.

2. Sharing economy: current debates and issues

The sharing economy is defined as: "an economic system that is based on people sharing possessions and services, either for free or for payment, usually using the internet" (Cambridge Dictionary). Goods are shared on platforms or peer-to-peer (P2P) networks. The idea behind the rise of the sharing economy is related to sustainability and social justice, promoting a new avenue to crowd-based capitalism and the democratisation of goods and resources (e.g., houses, cars, offices, etc.) (Sundarajan, 2016). However, soon enough the original P2P networks have grown to enter the realm of so-called tech unicorns[1], also thanks to the initial lack of regulation in the sector leading to substantial tax exemptions. These companies produce little economic growth in the cities they exploit whereas the largest bulk of income flows towards the corporations' pockets and eventually the region where they are based and pay taxes. The sharing economy has, therefore, started to be identified as a case of disruptive innovation: a technology that shocks an industry disturbing other existing and well-established technologies and creating a new industrial field, demand, or value chain from scratch (Christensen et al., 2015; Guttentag and Smith, 2017).

Because of the substantially different nature of the services offered, the sharing economy is imposing changes to existing regulations in different fields. Airbnb for instance has changed the usual dynamics of travelling with an impact on the local tourism tax collection and on the whole hospitality sector (Ferreri and Sanyal, 2018; Jiao and Bai, 2020). In cities like Barcelona, Venice, or Paris the phenomenon has also wrecked the local rental market; it has generated a wide rent gap fuelling gentrification and harming local residents with the lack of affordable houses to rent (Wachsmuth and Weisler, 2018b). Most of the difficulties encountered by local authorities in the case of short-term lettings referred to the difficulties encountered in keeping track of data. These difficulties have nevertheless had severe repercussions on long-term housing supplies in terms of unaffordability, supply scarcity and "uncontrollability" of the housing supply (i.e. prices and targets), suggesting the need for further regulations (Shabrina et al., 2021). Cities like Berlin, Paris, or Amsterdam have tried to cap the number of nights properties could be put on platforms for short lettings registration. In London, the limit is 90 nights, although local authorities found enforcing the law an almost impossible task due to the lack of adequate data storage and of tailored control measures (London, 2019). Other policies to limit the platform hurricane have included grassroots mobilizations and the claim for further transparency in the registration of short-term letting hosts (Aguilera et al., 2019). Similar struggles on the traceability of data and the different speed levels between the urban planning procedures of local authorities and the industry technologies have been also observed in Sydney

[1] From the definition given in 2013 by venture capitalist Aileen Lee a Unicorn is a privately led startup valued over 1 billion dollars, e.g. Airbnb, Uber, WeWork or Lyft.

(Gurran and Phibbs. 2017). Other issues that have emerged are related to security, e.g. guests not legally registered nor pre-vetted in let or sub-let properties.

In the case of Uber, protests by licensed taxi drivers and quarrels over traditional and private taxi licensing and taxation are also quite well-known for similar security reasons (Rogers, 2016). Further challenges associated with the rise of the sharing economy relate to the need for new legislation in terms of privacy policies and consumer protection regulation (Koopman et al., 2015). As it often happens with disruptive innovations, they require changes to legislations or new governance tools responding to the new phenomenon.

2.1 Overview of existing blockchain-based approaches

Blockchain technology is emerging as a suitable choice to tackle pressing issues triggered by the sharing economy and as an additional layer to the smart city endowment of services (Lim et al., 2018; Vecchio and Tricarico, 2018). In the last few years, the interest of practitioners for blockchain technologies has significantly risen. Early studies on possible implementations of blockchain for digital governance and public services include a policy report published by The European Commission (2019) identifying benefits like enhanced safety and security, efficiency gains, and wider possibilities for equalitarian and collaborative governance practices. The decentralised nature of blockchain has in fact raised theoretical debates on the sociological implications of decentralised governance and the consequent changing role of governments. Most studies concluded that the new technology is not intended to entirely replace the institutions, but rather to contribute to their modernization (Atzori, 2015; Reijers et al. 2016). In planning, the shift from centralised governments to more collaborative tools of governance is already a well-established idea. The decentralised system offered by blockchain technologies would allow for a more coordinated and horizontally integrated system of governance (cf. Lefevre, 2002), while protecting innovation and the transparency of transactions for a smoother regulatory process.

Nevertheless, research proposing applications of blockchain technology to planning and real estate problems is still in its infancy. Our paper precisely aims at contributing to this debate.

Early studies mainly stemmed from corporate research. Deloitte (2016) analyses the impact of using blockchain to decentralise and automatise various processes in commercial real estate (e.g. from property search to the execution of sale). Studies from FICCI and PwC (2018) are related to the broader topic of smart cities. Those studies discuss ways to enhance developments in the Global South leading to substantial changes in areas such as land registry and civil registration, the digitisation of health records, education, and national security. The ecosystem of startups in the urban-tech and smart cities space is also growing at a fast pace, with more than $75 billion in venture capital investments globally from 2016 to 2018 (CityLab, 2018). This phenomenon increases the demand for suitable spaces and has stimulated discussions over the necessity to support incubation and acceleration spaces for startups or more in general of co-working spaces. In this specific context, two startups are leading the way in Europe and the USA for the management of co-working spaces management via blockchain. Primalbase [*https://primalbase.com/en/*] is developing a blockchain platform based on the Ethereum blockchain architecture to offer "decentralised" rental services. Meridio [*https://www.meridio.co*] is more generally working on a blockchain-based platform for real estate investments, aimed at offering a new concept of fractional property ownership (Knight Frank, 2019).

Despite the widespread interest in this new technology, the academic literature discussing implications of blockchain for smart cities, sharing economy and planning is still scarce. The available studies usually refer to the value of platform services and e-governance in smart cities (Offenhuber, 2019; Riggs and Gordon, 2017). Others refer to platform-based real estate management systems (Shaw, 2018), or to the way blockchain platforms could impact the development of smart cities by automating (via smart contracts), decentralising and making processes more transparent (using distributed ledgers) (Sun et al., 2016; Chinnasamy et al. 2021).

Our paper contributes to this discussion by presenting an actual proof-of-concept of a blockchain BMS for co-working spaces management. We are using the case of co-working spaces management as an example of the use of the technology that might lead to benefits for both the private and public sectors.

2.2 Co-working spaces: typologies and governance

The concept of sharing an office between different professionals to reduce rental costs is not entirely a new idea. Nonetheless, in the last decade, CWSs have progressively entered the debate over the changing dynamics of the labour and office markets, initially standing as an affordable reaction to crisis scenarios. This section reviews the initial trends and existing studies on the subject.

The literature has first looked at the sociological implications of CWSs, for freelancers looking for networking opportunities and escaping the alienation of remote working (Spinuzzi, 2012; Merkel, 2015). The most recurring orientation of such investigations looked at the network bonding and the social interactions, or knowledge spillovers fostered in such spaces (Brown, 2017; Schmidt et al., 2017). This strand of literature looked at CWSs as places where the same dynamics observed in clusters and the multiplier effects of agglomeration economies could be activated on a very small scale (Capdevila, 2015). CWSs became associated with the creative economy, often as a fundamental ingredient used by policy makers to promote planning and regeneration strategies in our cities (Moriset, 2014) and subsequently even in peripheral locations (Fuzi, 2015). Other established opinions initially identified CWSs as bottom-up affordable solutions to curb higher office costs especially at a time of crisis (Ferm, 2014).

As for the whole sharing economy movement, also the sharing of spaces and knowledge was induced by the general economic downturn. Studies on CWSs relate also to the changes in labour patterns characterised by an increased mobility of workers and freelancing, and the evolution of global entrepreneurial dynamics (Morandi et al., 2016). For this reason, CWSs are also increasingly an epitome of “social innovation” or “social entrepreneurialism” ideologies, fuelling studies on how those spaces could facilitate the creation of new activities at the local scale of neighbourhoods (Jamal, 2018; Mariotti et al., 2017; Van Holm, 2017). However, with the emergence on the market of real estate operators like WeWork, the perception of CWSs has shifted from being social and affordable amenities to commercial real estate products for profit. CWSs started also diversifying branching into different sub-typologies of spaces.

At this point, it is also worth briefly discussing the different arrays of CW spaces and possibilities available (Fiorentino, 2019). The most common types of CWSs only offer rental solutions for desks, meeting rooms, or a mix of individual small offices with different layout solutions, usually combined with a set of communal spaces and amenities (bar, cafés, cinemas, meeting points, etc.). In established urban markets with a large technology industry, like

London or New York, they have become an upcoming real estate product. Some of these spaces can be associated with programs for the incubation and/or acceleration of startups, offering connections to venture capitalists, investors, and/or large multinationals together with training, funding or institutional support to best shape business ideas. Finally, there is a more socially and bottom-up led category that includes also *maker-spaces*. These are spaces where technological machinery such as laser cutters and 3D printers can be shared to sustainably cut costs. These spaces have been featured in public spaces amenities - like libraries – for purposes of education and social integration.

The blurred boundaries between the different typologies imply a variety of managerial and structural solutions. Depending on the local socio-economic context and real estate trends, different cities can see the predominance of one typology or another. The lack of an ad hoc planning regulation has resulted in a mixture of both private and public ownership solutions either implemented for profit or as an institutional measure to support local entrepreneurship.

Research in different fields is debating around the future of this sector and on ways to develop bespoke regulations and solutions for each typology of shared working space. From a real estate perspective, studies point to the decline of traditional office spaces and increasing demand for flexible office spaces (CBRE, 2018; JLL, 2019). New horizontally integrated and sector-specific CWSs are also emerging, focussing for example on offering FinTech or environmental services. However, these new shared and flexible office solutions present new challenges to developers and landlords associated with the shorter duration of leases, the management of multiple tenants, and the risks of letting properties to startups that might vanish after a few months. International brands of CWS operators like WeWork and Regus have commercialised these managerial services for-profit.

On the other hand, more local and independent experiences, implemented as a social project, have used spaces (very often public ones) that had lost their initial function and brought them to a new use (Fiorentino, 2019). Cities like Detroit epitomise the attempt to bring derelict post-industrial premises to a new life as shared working spaces. In this case, the challenge pertains to the urban governance field and includes the regulation of leases, procurement contracts and private-public partnerships for the operation of spaces.

Beyond real estate matters, spaces where new ideas and prototypes are produced —like maker spaces, incubators and accelerators—also raise concerns on the intellectual property, the management of royalties and registration of goods and patents conceived within those spaces. Blockchain technology may offer a solution to all the above-mentioned managerial issues.

3. The blockchain ledger and management platform

In this section, we discuss the features of a distributed ledger or blockchain. This technology was conceived to remove intermediaries and central authorities in all operations of value or data transfers among peers (Ali et al., 2014). For example, the transfer of money is normally mediated by a bank, which keeps track, in a centralised way, of all exchanges taking place and updates its ledger and the connected accounts accordingly. Similarly, in the sharing economy scenario, a company, e.g., Airbnb, monitors all transactions between landlords and tenants, releases funds, and monitors accounts and data. The removal of intermediaries in a network of users and providers of a given service corresponds to moving from a *centralised* to a decentralised or *distributed* network. In the distributed network case, peers (or users) can directly communicate and transfer data without the need of a central trusted authority. Participants can perform different functions, from transaction validation to simple data storage and access to the platform.

The problem with distributed networks is to ensure that users – possibly distrusting each other—can safely exchange data and value. For instance, on internet-based engines for lettings users who wish to rent a house are in contact with unknown landlords. In the absence of an intermediary, the question is how they can be sure they are not engaging in a fraudulent transaction. To be protected from this kind of risk, a platform would need to have the following building blocks. Firstly, users need to connect via a *peer-to-peer (P2P) network*, facilitating the transfer of value and data, e.g., via computers connected over the internet. Secondly, a special ledger to record the transaction history is required; this is provided by the *distributed ledger technology (DLT)*. A DLT is a shared database, synchronised across multiple users (individuals or institutions) and countries, where exchanges of data or value are immutably stored. A notable example is the *blockchain*, a ledger where data and transaction history are stored in a *block* structure and *chained* together via cryptographic tools.

Cryptography ensures that, even in the absence of a central trusted authority, a malicious user would not be able to modify the transaction history. A set of cryptographic primitives is also used to authenticate transactions (e.g., digital signatures) or users (e.g., public-private keys, addresses), to build the ledger and reach an agreement on the transaction history. Cryptography is also at the core of the algorithms defining a common set of validation rules for transactions and the creation of the transaction history, the so-called *consensus mechanism.* By abiding by a pre-established set of rules, all users—and not only a central trusted authority—may contribute to the verification of the transactions.

Depending on the type of ledger, transactions may transfer value or tokens for accessing a service. In addition, also the so-called *smart contracts* can be deployed on a distributed ledger. Smart contracts are self-executing contracts, not requiring human third-party intervention. Clauses of a smart contract (similarly to a legal contract) are verified and executed according to a computer protocol in an automated way. An intuitive example could be the case of a landlord and tenant wishing to automate payments without the need of a third party: they may draft a smart contract enforcing the equivalent of standard tenancy agreement clauses. Specific programming languages exist to write, validate and automatically process smart contracts and transactions, e.g., Solidity for the well-known Ethereum smart contracts. Our implementation is written using the open-source language DAML. Those ingredients are essential to creating an environment that is open, immutable, and decentralised.

Distributed ledger's features may vary and may offer different levels of decentralisation or a different ledger's governance (e.g., data publicly available or with restricted access). In particular, these systems can be built as *permissionless* or *permissioned* platforms. Permissionless platforms store data in a publicly accessible format. Users are freely able to join the network by creating an address (or a pseudonym), submit transactions, and access the data stored on ledger. Typical examples of public blockchains are the Bitcoin and Ethereum ones. On permissioned platforms, instead, only authorised and endorsed users can access the ledger and submit transactions. This type of platform is more tailored to businesses, which might be concerned about sharing private information (Antonopoulos, 2014).

Our BMS is built on a *permissioned ledger*, which is more relevant for the sharing economy: only endorsed users can access the information stored on-chain. For instance, only landlords, local councils, and potential pre-vetted tenants—can perform actions, e.g., list an available space or submit tenancy applications.

3.1 Our prototype using DAML

In this section, we provide a high-level description of the *Digital Asset* platform used to build our prototype and test specific functionalities.

The smart contracts are developed in DAML, an open-source programming language, suitable for the implementation of complex business processes. Using DAML we can assign fine-grained permissions and different roles to users, distinguishing between parties who can only access the ledger data and parties actively performing actions (e.g., submit or sign transactions). Decentralised architectures, where all users can validate and submit transactions and have the same permissions, are also feasible.

The Digital Asset platform also provides an open-source interactive testing environment for the business logic, where multiple parties and transactions can be simulated and visualised.

In Figure 1, we show the platform architecture. The distributed ledger or *Global Synchronisation Layer* (GSL) stores encrypted information of the events (blocks or transactions recorded) while data are held in the so-called *Private Contracts Store* (PCS).

This configuration allows for controlling the data visibility on the platform, as participants can be selectively enabled to access information. Operators are entities managing the platform, e.g., validate transactions, while a party represents a simple user who can submit transactions and requests. In our context, operators are landlords and local councils who supervise operations and manage processes, while parties are companies wishing to rent a space.

In our example, a transaction initiated by P1 is checked through the DAML libraries for correctness and is subsequently sent to the operator. The operator checks that the new proposed state (e.g., changing the status of a tenancy from active to terminated) is valid and that it is referencing an existing contract (a new transaction may reference previously submitted contracts, e.g., a tenancy agreement renewal may reference a previous contract submitted by the same parties). If those checks are successfully completed, the contract is included in a new block, stored on the synchronisation layer, and forwarded to all parties.

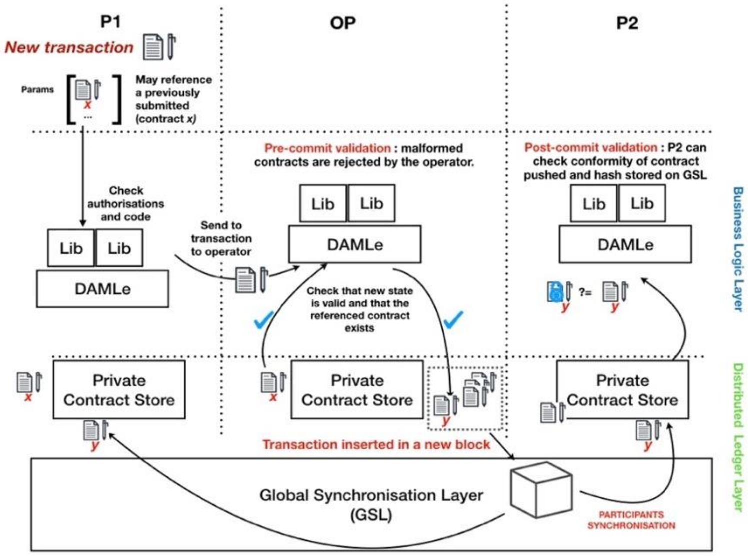

Figure 1 Digital Asset platform scheme of the architecture. Example of transaction submission on the ledger (GLS) by party P1 and synchronisation with P2. OP is a participant who can perform transaction validation.

By default, in DAML it is possible to create three pre-defined types of parties with different privileges: (i) *signatory,* (ii) *controller*, or (iii) *observer* parties. A signatory can propose an action, sign and submit contracts to the ledger. The controller is the counterparty, who can perform actions (e.g., accept or deny) on a proposal made by the signatory. Finally, the observer is a witness (e.g., regulator, auditor) with no controlling abilities, possessing only visibility and access to transactions and data.

Depending on the business process, we define so-called *templates* representing different types of contracts that will be stored on the ledger. For instance, a template could represent a tenancy application, which may contain data fields specifying tenancy length, name of tenant and landlord, or information about the space being rented. We can also specify different *actions* that the various parties can perform or oversee. For instance, a *create* action records the creation of a contract, e.g., reproducing a tenancy agreement compiled and signed by the interested parties. *Exercise* actions, instead, record an event where one or more parties have exercised a right on a contract (e.g., a landlord may have exercised an "extension to the tenancy agreement" or a tenant may have requested termination of a contract).

Finally, DAML has a built-in feature for testing functionalities of prototypes: we can build so-called *scenarios* specifying a series of actions performed by the parties, e.g., creating contracts and simulating a real-world business application. A well-compiled scenario generates a transaction graph, showing each event recorded on the ledger. Any modification to a contract is stored as a new contract, while the previous version is archived but will be still visible (as an *archived contract)* on the ledger: in this way, the full history of transactions and modifications will remain permanently stored and available on the platform.

3.2 Smart contracts for the management of CWSs

In this section, we describe the technical features of the smart contracts composing our BMS prototype. We include features that allow listings of CWSs, permanent and immutable recording of rent transactions on the distributed ledger.

We start by defining our business logic, i.e., the *templates* for the different types of contracts. We specify two main types of templates: (i) *CWspace* and (ii) *CWspaceApplication (see Supplementary Figure 2, Panel A)*. The first template corresponds to a CWS listing: it includes fields to specify features of the space (*description)*, price per month (and currency), square meters, and address. The template may refer to other contracts stored on the ledger. Landlords or managers can issue the contracts (they have signatory rights) and perform the following actions: (i) update the listing price, tenant or tenancy length, and (ii) remove the listing from the database. Depending on the specific business application, both the template data fields as well as functionalities can be easily extended or modified. *CWspaceApplication* represents an application made by a potential new tenant (listed as a party with signatory rights). In this template, we include a reference to a previously published CWS listing–from which we can retrieve all information about the space—and a reference to a contract transferring "cash" or digital tokens, as payment of the first month's rent as a standard practice for deposits.

Applicants can also add "special requests" to the manager of the space, indicating preferences, requesting to renegotiate the price, or asking for a shorter/longer tenancy. The digital token is defined as a separate template described in detail below. The manager of the space can act upon receiving a tenancy application by performing two actions, either accepting or denying the request. Denying the request simply archives the tenancy application contract submitted and returns the cash deposit submitted to the rejected applicant. Accepting the application has, instead, two consequences in our model: (i) the CWS listing is updated by changing the name of the tenant and assigning the space to the applicant and (ii) a percentage of the money paid as a deposit is *automatically* transferred to the local authority. In both examples, we assigned the local authority the role of observer, meaning that it has access to all data stored on the platform and can monitor transactions made by all parties (but cannot perform any action). The contract template is defined for a digital token, that we generically identified as cash, which may be issued by banks entering the network or other entities. Alternatively, via external exchanges fiat currency can be converted into a digital token specifically crafted to be exchanged for use of co-working space facilities (*see Supplementary Figure 2, Panel B)*.

The cash template defines a token in terms of its quantity, issuer and holder and specifies possible third parties acting as observers. Cash can, indeed, be transferred to a new holder, cash contracts can be split into multiple sub-contracts, combined into a single contract, or simply be de-issued.

3.3 Testing functionalities and simulating transactions.

Once we have defined contract templates and actions that can be performed by authorised parties, we can proceed with testing the platform functionalities in the *scenario* environment. We first list the participating entities in the BMS: in this example, we include two co-working space companies (e.g., "coworking_space1"), two startups (e.g., "Startup_1"), the local authority overseeing the operations, and a set of banks or entities issuing "cash" to be exchanged for services on the platform. We, then, let companies, landlords or managers of CWSs create the listing of their spaces, specifying –as mentioned above—features of the advertised space (e.g., private office, square meters, address, etc.).

In the testing, we assign some digital tokens to the startups. For the sake of this prototype, we introduce "banks" as entities that can issue tokens. Those tokens can be used by startups to pay for rent on the platform. We, then, simulate the case where some startups apply for one of the spaces listed on the ledger by submitting a tenancy application and transferring the deposit to the manager of the space.

In the application, a startup refers to a listing available on ledger and specifies their conditions, which will be either accepted or rejected by the CWS manager. In our example (Figure 3), "*Startup_1*" requests a shorter tenancy of 4 months instead of the originally advertised 12 months. After reviewing the application, the manager of space "*cw1*" decides to deny the request and refund the deposit to the startup (see Supplementary Figures 3, 4, and 5). A note is then added to the application specifying "Application Denied" and the associated contract is archived, i.e., it is marked as inactive on the ledger.

We also model a successful application submitted by "*Startup_2*" accepted by the manager of co-working space "*cw2*". Upon acceptance, two events are triggered (see Supplementary Figure 6): (i) the name of the tenant is changed in the listing with the applicant's name and (ii) part of the deposit is paid to the local authority. As a final example of our "scenario testing", we also included the case where the manager of one of the spaces listed, "*cw3*", submits a request (recorded on the ledger) to remove the listing. As a result, the contract associated with the listing is archived, and we will not be able to reference that space in successive tenancy applications.

In real-life implementations, the complexity of the underlying blockchain platform will be simplified by adding a user-friendly interface. Tenants, landlords and other users will have access to the platform as if they were using a standard website for letting and rental exchanges. Nonetheless, data and transaction will be stored "under the hood" on a tamper-proof immutable ledger. In the following sections, we summarise the main takeaways and the real estate policy implications.

4. Governance implications of blockchain management systems (BMS)

The sharing economy represents a form of decentralized marketplace where single users can contribute by offering a service. However, companies such as Airbnb or Uber, formally only providing a communication and exchange platform, control and centralise the system by acting as a trusted party. These tech unicorns control advertisements for the services and collect users' fees, in most cases without paying taxes to local authorities. This system creates issues of profit extraction and may fuel economic inequalities. A variety of regulatory attempts has been proposed (cf. Shabrina et al. 2021).

Centralising regulatory processes in the hands of local authorities may limit innovation, data availability and users' tracking capabilities. A regulated gradual integration of the sharing economy services in the wider offer of urban amenities would instead maximise their positive multiplier effects.

4.1 Widening participation and ensuring transparency.

There are several benefits arising from the use of a blockchain-based management system. First of all, all transactions can be tracked and accessed on the platform: the enhanced transparency and the availability of a digitalized shared database mean that information is accessible by all parties and relevant stakeholders. In the case of CWSs, landlords could directly manage their portfolio of properties, leases and tenancy agreements. Selected "super-users" can also participate in the platform enjoying full view-only privileges for all transactions: for example, local authorities could get access to tenants' records for fiscal or even security purposes.

The use of this system would also generate a significant cost reduction thanks to the elimination of intermediaries and the automation of the processes via the use of smart contracts. These contracts can embed use case-specific functionalities that can be as complex as needed. For example, when accepting a tenancy application, a percentage of the first month's rent or deposit could be automatically paid to the local authority on behalf of the space manager. This feature might be particularly relevant for public premises or publicly managed CWS or for tackling any additional fiscal issue like business rate collections.

Additional building blocks of the platform may include a rating system associated with rental transactions and a system for automated rent payments. Both features may be implemented by extending the functionalities encoded and the type of contracts stored on the platform. In cases like short-term lettings, the local authority would become able to track the number of days during which a property or a room is rented on platforms like Airbnb, together with the number of occupiers, and to automatically issue fines or collect tourist taxes.

The possibility to oversee transactions and actively manage functions like tax collections and data storage offered by BMSs to local authorities represents an incremental step in the smart city trajectory and substantial bureaucratic innovation. Local authorities would take a more active role in tracking goods and services generated by the platform economy. BMSs reduce the number of intermediaries while contributing to the simplification of certain contractual and procurement procedures (see figure 2). This simplification would lead to improved management of CWSs, run directly or procured by local public authorities and acting effectively as a social infrastructure. Finally, by tracking a wider variety of data local authorities may be able to introduce rent-caps for both affordable workspaces and short-term lettings.

4.2 Smart contracts: new data capabilities and possibilities for tax management.

A common issue arising from the presence of different types of users (e.g., local authorities, tenants, managers, etc.) and processes to be monitored (e.g., tax collections, rent payments, etc.) is the fragmentation of information over various – often incompatible – platforms. Our BMS also increases system interoperability, i.e., different actors would rely on the *same* shared transaction history and data. Moreover, ledgers can be easily linked to other applications, for example via a suitably built API (Application Programming Interface). In our context, an API is a piece of code allowing access to data stored on ledger and it could be created to allow external users (non-members of the platform) and third parties to access data stored on the platform for auditing purposes. For instance, a landlord could give access to its rent registry to the government for tax collection. All information about users' listings, space operators, available and occupied spaces, and tax payments will be immutably stored on one *unique* ledger, reducing costs for multiple duplicated databases of different service providers and data reconciliation (i.e., consistency checks for data across multiple sources).

All network participants will have a synchronised shared view of the "state of the world" and history of transactions. This system would generate a continuous stream of data that could be used for research purposes or to compile public registries. In this context, a shared transaction record could be used not only for bookkeeping of transactions but also for accounting with additional financial control functionalities (Ibañez et al., 2021). A real estate application would be selling suitably anonymised data to third parties to produce statistical analysis and reports on general market trends, transaction costs, rental market trends, and property valuations.

Integrating these data into larger real estate database that spans from property values and features to urban governance and land registry data is a crucial step for the technological development of the sector (Treleaven et al, 2021).

Privacy issues can be sorted by adding ID management functionalities to the BMS, whereby the users wishing to access the platform are endorsed upon ID verification.[2] Using our BMS all rental transactions, tenancy applications and property listings are stored on a unified, accessible and transparent ledger, while all actors involved (users, local authorities and property developers) can have different access levels to the platform.

The use of BMS for planning governance purposes and targeting the public sector would require that local planning authorities initiate the process and integrate BMSs into their services. Local authorities can procure/delegate the initial set-up and software development work to an intermediary such as a consultancy or - coherently with the purpose of reducing intermediaries - develop it in house. Local authorities may also coordinate to create consortia pulling resources together to develop a shared infrastructure. Other possible applications for BMS in the public sector include innovating and digitalising land registry systems or any other governance service for smart cities requiring matching data from different sources. Further research is called in the future to develop new implementation tools.

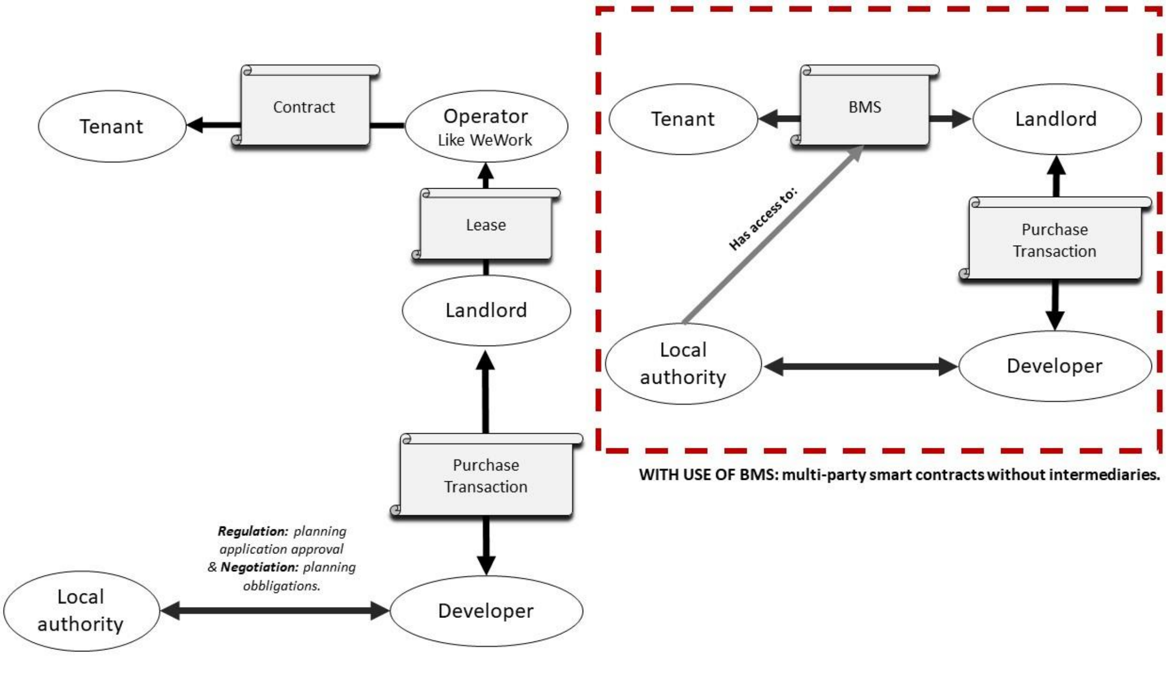

Figure 2 – Use of BMS in multi-tenant leases and platform-based short-term lettings of working spaces or of flats. The first case on the left shows the current relational situation without the use of BMS. The diagram on the right shows the situation when implementing BMS contracts. In this case, the developer can retain ownership, hence covering also the role of the landlord and further simplifying the governance processes. In the first scenario, local authorities cannot actively monitor the operations once the planning permission is granted, and the development is delivered. In the second case, the local authority

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2 Note that in permissioned blockchain platforms the identities of the participants are disclosed, while in public blockchains (e.g., Bitcoin) users normally transact from pseudonymous addresses and their real identities remain concealed.

is able through the BMS to oversee transactions and data, as well as to perform specific tasks and obtain permissions within the BMS framework.

5. Take away for practice

The sharing economy has emerged as a form of disruptive innovation highlighting a series of "regulatory voids" left out by "outdated policy frameworks" (Babb et al., 2018:1). In particular, throughout the paper we have shown that BMSs allow for a reconciliation of the new possibilities offered by platform-based services with a more efficient use of local resources.

For local authorities, the adoption of BMS would imply the integration of new professional figures: planning officers with knowledge of the blockchain technology that would oversee the validation of transactions and issuance of contracts. At an initial stage, this would also mean facing costs like design and development of the new BMS infrastructure, training for existing officers, and recruitment of new skilled staff. Nevertheless, the process would create new employment opportunities, resulting in the longer-term modernisation of LAs, which is part of any natural generational turnover. Moreover, the cost of the new hires would be optimised by the possibilities of an easier and more direct collection of taxes (both tourist taxes for short-term letting or business rates in the case of coworking spaces). In the case of publicly subsidised shared working spaces or other similar local amenities (such as maker spaces), BMS would represent an innovative tool to manage the conditions required by the shorter leases or the procurement contracts to operate the spaces.

Data concerning details of transactions and contracts are stored in a secure and unalterable system but at the same time easily accessible by stakeholders. BMSs will indeed allow for the creation of a wider ledger-based database of information that can be unified among the private sector stakeholders (e.g., tenants, winners of procurement bids or even sharing economy platforms) and public sector participants (e.g., local authorities or tax collection governmental bodies). Each party would only access data pertinent to their functions, interests and predefined permissions. All parties will in fact define the type of access while signing the contract (see Figure 2). This would allow monitoring the firms registered within CWSs or the number of people accessing the working spaces daily. Moreover, it would be possible to track the services used and to easily calculate both the income produced locally and the CWSs' impact. In the case of short-term lettings, BMSs will allow monitoring the number of nights flats are rented out for, as well as the number and identity of customers. This will improve regulatory, tax and security-related issues.

The possibility of building a platform-based record that is immutable will also allow for an improved and comprehensive tracking and monitoring of the socio-economic development of urban areas, to produce long-term forecasts supporting the next generation of evidence-based planning and policy regulation tools for smart cities.

In the specific context of *maker spaces* or startup incubators, the additional possibility of registering patents and intellectual properties in a more straightforward and transparent fashion will allow for a more holistic approach to innovation creation. The participation of multinational corporations in incubation programs will be encouraged by this improved traceability. At the same time, this will allow for a certain degree of inclusivity for vulnerable groups of the labour pool, fostering a fairer and stronger local economy.

Finally, for the property development industry, the adoption of a BMS implies changes in the typical contractual dynamics between landlords and property operators. Developers might more easily adopt the *developer-to-operate* model. The use of BMS would cut costs of the operators while reducing the risks of dealing with a large number of tenants and short leases, by only hiring some dedicated ledger validators (see Figure 2).

In summary, this platform-based approach and the automation of processes via smart contracts encourage the cooperation between individuals and authorities, simplifying processes, reducing costs, and increasing monitoring capabilities of urban processes. In this sense, the blockchain management system that we presented can be used in combination with other technologies (e.g., 5G; Internet of Things (IoT), etc.), to create main infrastructure of the smart city or the so-called *digital twin city* (Deng et al., 2021; Yitmen & Alizadehsalehi, 2021; Bagloee et al., 2021).

6. Conclusions

In this paper, we discussed some of the long-standing issues in the sharing economy impacting urban planning and real estate. We show how a solution could be offered by a suitably designed platform to effectively manage shared resources and limit the need for intermediaries. BMSs are surely not the cure for tech giants' monopolies but they are a new governance solution that might allow greater control from local authorities and tax offices. Further research could certainly foster a rapid digitalisation and modernisation of the bureaucracy and public service practices.

We have developed a working prototype of a BMS to manage tenancy applications for a CWS, envisioning that in the future shared workspaces could also become part of the local offering of public amenities supported by the local public authorities. In our BMS, endorsed tenants and landlords can interact over a decentralised blockchain platform, where all rent transactions are immutably recorded. Moreover, using smart contracts, taxes can be automatically paid to local authorities by tenants and landlords. BMSs would facilitate a substantial reduction of costs through the elimination of intermediaries and the full automation of processes. The increased transparency offered by the shared ledger between stakeholders, would on one hand reduce the risk of fraudulent behaviour while at the same time facilitating tax auditing processes. The flexibility of BMSs allows for tailored customisation of features based on the specific use cases and applications in planning.

Our BMS prototype also demonstrated how the public sector can become more involved in sharing economy services. This encourages the possibility of delivering shared workspaces as a new form of locally provided social infrastructure. Especially in the recovery from the current pandemic, we are expecting changes in the commercial real estate market with rising levels of agile and remote working patterns. A considerable challenge will be offered by the transformation of vacant properties. All suggests the need for local workspace hubs, with BMS offering a flexible and transparent tool for the management of spaces repurposed for shared uses.

Features of BMSs can be assessed on a case-by-case basis. For example, in cities like London, SMEs are penalised by high rental costs but the demand for spaces, employment opportunities, and the flow of investments are all substantial. In more peripheral locations, the focus is instead on the need to foster employment, uplift local skills or invert the vacancy rate of old and no longer fit for purpose industrial and commercial premises. Governance tools need to be tailored and are currently inadequate for the task. Local authorities struggle as they lack the skills and tools to manage the spaces or partner with private operators. BMSs would instead offer the possibility of extracting social value from currently capital-intensive activities within the sharing economy.

This initial investigation lays the foundations for further debates aimed at assessing the risks and benefits of BMSs for planning purposes. We have focused on the case of CWSs and the sharing economy to show one of the possible applications of blockchain technologies to planning regulations, although similar prototypes can be developed for other public policy purposes. One may devise solutions for other types of platform-economy issues, such as the management of short-term lettings and Airbnb regulation (i.e., introduction of rent caps, new tax collection measures, flexible lease contracts and easier access to data for public officers). Other applications may include managing the wider management of real estate portfolios, leases and transactions and updating the bureaucracy via digitalized datasets for land use registry and planning applications.

In the nearest future, the use of BMSs could represent a valuable opportunity for the public sector to rethink and innovate traditional governance tools, allowing for a more transparent, simplified and less costly data management system, while taking smart cities to the next level of technological sophistication.

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Appendix

Supplementary Figures

A

```
daml 1.2 module Main.CWspace where
import Main.DataTypes
import Main.Cash

template CWspace
    with
        price: Decimal
        currency: Currency
        manager: Party
        tenant: Party
        loc_aut: Party
        address: Text
        tenancy_length: Decimal
        square_meters: Decimal
        description: Text

    where
     signatory manager
     observer loc_aut

     controller manager can
        UpdateListing: (
            ContractId CWspace
            )
            with
                newTenant : Party
                newPrice: Decimal
                newtenancy_length : Decimal
            do
                create this with
                    tenant=newTenant
                    price=newPrice
                    tenancy_length = newtenancy_length

        RemoveListing: ()
            do
                assert(
                    manager == tenant
                    )
                return()

template CWspaceApplication
    with
        applicant: Party
        manager: Party
        loc_aut: Party
        onemonth_rent: ContractId Cash
        space: ContractId CWspace
        tenancy_length: Decimal
        notes: Text
    where
    signatory applicant
    observer loc_aut

    controller manager can
        UpdateApplication: (ContractId CWspaceApplication)
            with
                newnotes:Text
            do create this with
                notes = newnotes

        DenyRequest: ()
            do
                money<-fetch onemonth_rent
                returnCash <- do
                    exercise onemonth_rent Transfer with
                        newHolder = applicant
                return()

        AcceptRequest: (
                ContractId CWspace
            )
            do
                cash <- fetch onemonth_rent
                location <- fetch space
                assert(
                    cash.holder==manager
                    &&cash.amount==location.price
                    )
                exercise onemonth_rent Split with
                    newHolder=loc_aut
                    splitAmount= 8.0*cash.amount/100.0
                exercise space UpdateListing with
                    newTenant = applicant
                    newPrice = cash.amount
                    newtenancy_length = tenancy_length
```

B

```
daml 1.2 module Main.Cash where
import Main.DataTypes

template Cash
    with
        amount: Decimal
        currency: Currency
        issuer: Party
        holder: Party
        regulator: Party
        observers: [Party]
    where
        signatory issuer
        observer regulator, observers

        ensure(
            amount>=0.0
            )
        controller holder can
            AddObserver: (
                ContractId Cash
                )
                with
                    newObserver: Party
                do
                    create this with
                        observers= newObserver :: observers
            Transfer: (
                ContractId Cash
                )
                with
                    newHolder: Party
                do
                    create this with
                        holder=newHolder

            Net: (
                    ContractId Cash
                )
                with
                    otherCash: [ContractId Cash]
                 do
                    let
                        sumCash
                            (acc: Update(Decimal))
                            (cash: ContractId Cash)
                            =
                            do
                                total <- acc
                                oc <- fetch cash

                                assert(
                                        oc.holder == holder
                                        && oc.currency == currency
                                        && oc.issuer == issuer
                                        && oc.regulator ==regulator
                                    )

                                trans <- do
                                    exercise cash Transfer with
                                        newHolder = issuer
                                  do
                                    exercise trans DeIssue

                                return(total + oc.amount)
                    total <- foldl sumCash(return 0.0) otherCash
                    create this with
                        amount=(amount + total)
            Split : (
                    ContractId Cash, ContractId Cash
                )
                with
                    splitAmount: Decimal
                    newHolder: Party
                do
                    assert(
                            splitAmount<=amount
                        )
                    give <- create this with
                        amount=splitAmount
                        holder=newHolder

                    keep <- create this with
                        amount=(amount-splitAmount)

                    return(give, keep)

        controller issuer can
            DeIssue : ()
                do
                    assert (
                            holder == issuer
                        )
                    return()
```

Supp Fig 2 - Panel A: Templates for contracts associated to co-working spaces: two main types of templates are specified: (i) CWspace and (ii) CWspaceApplication. Panel B: Templates for contracts associated to cash/tokens exchanges or CWspace Application.

```
daml 1.2 module CWtest2 where
import Main.Cash
import Main.CWspace
import Main.DataTypes


Scenario results
cWtest = scenario do
--Define parties
loc_aut <- getParty "Local_Authority"
cws1<- getParty "CoWorking_Space1"
cws2<- getParty "CoWorking_Space2"
st1<- getParty "Startup_1"
st2<- getParty "Startup_2"
bk1 <- getParty "Bank_1"
bk2 <- getParty "Bank_2"
reg <- getParty "Regulator"

let
-- Define currency and address of CWSs
    currency = GBP
    address1 = "Address_1"
    address2 = "Address_2"
    address3 = "Address_3"

--Create CWSs listing
cw1 <- submit cws1 do
    create CWspace with
        price = 2600.0
        currency
        manager = cws1
        tenant = cws1
        loc_aut
        address=address1
        tenancy_length = 6.0
        square_meters= 30.0
        description = "Private Office, 3 people"
cw2 <- submit cws2 do
    create CWspace with
        price = 5000.0
        currency
        manager = cws2
        tenant = cws2
        loc_aut
        address=address2
        tenancy_length = 12.0
        square_meters= 70.0
        description = "10 x hot desks"
cw3 <- submit cws2 do
    create CWspace with
        price = 5000.0
        currency
        manager = cws2
        tenant = cws2
        loc_aut
        address=address3
        tenancy_length = 12.0
        square_meters= 95.0
        description = "2 x meeting rooms"
```

Part 1

```
-- Startups exchange fiat for tokens via banks and exchanges
st1Cash <- submit bk1 do
    create Cash with
        amount= 70000.0
        currency
        holder = st1
        issuer= bk1
        regulator=reg
        observers=[]
st2Cash <- submit bk2 do
    create Cash with
        amount= 100000.0
        currency
        holder = st2
        issuer= bk2
        regulator=reg
        observers=[]
 -- st1 applies for cws1 and sends 1month rent
(onemonth1,st1Cash2) <- submit st1 do
    exercise st1Cash Split with
        newHolder = cws1
        splitAmount= 2600.0
st1App<- submit st1 do
    create CWspaceApplication with
        applicant = st1
        manager = cws1
        loc_aut
        onemonth_rent = onemonth1
        space =  cw1
        tenancy_length= 4.0
        notes= "Shorter tenancy length, 4 month"
--request denied and refund of deposit
st1Tenancy<- submit cws1 do
    exercise st1App UpdateApplication with
        newnotes = "Application denied"
st1TenancyDeny<-submit cws1 do
        exercise st1Tenancy DenyRequest
--st2 applies for cws1 and sends 1 month rent
(onemonth2,st2Cash2) <- submit st2 do
    exercise st2Cash Split with
        newHolder = cws2
        splitAmount= 5000.0
st2App<- submit st2 do
    create CWspaceApplication with
        applicant = st2
        manager = cws2
        loc_aut
        onemonth_rent = onemonth2
        space =  cw2
        tenancy_length= 18.0
        notes= "Longer tenancy, 18 month"
--st2 application is accepted and listing is updated
st2AppAccept <- submit cws2 do
    exercise st2App AcceptRequest
--cws2 remove cw3 from the listing
cw2remove <- submit cws2 do
    exercise cw3 RemoveListing
return()
```

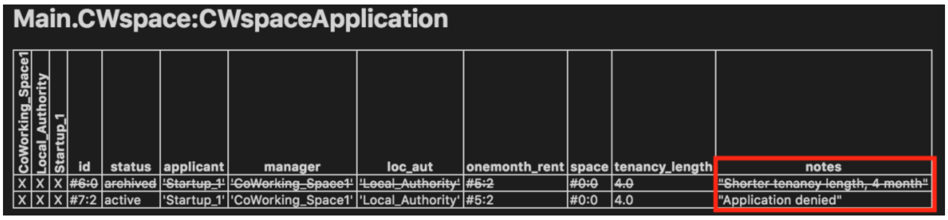
Part 2

Supp Fig 3 - The scenario testing, where we simulate users submitting requests, transactions and contracts to the ledger. In the application, a startup refers to a listing available on ledger and specifies their conditions, which will be either accepted or rejected by the CWS manager. In our example (Figure 3), Startup_1 requests a shorter tenancy of 4 months instead of the originally advertised 12 months.

Main.CWspace:CWspace

CoWorking_Space1	CoWorking_Space2	Local_Authority	id	status	price	currency	manager	tenant	loc_aut	address	tenancy_length	square_meters	description
X	-	X	#0:0	active	2600.0	Main.DataTypes:Currency:GBP {}	'CoWorking_Space1'	'CoWorking_Space1'	'Local_Authority'	"Address_1"	6.0	30.0	"Private Office, 3 people"
-	X	X	#1:0	active	5000.0	Main.DataTypes:Currency:GBP {}	'CoWorking_Space2'	'CoWorking_Space2'	'Local_Authority'	"Address_2"	12.0	70.0	"10 x hot desks"
-	X	X	#2:0	active	5000.0	Main.DataTypes:Currency:GBP {}	'CoWorking_Space2'	'CoWorking_Space2'	'Local_Authority'	"Address_3"	12.0	95.0	"2 x meeting rooms"

Supp Fig 4 - View of spaces listing as recorded on ledger. Available spaces are listed as they would appear on a users' interface or on ledger, indicating which parties have visibility on ledger of those contracts. In this context the local authority has access to all information about the listings.



Main.CWspace:CWspaceApplication

CoWorking_Space1	Local_Authority	Startup_1	id	status	applicant	manager	loc_aut	onemonth_rent	space	tenancy_length	notes
X	X	X	~~#6:0~~	~~archived~~	~~'Startup_1'~~	~~'CoWorking_Space1'~~	~~'Local_Authority'~~	~~#5:2~~	~~#0:0~~	~~4.0~~	~~"Shorter tenancy length, 4 month"~~
X	X	X	#7:2	active	'Startup_1'	'CoWorking_Space1'	'Local_Authority'	#5:2	#0:0	4.0	"Application denied"

Supp Fig 5 - Example of tenancy application denied by CWS manager.

Supp Fig 6 - Summary of contracts stored on ledger of a tenancy application submitted by "Startup_2" , accepted by the manager of "cw2"and the transfer of taxes paid to the local authority.