Blockchain for architects

28 Word Abstract
Cryptocurrencies, blockchain technology and other aspects of the sharing economy offer practical benefits and challenges for architecture. They also furnish interesting metaphors about urban living.

Blockchain for architects: Challenges from the sharing economy

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Economic systems and their attendant technologies change at a rapid rate and inevitably influence urban environments.[1] Digital innovations and their social consequences are likely to become a feature of the next 25 years for architecture. Such changes are already evident in the concept of the sharing economy.

The sharing economy aims to democratise commerce and to challenge dominant highly corporatized methods of exchange. In his book on the subject, Arun Sundararajan maintains that commerce is shifting "away from traditional corporations and toward a crowd of entrepreneurs we find through a digital marketplace."[2] Though the reality and benefits of such initiatives are under challenge, we maintain here that such approaches encourage interesting ways of looking at architecture and urbanism, not least through the metaphors they invoke.

Within the constellation of these putatively new business models Sundararajan places Airbnb (airbnb.co.uk), a platform that allows individuals to capitalise on their own under-utilised domestic space. At least in its conception, Airbnb provided a platform to put people in touch with one another to share and monetize private accommodation. More localised services such as Lyft (lyft.com) in San Francisco provide platforms for private car owners to offer rides to trusted passengers registered on the system. Kickstarter (kickstarter.com) provides a method for peer-to-peer funding arrangements for start-ups and would-be entrepreneurs. Fiverr (fiverr.com) puts freelancers and potential clients in touch with one another. At the apex of this assembly of new, shared, Internet-based entrepreneurial projects, lies the idea of digital currency. Though they do not depend on it, the shared services described above are emboldened by the success of peer-to-peer digital money transactions. Digital currencies deploy several algorithmic techniques to exchange money and goods privately and securely with someone else while ostensibly avoiding either banks or cash. As an indication

of their growing importance, such currencies are now listed on futures exchanges.[3] The technology deployed goes by the name of the "blockchain," which we will describe further on in this article.

Digital cooperatives

The sharing economy continues the tradition of grass roots cooperatives. Architecture has a long tradition supporting cooperative and community-based building projects, along with activism in various guises.[4] Some cooperative arrangements grow into fully fledged companies with far reaching networks. The shared digital economy arguably amplifies, extends and accelerates the creation of such innovations, which in turn impact on the city. Sundararajan thinks it is significant that this sharing can now take place not just between people who know each other, but amongst *strangers*. The sharing economy extends and reconfigures relationships of trust. Such sharing initiatives act as a foil against some aspects of urban living that speak of increased state and corporate control, centralisation and regularisation in the digital age. Think of mass surveillance, the power of financial institutions, mass media, and the ways IT companies now wield unprecedented influence over people's social interactions. Whatever their successes, the sharing economy pits itself against the forces of such centralised control.

The strong claim of the sharing economy is that it will affect every area of commerce in some way or other. Professional and social media peer-to-peer platforms support freelanced architectural service providers, and the purchase or exchange of assets across the construction sector. As well as products and materials, there is the possibility of exchanging intellectual property, such as designs, specifications, processes, and CAD and BIM library elements.[5] Commentators refer to the potential of peer-to-peer real estate procurement, especially in light of "smart contract" algorithms coded into transactions.[6] Secure peer-to-peer money transactions can also include bits of computer code that become active when certain conditions of a transaction are met. Ideas about the sharing economy also feed into the so-called smart city.[7]

Though ostensibly counter to their centralised mode of working, banks and other financial institutions are investing in the sharing economy. They may seek to adopt some of the benefits of peer-to-peer transactions into their own business practices, provide shared platforms that support their customer communities, or they may want to investigate how alternative business models threaten their own centralised operations. In any case, the sharing economy poses challenges that affect every area of business, not least in the areas of quality control, security, and accountability.

Blockchains

Blockchain is the name given to the technology that supports Bitcoin, Ethereum and other digital currencies. How can you transfer money to someone over the Internet without organising the transaction through a financial institution? Apart from cash, one means to secure the value of a transaction is to record each transaction on a digital ledger. But instead of keeping the ledger with a bank, it is copied to everyone who has signed up to the bitcoin network. People are prevented from hacking (i.e. altering) the shared transaction ledger by means of cryptography.[8]

In a blockchain, collections of time-stamped transactions are authenticated, secured and locked down when one of the computers on the network manages to solve an encryption puzzle derived from that block of transactions.[9] Computers on the network compete to solve the puzzle. The winning solution looks like an arbitrary string of characters and gets encoded into the block. Any would-be hacker would have to expend an inordinate amount of CPU time, at great cost, to break the code and get into the block to change any of its transactions. The owner of the computer on the network that first comes up with the solution to the cryptographic puzzle is rewarded with some bitcoin. Individuals and companies that dedicate CPU time to securing the blocks are called "miners," as they are given currency as a reward for their role in keeping the currency secure. They effectively generate money. There are costs of course, to individuals, companies and the environment, not least the high cost of duplicating a ledger across nodes on a globally distributed network, and the intensive CPU effort required to secure the data.

Smart contracts

Blockchain technologies support peer-to-peer monetary transactions, where lines in a shared ledger indicate payer, payee, date, amount and the goods or services to be exchanged: as is the case in a line in a bank statement. But, instead of a text line simply indexing the product being exchanged, that line can also include a piece of computer code that implements an action in response to some trigger event. The Ethereum blockchain platform (ethereum.org) supports the idea of transactions as code. An Ethereum ledger line can contain a "smart contract," an active piece of computer code that carries out some actions as part of a blockchain transaction. The signatories to the contract are anonymous, but the code, i.e. contract (or parts of it), can be seen by anyone on the public ledger. The fact that parties have entered into an agreement is visible and supposedly keeps them honest.

Possible code triggers include: approval of the transaction by the blockchain; the money transaction is completed; a certain amount of time has elapsed or a date reached; time passed; the goods are at the optimal price for the purchaser; an item to be purchased is of a particular (approved) type (e.g. you can spend this bitcoin on building materials but not labour); or the item in the transaction has been resold. Possible actions from these triggers

include: the code prevents or enables certain transactions, funds received now get distributed to other parties, the supplier awards a refund, imposes a fee or fine, sends an email, or issues a private key that unlocks some data or service (e.g. entry to a building, the heating comes on, you can open the service hatch). Sundararajan summarises the smart contract idea:

> *"the smart contract protocol can specify, as computer code, terms under which certain obligations are fulfilled, and can execute actions like sending a payment or deactivating a file once there is evidence of the contract's terms being fulfilled. … the risks associated with peer-to-peer contracting can be reduced by the introduction of three new provisions: autonomy, self-sufficiency, and decentralization."*[10]

He explains that smart contracts are autonomous in that the contract signatories need never make contact again. Self-sufficiency refers to the idea that the digital contract has access to its own resources, as it is "self-executing." As for other aspects of the shared economy, such digital contracts are decentralised, i.e. distributed across network nodes.

Anything that applies to contracts applies to architectural and building contracts of course. Imagine a series of contract variations in a blockchain. A smart contract item can also be used to describe and visualise a parameterised building component (e.g. door, wall, staircase), with attendant actions, constraints and rules for use. The code in the contract could also indicate how agents can deploy, exchange, copy, reproduce or dispose of such digital assets. If you wish to pass a copy of a digital asset you have acquired on to someone else then the asset's contract code may unlock various asset functions on transfer of a royalty payment to the originator.

Blockchain city challenges

The sharing economy comes under criticism from various quarters, not least in reports of unfair employment practices in the case of Uber drivers and distortions to property markets as a result of Airbnb lets.[11] Automated contracts also pose challenges. Are contracts like computer code? Try as we might to be exact, contracts are ambiguous, contingent objects that fit particular situations. The automation of a complex contract implies that the contract code must account for every eventuality in the domain of application. Furthermore, peer-to-peer contracts will have to draw on expertise, or at least conform to contract templates put together by expert practitioners.

Digital currencies, as part of the sharing economy, ostensibly enable peer-to-peer exchange independent of centralised control hierarchies. They carry the benefits and vices of cash economies. As with black and grey economies, you can exchange digital money for goods and services without being traced, or having to declare income to the tax department. Increasingly centralised trading exchanges such as Coinbase and Jaxx, and Bitcoin's new

status as a pseudo-commodity are drawing such transactions into the realm of mainstream audits.[12]

Digital money is becoming corporatized. The authors' bitcoin wallets are connected to a network node or hub in Luxembourg. Though there are small, independent miners, Bitcoin mining is dominated by big companies with huge CPU farms, many of which are located in China.[13] Where large profits are involved, successful small enterprises and initiatives eventually succumb to the pressures of scale. Large firms take over small, independent enterprises, or small firms may grow to become big monopolistic organisations. The US technology company NVIDIA seems set to dominate cryptocurrency mining platforms with its enterprise grade GPUs (graphics cards).[14]

Criticism of the sharing economy are well aired in the press and the academic literature. According to critic Tom Slee, many people mistakenly believe that

> *"By taking part in the Sharing Economy we help to build our community instead of being passive and materialist consumers; we help to create a new era of openness, in which we can find a welcome and a helping hand wherever we go. The Sharing Economy promises to help previously powerless individuals take more control of their lives by becoming 'micro-entrepreneurs'."*[15]

According to Slee, many expect the sharing economy to introduce flexible ways of working, to bring people together, encourage trust amongst strangers, and to counter the hegemony of hotel chains, fast food outlets, banks and financial institutions. Perhaps sharing economies soak up unused resources and are more sustainable. Of course, the idea of the sharing economy is sustained by the Internet and its long-standing egalitarian visions.[16] As for so many idealistic claims of the digital age, such benefits are rarely realised, or at least are not available to everyone.[17]

There are fascinating political, legal, social, privacy and ethical issues surrounding the aims of digital money. The idea of decentralised commerce sounds suitably liberal and democratic. But by some readings, it also harbours an undercurrent of right-wing, anti-establishment, self-reliance, and mistrust of the state. For David Golumbia, digital currencies "emerge from the profoundly ideological and overtly conspiratorial anti-Central Bank rhetoric propagated by the extremist right in the U.S."[18] So, digital money is arguably money for anti-establishment "preppers" suspicious of the "deep state," and other targets of alt-right opprobrium.

There are challenges from the sharing economy even without the effects of digital money. Think also of the apparently unregulated and unfair practices surrounding Uber, the global car hire firm that designates its drivers as self-employed. Once subscribed, you book a car and driver via your smartphone. You track your nearest available ride on the Uber map. Drivers registered with Uber are semi-independent and free to work when they like

and upon request — but without a guaranteed wage, holiday pay and other rights. In some cities, Uber drivers also outcompete local highly regulated taxi services, further disrupting local practices and regulations.

As a different kind of sharing service, with Airbnb you can rent out a room, or a whole flat, to strangers for any period, and independently of how the local area is zoned, and what the neighbours think of living next door to an ersatz hotel. Press reports focus on how a sense of local community gets destroyed as properties in highly desirable neighbourhoods are handed over to short term tenants. There are also stories about owners who find their homes damaged by Airbnb tenants, with little chance of compensation. Developers also buy up properties with a view to leasing them out via Airbnb. Initiatives that start out as enablers for small scale, local, micro-entrepreneurs often end up in the hands of large businesses.

The darkest side of this sharing narrative is that consumers and the short-term contracted labour force are fed the idea that they are participating in a new democratised economic order. The sharing economy is just part of a sales pitch, and a way of dressing up questionable business practices. Having set up the idealised narrative of sharing it is fairly easy for any critic to show how far short the industry around the ideal falls short. Perhaps the idea is misnamed. Call it "the gig economy" (a temporary job with prospects analogous to a musician's one-night stand) rather than "the sharing economy." At best, the sharing economy entails a raft of technologies and business practices that disrupt some of the usual ways of thinking about work, service, and the economy. It buoys up some existing urban metaphors and introduces new ones, to be expanded in the rest of this article.

New urban metaphors

Computing brings metaphors to bear on how we think of cities — as flows of data, networks, circuits, grids and an "Internet of things," as if cities are made up of bits, memories (RAM), sensors, actuators, and with communication systems, inputs, outputs and operating systems. The metaphor of the blockchain is potent. It provides analogues with city living, not least as we think of the data intensive "smart city," the overlay of integrated and responsive digital infrastructures that draw on big data streams from mobile apps, sensor networks, social media feeds and transport information, to make buildings and transport systems more responsive to changing conditions. So far, policy makers assume such infrastructures will operate in a highly-centralised manner. Blockchain technology supports the potential for an alternative, localised, grassroots, and democratic dimension to the smart city. Cryptocurrencies built on blockchain platforms are arguably a response to failing economic systems in cities. After all, much of the narrative force of bitcoin derives from its appropriation by black and grey market traders in

cities, particularly in those parts that are failing, or at least that operate under the radar. Such tactics contribute to survival in some cities.

Cities and their inhabitants undergo constant reconfiguration under the sway of changes in communications media and technology, as well as social and political change. Cities are in flux, subject to plays of power between antagonistic forces. It has always been so, except that the pace of change varies now and again. Inner city residents have not yet caught up with the social and financial implications of short term and opportunistic peer-to-peer property rentals, facilitated by Airbnb for example.

The idea of the sharing economy borrows from what cities do anyway. Cities are made up of families, communities, neighbourhoods that have been described by some as societies of the gift,[19] a sentiment that spills over into online sharing.[20] Metaphors derived from the sharing economy promote the idea of the city as a "community of strangers."

Applied to public housing, the metaphor of decentralised and distributed ledgers draws attention to the financial instruments at play: the open market, privatization of central government resources, financing and investment, tax credits, tax avoidance and other monetary incentives similar to the enterprise logic of Uber and Airbnb. As the scope for blockchain technology expands to land registries,[21] some think that decentralization has the potential to increase diversity of housing types.[22]

The introduction of blockchain processes also add weight to the geological metaphor of stratification. In a blockchain, data gets layered in a time ordered sequence. The oldest is the deepest, with layers of data cemented by computationally byzantine verification procedures. Cities are like that in some respects. As well as physical stratification, people talk about cities as layers and accretions of memories, some of which are inscribed in the fabric of a place. We like to peel back the layers and watch translucent layers interact as they get scoured and replaced, as in a palimpsest. But, at the same time some like to think of a city's memory strata as immutable. Try as they might, those who would like to hack the past find resistance from the accretion of embedded layers. Blockchain transactions become even more secure as time passes. Encrypted transaction blocks incorporate the encrypted hash of the previous block, making it virtually impossible to make alterations without unpicking the whole ledger. Encrypted hash strings remind us that you cannot backtrack the history of a place. You cannot change the past, some say.

Technically, blockchains deploy a form of *Merkle* tree: chaining data together through hashing. A hash is a near unique signature of a document. The file can be of any length, but its hash may be just 64 characters long. The clever aspect of this cryptographic technique is that a small alteration to the original document will result in an observable change in the sequence of characters in the hash. That's one way that computer algorithms check if a

digital record has been tampered with. In a hierarchical Merkle tree, the legitimacy of one item of data depends on the legitimacy of another. Some hierarchies are like that, and the structures of city governance. But so are informal relationships in communities. The good pupil inherits the respect accorded to her teacher, who in turn is deemed a good citizen by local shopkeepers, who are in turn legitimated by the respect they gain from their customer base. Somewhere in the chain's lineage resides the elusive Merkle root, the start of the inheritance train. This is a conservative social model. As in architecture, we build on the credibility of the achievements of others.

We mentioned the process of mining to secure the blockchain. This is the process by which nodes in the blockchain network contribute CPU time and effort to solve extremely difficult and arbitrary cryptographic puzzles, the solution to which gets printed into the blockchain to confirm the legitimacy of a block of transactions. A hacker would need to expend at least as much energy to access and change the data, and the task becomes even more difficult as more data gets added to this chain. In the social realm, to expend effort is to indicate a commitment and to validate your intentions. Think of the circumstance where political campaigners go from door to door to persuade would-be voters. It is not always the reasoning that persuades people, but the fact that someone braved the weather and spent the petrol and shoe leather in an effort to come and talk to them at home. Would-be persuaders are even more persuasive when they invest effort in something — preferably related to their cause.

To expend effort is to prove that something is of value. Putting in the effort shows the strength of your conviction. There's an argument here justifying otherwise unprofitable civic projects: follies, memorial statues, the pyramids, and public art. That someone cared enough to spend valuable resources, money, design effort, good will and controversy on a building, artwork or infrastructure project strikes any city visitor as a statement that the city has values. There is care there.

Making something visible, or at least accessible in a public way contributes to trust. That's one of the attributes of the distributed ledger idea in blockchain technology. The structure and its content are visible to anyone who wants to inspect them. Transparency is a watchword of good governance. It is a way of keeping people honest. In his *Utopia*, Thomas More said that people behave themselves as "everyone has his eye on you."[23] The ideal city was designed without places to hide. Much has been said about the city as panopticon. As with digital surveillance, the blockchain idea amplifies such metaphors of trust. But blockchain transactions are purposefully peer-to-peer, with the most private parts of the transaction encrypted, as long as you don't lose the key.

The encrypted city

Encryption of course references the architectural space of the *crypt*, a hidden underground place. Archaeologists refer to Monte Alban, the ancient city in Mexico as the "encrypted city."[24] The city ruins are marked with so-far secretive undecipherable symbols and markings. Robin Heyworth claims that the lines of the city's geometry are similarly coded: "Whilst the lines alone could be dismissed as meaningless … the numbers of proposed alignments add weight to the idea the city is encrypted with astrological information that would be easily deciphered by the High Priests of the city."[25]

A "blockchain city" is also an encrypted city. The city as distributed ledger lays everything out to be viewed, used, modified and accessed. But, like our bitcoin wallets, access is only granted to those with the decryption key. There are many parallels here with the distribution of software and other online assets. You need the key to unlock the features you have paid for. As any architect knows who has had to draw up a key schedule, a building is a system of locks and keys. So is a city — a matrix of locks, keys, vaults, hidden spaces, security doors, cameras, contactless sensors, keypads, and pass codes — fixed and mobile. Under the blockchain metaphor, cities reveal themselves as hyper-encrypted and hashed, and the city depends on that.

Conclusion

Notions of encryption as motif infiltrate contemporary architectural discourse. Architect Joseph Grima speculates about the implications of a "crypto-architecture" and the struggle between privacy and security.[26] Colleagues Debbie Maxwell and Chris Speed explore further the implications of the blockchain and the sharing economy in design.[27]

In this brief introduction, we have attempted to show the practical and current opportunities offered by the sharing economy in architecture, focussing on peer-to-peer transactions and smart contracts, and their challenges. We also alluded to what the sharing economy, blockchains and encryption offer as metaphors for the city, which in turn become indistinguishable from what architecture is, or is becoming. Some of the concepts outlined here may appear initially to require highly specialised knowledge outside of the usual orbit of architecture. Yet we have attempted to show the potential of thinking about such concepts with an architectural frame of mind, which is surely one of the hallmarks of architectural research, now and in the future.

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WEB ABSTRACT (300 words):

Concepts of the sharing economy are gaining traction in retail, finance, business and law. What has it to do with architecture? We examine the sharing economy's basis in peer-to-peer exchange, and its relationship with the intriguing technology known as the "blockchain." We look critically as the practical applications of the technology to architecture in areas such as the exchange of digital assets and the automation of certain types of contracts, as well as the metaphors about the city it brings to light as a stimulus to design.

PULL QUOTES (if no illustrations):

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