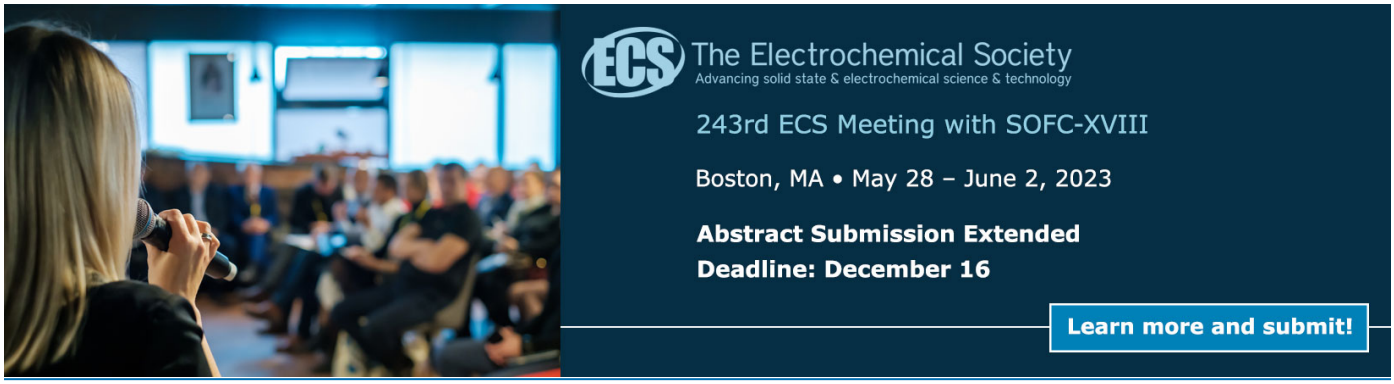
Block by block: potential and challenges of the blockchain in the context of facilities management



Block by block: potential and challenges of the blockchain in the context of facilities management

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Abstract The purpose of this paper is to demonstrate possibilities for the blockchain to impact Facilities Management and the challenges that its implementation would present. This paper mostly takes the form of a theoretical study involving desk research and limited case study examples. The paper shows that the growth of blockchain technology is becoming more and more embedded in various industries and that the building and FM sectors may be potential candidates for its future implementation under certain circumstances. Blockchains are not a fully established technology in FM so the potential value of them is yet to be established. Smart contracts and documentation recording in blockchains such as Ethereum can schedule maintenance better, ensure supplier, landlord and tenant contracts are more robust and easier to action. This paper also shows that blockchain technology is not without its challenges such as a lack of privacy and the fact that it is still an emerging technology. However, new competencies and understandings are essential in preparing for what is increasingly likely to be an inevitable future for the industry. This leads to the question of whether blockchains shape their infrastructure to FM, or whether FM should be the medium to change. The results of this paper can be of benefit to facilities and building managers, property developers, blockchain experts as the era of big data, digital twins and smart buildings becomes increasingly pervasive

1. Introduction

It is without dispute that the impact of digitalisation in the field of Facilities Management (FM) is not simply a component of the organisational practical application but is fundamentally changing the way FM is conducted day to day [1]. While FM is primarily reliant on document-based and 2D information, technology is racing ahead with a new development of Smart Building where FM must find its place and a tool that can facilitate its transition from digital dormancy to the digital revolution. From digital repositories of manuals to cloud-based open data solutions with multi-stakeholder access, FM is truly moving into a digital age ripe for innovation and even challenges. Existing technologies in buildings are being transformed through automation where such technologies had not been employed previously, such as remote heat pump control and digitally remote managed passive housing systems [2].

There are many examples to be found of digitalisation in the field of FM, it is still behind its construction sibling. Emerging technology, specifically Blockchain, has the potential to bring value from 2D information storage to more intuitive document storage. Blockchain is most famous for its association with the cryptocurrency *Bitcoin*'. At its most basic level can be described as an open ledger with distributed computation between potentially millions of computers containing information on monetary transactions, the contents of digital wallets and other relevant information [3]. In more simple terms, a Blockchain is a timestamped digital database that stores multiple kinds of data and even executes basic programs. This large database has increased legitimacy because identical copies are

stored on multiple (often millions) computer processors. It is considered un-hackable as every computer with an exact copy of this data would have to be altered. Multiple Blockchains exist, however, one of the more well-established ones 'Ethereum' with its '*Smart Contract*' technology. This has the potential to change how global finance is conducted, and specifically to FM to change service management contracting and green leasing.

This paper aims to fill a gap in existing research and literature by looking into the potential of Blockchain technology to contribute to the efficiency, security and sustainability of FM. It will also examine the challenges associated with embedding Blockchains in the FM field related to the sectors of service provision, data and document storage, and contracts, particularly Green Leasing.

1) In what ways can blockchain technology be applied to FM?
2) What are the challenges associated with Blockchain technology in the context of applying to FM and Green Leasing?

Through desk-based research in academia and practice texts, this paper will firstly describe the methodology and later the research questions individually before discussing conclusions.

The next section of this paper will look at the definitions of key terms and concepts to provide a contextual foundation for the rest of the article.

2. Methodology

This study consists primarily of a literature review of academic and industry-focused literature from 2015 to November 2021with minor exceptions used for theoretical contextual grounding.

Firstly, Google Scholar was used for academic literature. This is due to the depth of research scope possible for this search engine. The keywords search conducted focused on the terms "*facilities management*" and "*blockchain*" along with "*distributed ledger*" were used. These terms were either expanded upon or truncated where the terms did not provide relevant hits. To give an example of the output, a search for "*facilities management blockchain*" in Google Scholar yields 26,200 results. Some books were also used in this paper, through google searches on the internet for the existing literature on the topic from major Bitcoin, cryptocurrency and blockchain sites. The books were skim read to examine their quality and overall relevance for this study. This search was used to get a sense of the history of the concept as well as a deeper understanding of the mechanism of distributed ledgers.

3. Contextual Framework – Relevance of Blockchain to FM

In the following section, this paper will establish what is meant by key terminology and concepts to act as a starting point for grounding how blockchain is understood in FM and contribute to the body of knowledge on the topic.

3.1 Facility Management and Green leasing

The field of FM whilst often associated with building maintenance is a considerably more diverse field encompassing many skills and disciplines from engineering to architecture, law, the social sciences, computers programming and even to an extent urban planning [4]. Well-integrated information is important in FM for good decision making which impacts how sustainable a facility can be. Green leasing is an approach in which there is an agreement between two organisations (the owner and the service provider) agree to terms that ensure the facility is managed sustainably. In this context, Green Leasing is viewed to be an FM term through its emphasis on sustainable facility management [4]. One example is when green leasing is used in organisations to align the incentives of landlords to engage in green leasing which is primarily motivated by corporate culture with those of tenants who are motivated by reducing operational costs [4]. Green leasing provides the opportunity for a better-managed facility when facility managers are part of the lease development process such as being involved in the development of data and systems that are linked to leasing objectives. Better management and open information are a game-changer for how FM manage buildings. Blockchain is a technology that is a mediator for this type of information processing.

3.2 The Blockchain and the Sustainable FM Paradox

Whilst most associated with the cryptocurrency Bitcoin, Blockchains, is also known as '*Distributed Ledger Technology* (DLT) to better generalise the term, as the word 'blockchain' has associations more linked to Cryptocurrencies. DLT is essentially an open ledger shared by multiple computer central processing units, which have an identical version of the ledger. *In t*he case of Bitcoin, this ledger contains details of every single Bitcoin transaction ever conducted, as well as the amount and balances stored in Bitcoin 'Wallets'. The ledger cannot be altered by one user or computer, in essence, making the system back proof and incredibly difficult to amend. The '*block*' in blockchain refers to the incremental blocks of timestamps and multi-computer verified data created at regular intervals. This also includes the creation of Bitcoins themselves, referred to as '*Mining*' as part of the data creation and validation process [3]. However, mining cryptocurrencies and running DLTs bring with them a series of environmental concerns. These processes all create a large amount of heat and electricity consumption. To once again refer to the example of Bitcoin, by 2024 China's use of DLT is expected to be at around 296.59 Twh which will correspond to 130.50 million metric tonnes of carbon. To put this in context, these emissions will exceed the total annualised Greenhouse Gas emissions of the Czech Republic and Qatar [6]. Some DLTs such as the '*Wax Cloud Wallet*' are claiming to move toward more sustainable power solutions, using Carbon Offsetting to achieve this [7]. Therefore, while Blockchain has implications of creating efficiencies in FM decision making where large amounts of data can be analysed to identify what areas in a facility can be managed sustainably, it also increases carbon emissions on how FM manage a building.

The sustainable paradox for FM questions how much a facility can increase its sustainability based on the opportunities that a blockchain can provide. Whilst the Bitcoin DLT is primarily focused on recording transactions, the open ledger approach embedded in blockchain means there is potential in using this technology to store and enforce other streams of information. An example of a Blockchain offering this possibility is the world's largest, known as '*Ethereum*'. Ethereum is the broadest and most widely adopted Blockchain and it can store data far beyond simple transactions by the likes of Bitcoin users. One of the most unique qualities inherent in the Ethereum blockchain is something called '*Smart Contracts*' (SCs). An SC is a piece of executable code in a Blockchain that creates, facilitates, executes, and enforces a specific outcome. Each is unique and can result in a variety of specific outcomes and its aspects can be seen on the Blockchain [8]. An SC, for example, could be used to establish and enforce rental contracts, exchanges for goods and services and even loans. A landlord and tenant in a leasing arrangement could guarantee payment of rent and building access due to the automatic nature of SCs, whilst also allowing for an unprecedented level of transparency of such a transaction due to the open nature of data in a DLT based system. Such an agreement can then ensure that terms that fall under a green lease are met. This system however is not perfect, as cancelling a smart contract can be difficult to impossible, as well as presented concerns about privacy, as is the nature of DLT, as well as concerns about sustainability as mentioned earlier in this section. The open ledger in turn can offer greater accountabilities for all of these practices and could be of interest not just to owners and tenants, but also to potential clients who want to ensure that their building of prospective occupancy is cared for to a high standard.

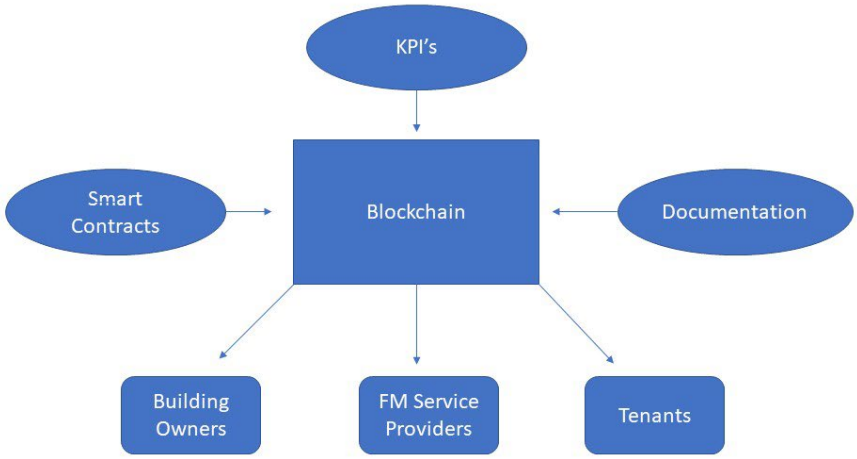

Figure 1 – The Blockchain in FM

Figure 1 outlines how DLT operates in FM at its most basic level. As the figure shows, the Blockchain in the middle represents the medium by which the data is held and viewable by the stakeholders. As stated, various inputs are possible in DLT such as Ethereum. The examples given here are Smart Contracts, Key Performance Indicators (KPIs) and documentation. This is then stored in the Blockchain and is subsequently accessibly by anyone interested in seeing it, here being the Building Owner, FM Service Provider and Tenant. DLT is considerably more complicated than described in Figure one, and the inputs and stakeholders are much vaster. However, at a basic level, this is the relationship lens that this paper will follow in terms of how DLT can operate.

There is potential to go a step beyond Smart Contracting with Green Leasing in setting targets and goals in green lease contracts that could be tracked and acted on to increase the sustainability of the building and thinking broader into cities. If we consider Blockchain from a city perspective rather than a building perspective and by spreading the information gained from a blockchain beyond building borders, the impact of increased carbon emissions may be reduced. However, we are not at this point as building owners tend not to consider this broader perspective drawing up leasing contracts.

4. Green leasing FM through Blockchain

4.1 The Blockchain as a potential Scheduler for a green lease

Owing to DLT's open nature accessible by all, Blockchain presents significant potential to be used as a scheduler for a variety of functions. Space is a problem in FM as it is a cost for an organisation. Bindra et al (2021) for example suggest that inputting the frequency of usage of rooms into the Blockchain ledger can offer interesting possibilities to schedule maintenance and cleaning [8]. For example, DLTs could record data on when areas were last cleaned or even use sensors to detect the likes of dirt accumulation. This information could be shared in a large DLT of various types of FM relevant metrics. Such metrics could be viewable by FM service providers or even automatically trigger interventions by service providers using data to enact a Smart Contract. This information could be used by cleaning personnel to know when the optimised time for cleaning would convert cleaning to a service based on need, not by schedule. The knock-on effect of this approach to cleaning is not just for good resource deployment but also results in more sustainable cleaning practices, by having cleaning routines when

needed and not when scheduled. Similarly, the date of installation of windows, carpets, and building management systems (BMS) in the blockchain could trigger automatic preventative maintenance with smart contracted FM providers which results in more systemised and transparent maintenance practices. In terms of what is meant to be a 'contract' in the context of FM and building maintenance, this could consist of outsourcing cleaning services, air conditioning rental or even energy performance contracts (EPC) [9]. However, due to the agility, this adds to cleaning services, such an approach would need to be formalised within a Green Lease contract where tenants would be expected to work with service providers to develop agreements that enable a Service Level Agreement (SLA) that is agile enough to work with the flexibility of services. It is within this space that the blockchain scheduler comes into its own as the openness of document processes has the potential to enable services to be transferred to areas in a facility that may require more cleaning than expected easily from areas that require less cleaning.

This system of schedule however is not a panacea and is open to challenges of various degrees of possibility to mitigate. The maintenance standard in the ledger is only as accurate as the information stored in it. This means that less than diligent service providers and building managers could lower the value and accountability of their building maintenance program if the Blockchain does not reflect the true level of care. In addition, data privacy is an issue [10]. Access to maintenance schedules and similar information can compromise corporate confidentiality as well as the likes of competitive advantage. Whilst this can be partially mitigated by using a bespoke blockchain of some kind, access to a more commonly used one like Ethereum does not offer this possibility so easily due to transparency being at the very heart of the technology.

4.2 The Blockchain as an information repository

The potential use of DLTs is the ability to store information of various kinds in an open, accessible, and incorruptible way. One such example is in certifying and maintaining sustainable certifications for buildings, such as the Building Research Establishment Environmental Methodology (BREEAM). Not only could building information be stored to support the certification, but it can also present important possibilities for transparency for relevant stakeholders, such as maintenance personnel and service providers who want to renovate and improve the building without compromising its sustainable credibility. Similarly, this information would be available to a variety of different bodies and agencies such as municipalities, insurers, and other groups [11]. If correctly managed with accurate data, this would lead to ensuring better Green Leasing possibilities by ensuring that buildings are well kept and more appropriately renovated to the longitudinal maintenance information of the building. Furthermore, this can make for more attractive buildings, particularly when concerning energy consumption over a building's lifetime. Research suggests that a reduction in operational costs is important to tenants over the factors of legislation, corporate social responsibility, company culture and consumer pressure [12]. DLT can allow prospective tenants to view relevant green leasing metrics in advance, such as the energy consumption per square metre of a previous tenant.

When considering the maintenance, refurbishment, upgrading and legal frameworks of a building, the availability of documentation related to those needs is paramount. The importance of document management is not new, and systems such as Building Information Modelling (BIM) have already integrated this as a function into their software [13]. However, whilst DLT can also serve this function, it has several benefits over systems reflective of the likes of BIM. Storing documentation on the Blockchain allows for easy access to manuals for maintenance, plans and schematics that are all more easily in reach when using Blockchains as an all-access repository [14]. Of particular interest specific to the nature of how Blockchains work, is that of timestamping. The timestamping of documentation over DLT reinforced the reliability of such a stamp due to the incorruptible and unhackable nature of Blockchains [15]. This timestamp refers to the point when the data enters the system and can never be altered or falsified. Whilst this has obvious application in legal documentation as smart contracts, the use of timestamps in scheduling routine maintenance, confirming its completion and scheduling upgrades is incalculably important information that benefits the works of FMs and building owners that is best shared transparently by DLT technology.

In terms of a real-world example, DLTs could also further assist in the development of the emerging concept of '*Digital Twins*'. Digital Twining is the provision of real-time data access that is trustworthy and reliable to asset managers and other interested stakeholders. Whilst the data can be trusted in terms of not being altered since its input, it is nonetheless only as reliable as the data that entered it in the first instance. It is also heavily embedded with the concept of the '*Internet of Things* (IoT) and automation protocols Blockchain [15]. These types of information and automation metrics are ideal for DLT utilisation. In the case of real-time data access, time-stamped information on building health, energy usage, waste disposal etc can be useful for scheduled and reactive maintenance, as well as supporting operational phase sustainability systems and infrastructure such as Green Leasing.

In terms of the automation of building processes and schedules, this fits very much into the smart contract possibilities offered by many Blockchains. Whilst Digital Twins are still an emerging concept in the real estate sector, leveraging DLT for their development could be an interesting route for it to take. If it is in the interests of the organisation, time verified data that is unalterable and enacted through automated SCs could allow for ease of data access for multiple stakeholders and service providers whilst also offering the possibilities to automate certain processes, such as recording energy usage and automatically alerting tenants if they are close to an energy cap or automatically triggering the maintenance of an air conditioning system through using an SC to either start routine maintenance or use cloud data from the device if it requires work more urgently to wear and tear or a breakdown. However, DLT as they currently stand is not feasible for an organisation that wants to have more closed data loops. This is particularly the case with Green Lease provisions, where energy caps that are surpassed and other aspects can result in defaulting on lease clauses [16]. In this context, this information the Blockchain will have a multi-stakeholder benefit, which in this case is the landlord, tenant, and FM.

4.3 The Blockchain as a Contract Manager, Lawyer and Enforcer

The nature of Smart Contracts in DLT leads naturally toward contract-based processes and needs in the context of FM and real estate development. As noted previously, whilst this application of DLT can allow for accurate scheduling and verification, it is still vulnerable to challenges related to transparency.

Green Leasing and Green Leases is an example of a concept that could benefit from DLT implementation, whilst also showing its potential weaknesses as a system. In essence, a Green Lease is a standard form of a lease with extra clauses that positively impact the sustainable credentials of a building [4], whilst Green Leasing is the act of renting out a building in a sustainable way that may but may not be formed under a formal green lease agreement [4]. By using an SC, energy caps could be better enforced by automatically triggering fines or other interventions should such a cap be exceeded. On the opposite, an SC could also automatically result in a pay out of the Green Lease as a savings sharing option or even reward tenants for lowering their energy consumption. Whilst this would take the responsibility away from building managers, it would nonetheless result in an SC that is impossible to alter until it has expired as well as leaving operational data (such as energy consumption) available for everyone to see unless one more confidentiality focusing on DLT is developed. Once the data is inputted in the DTL and agreed to, it will be managed completely remotely and in principle impossible to alter.

A similar scenario exists for FM service contracts. DLT SCs can provide third parties (such as service providers) with all of the information they need on a building as well as trigger maintenance and repair when certain conditions are met. Veuger (2017) sees the potential for this logic in what he calls a 'Building Passport' that can include information on maintenance, valuation, history, plans for renovation and tenants. He claims that this type of repository possibility is not just suitable for service providers, but also for banks who can follow financing and cash flow in these properties more easily. In some respects, this eventually led to the end of building auditors as they are known today [18]. However, previous concerns about the quality and reliability of the originally inputted data, along with the degree to which you want third parties to have access to this information can risk casting serious doubt on the viability and attractiveness of DLT in his context in the longer term.

One potential ongoing use for a DLT further into the future is that of its implementation in Smart Cities. Whilst the data transparency issue still holds (and could be even more of a concern at the city

scale), allowing for wider maintenance and service opportunities could apply to DLT applications. One example of this is Urban Facilities Management (Urban FM) which takes the principles of FM and places them at the community and city scale [19]. Using this combined with DLT thinking, the building level possibilities for FM by demand and not schedule could benefit not just from SC orientated triggers, but also from a clearer focus on ensuring these are very data-driven with good quality data inputs.

5. Discussion

The following section will delve deeper into the implications of the literature, and this addresses the needs of the research question more broadly.

5.1. Applying Blockchain/ DLT to Facilities Management

When looking into what has been found in the literature, there are numerous areas in which DLT can be contextually relevant to FM.

The openness of the ledgers is of potential utility in this case. In terms of the routine maintenance and service provision of buildings, having accurate levels of information stored in one place could be of immense value. If FM service providers could access the same information, it can ease some of the challenges with maintenance that are often associated with poor documentation and schematic management [4]. This data could then be added and supplemented by interested stakeholders to assume that records and documentation are as recent as feasible. Referring to the qualities of Ethereum mentioned in the theoretical framework of this paper, this is not a technological possibility, but a technological reality (with the arguable exception of document storage) that could be implanted with existing Blockchains.

The potential offered by SCs in terms of automation has many application possibilities in FM. Whilst automation already exists (even at the contract level), having these mechanisms in one place and operating under one format has lots of advantages. Landlords and tenants for example can enjoy identical levels of access to their Green (or otherwise) rental contract that can be enforced by a digital gatekeeper and not a lawyer [20]. Contracts can afford the same advantages for FM service providers; however, this can be combined with routine or reactive inputs that can trigger the enaction of such services, whilst also being open to the service provider and service purchaser.

The enforcement possibilities for FM can provide legitimacy for actions that would be difficult to enforce at the same level by other means. For example, an SC rental agreement will not always ensure that the landlord received their rent, but also can help to ensure that access to the building can be ensured if the security protocols are also enacted via DLTs. This can not only guarantee this action takes place, but also can potentially remove the need for virtually all physical landlord intervention at the point of contact [21].

Furthermore, the value of unalterable timestamped data adds an extra level of legitimacy to FM contracts. With unhackable DLT in place, a timestamped SC can be trusted and will be replicated across the entire Blockchain allowing for transparent reliable SC enforcement.

5.2. The challenges associated with Blockchain technology in the context of applying to FM

Whilst the previous section states that there is lots of potential for FM to take advantage of DLT, it is not a panacea and several aspects of the technology need to approach with caution.

Whilst the early stage of the development of DLT and its application in FM is a natural concern to possess, the lack of malleability is also a concern. As mentioned in the Contextual Framework, the Bitcoin Blockchain for the most part is only able to record transactions made with Bitcoin and little in the way of other forms of data. However, with the introduction of the ‘Taproot’ update to the Bitcoin blockchain, there is no scope to implement the likes of Smart Contracts as is currently possible with the Ethereum Blockchain. Ethereum can store many different things and can operate SCs well, however, the likes of maintenance triggers and document repository possibilities are still not possible in any commonly used DLT. This means that in 2021 only basic aspects of the possibilities discussed in this paper are feasible in the present day.

An ongoing concern broadly in DLT in and outside of the FM context is that of data reliability. Whilst the timestamping aspects of DLT ensure that data cannot be changed, the Blockchain is at the mercy of the reliability of the data input in the first place. If data is incorrect and not reliable, this can result in significant problems when SC is utilised. DLT is not controlled by individuals, but by the Blockchain themselves and cannot be stopped until the SC expires. This lack of human intervention can result in poor maintenance scheduling, fraud or even putting buildings in a stage of poor and dangerous repair [22]. This could be potentially mitigated by good levels of data checking, but the lack of tactile intervention beyond this point puts the entire principle of DLT in the context of FM at risk.

A further challenge is evident due to a characteristic that is at the heart of the existing DLT – its transparency. The previous section demonstrated that has its value, however, the placement of commercials sensitive data viewable by everyone is not an attractive prospect. Whilst there is no obligation or compulsion at present to put this type of data in a blockchain, the nature of data transparency makes DLT unattractive at the portfolio level in terms of valuation data and costs [15]. Whilst institutions such as banks are developing DLT that offers some degree of possibility to close the loop in Blockchain information transparency [3], the real estate industry as things stand would also have to develop their own DLT. This may not be resource or cost-efficient in the current climate.

6. Conclusion

To conclude, this paper hopes to demonstrate that DLT is an emerging technology that is only at the beginning of its developmental potential. It is also hoped that this study has demonstrated that whilst there is a considerable possibility for FM to employ and embed DLT, some of its fundamental qualities it should also mean that development should be approached with respect and caution.

Whilst the openness of DLT allows for multistakeholder access, its transparency can make it unattractive to the portfolio owners and FM companies that would be the most likely to use it in this way. SCs are exciting as a way of developing contracts that can be automated, however, the lack of human intervention should things change places further doubts on the viability of DLT. Further to this, the lack of reliability of the human element in terms of data entry puts it at risk of the unreliability of databases at their stand, however, automation corrects poor data close to impossible. That being said, for viability purposes, there is lots of potential in the timestamps offered by DLT.

Blockchains are most well-known at present for their possibilities in managing Cryptocurrencies, and their further utility is in the early stages of development and their further entrenchment in FM and related disciplines is unclear at present. However, it is hoped that the finding of this paper will not only clear some of the fog but also provide relevant information for the field of city planning, law, contracts, and related disciplines. It is also hoped that further research could be done on actual Blockchains to see if any other aspects and potentials here could be applied in the real world, and the challenges and possibilities they in turn could offer.

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