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Digital Twins and Blockchain: How an Alternative Built Environment Business Model Can Be Enabled by Tokenisation

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Abstract: The paper considers the poor state of the construction industry in UK and ways in which it might improve for all stakeholders. The transition from present state to a desirable future is mapped using the "three horizons" and "four capitals" concepts. Servitisation is suggested as a key innovation for engineering systems in buildings, the dominant lifecycle cost area. Digital twinning facilitates this method of provision and blockchain technology can support its commercialisation, enabling payments for service delivered and keeping safe records.

Key words: Three horizons, servitisation, digital twin, blockchain.

1. Introduction

The aim of this paper is to explore how the UK construction industry could transform itself and its customers' experience by retaining ownership of the engineering systems it provides, offering them as a service. Digital technology enables this, monitoring assets and linking them to design models so that performance can be continuously optimised. Technology also supports commercialisation of this service provision, handling payments and record keeping.

Construction in the UK today is poised between a failing business model and possibly successful future ones. Using the Three Horizons and Four Capitals approaches we can map transformative innovation (please refer to Fig. 1 from Ref. [1], "The Three Horizons Concept", and Fig. 2 from Ref. [2], "The Construction Industry: 4 Capitals across 3 Horizons"). One can say that the first horizon, the present, is characterised by transactional approaches to procurement, cost-driven purchasing, low margins, weak productivity and innovation, poor quality and the treatment of natural, social and human capital as externalities.

The second horizon consists of innovations which can improve the first or become bridges to a third horizon of transformed approaches. Elements already visible in the second horizon include a new awareness of the outcome value of assets, rising desire and ability to embrace natural, social and human capital factors, increasing interest in collaboration and partnership, industrialisation of building production, digital information management and the addition of smart sensors and analytics to the built asset. The Grenfell Tower disaster of 2017 [3] has also set in train a major realignment of regulation, requiring long-term asset information retention to allow safer stewardship of buildings. The digital twin concept is a third horizon idea which may result.

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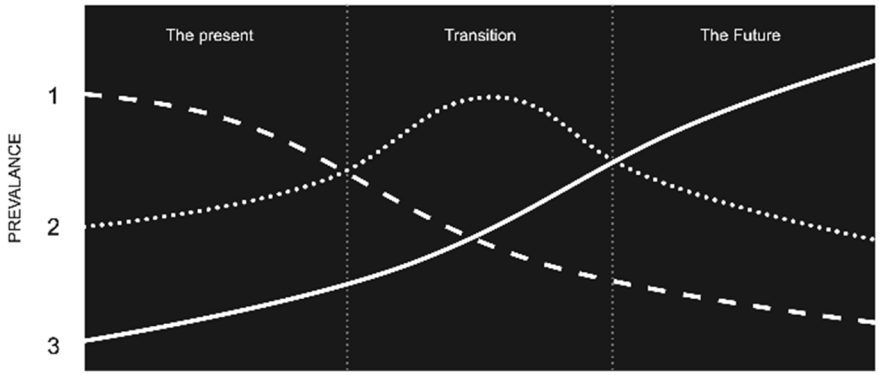

Fig. 1 Three horizons of change.

Four Capitals: Three Horizons	Horizon 1: the present	Horizon 2: transition	Horizon 3: the future
Produced Capital	Focus on capital spend and value. 'Product' mindset and business models Short termism; silo mentality Write-off after investment cycle Landlord and Tenant Act basis Housing supply prioritises sale	Whole-life costing; Systems thinking Digitalisation: BIM, CAFM, Digital Twins, Blockchain, Smart buildings; Internet of Things, Artificial Intelligence Servitisation; Build to Rent Get It Right Initiative	Outcome-based approach; long termism 'Service' mindset and business models 'Cyberphysical' assets Automated and optimised operation Housing supply serves all community Circular economy, no waste High productivity
Natural Capital	Impacts on the natural environment regarded as externalities Some regulation to comply with Services from the natural environment not valued	ESG Culture in investors. Net Zero Carbon policies (led by LETI) Performance based design (NABERS) Fabric first; Refurb first SUDS approach to drainage Active building (energy generating) Biophilic design;	Regenerative built environment Net-positive operating carbon Low embodied carbon Minimal new resource use; circular economy Nature-based solutions
Human Capital	Subcontracted human resources Minimal training; poor diversity Inadequate and precarious incomes Basic site safety; little health concern Unattractive work sector Artificial indoor environment for occupiers Non-diverse workforce	Modern slavery ban; EDI push Investment in skills, green and tech Concern for mental health and wellness Push for higher productivity and wages Robots as partners Offsite production	Health-oriented sites and buildings Access to nature Dangerous work done by robots Attractive work sector with good work-life balance; representative demographics IT, craft and green skills attract youth
Social capital	Transactional procurement, adversariality Risk dumping Social value as an externality On site work, remote from home Weak duty of care Exploitative supply chain relationships	Framework agreements; collaborative contracts; Construction Playbook; P13, FAC-1, IBA. Value Toolkit: '4 capitals' scoring Social Value Act DfMA; Project Bank Accounts Building Safety Act; Golden Thread	Long-term alliances, Integrated Project Delivery Platform MMC with stable factory jobs Socially equitable solutions Strong placemaking and community asset creation Strong duty of care

Fig. 2 Three horizons four capitals matrix.

2. Servitisation

An idea which is of growing appeal to the industry is servitisation as it offers advantages to both buyer and seller and supports many of the second horizon initiatives. In servitisation, the buyer does not purchase the asset but leases its availability, paying for delivery of its service at the agreed level rather than making capital payments. The buyer benefits by not having to find capital, nor needing to be able to operate or maintain anything. The supplier benefits by receiving regular income streams rather than lump sums determined by competitive tender. Positive effects from servitisation also include incentives to the supplier to continually improve the performance of their supplied system, to save themselves cost and potentially to share in resultant income received by the client. The supplier retains ownership of the system, recovering replaced parts and the whole system at end of life. Circular economic models are encouraged. Given the highly fragmented nature of the present construction industry, the risk of future monopolies must be low.

Servitised offers are arriving in parts of the built asset ecosystem already. Suppliers find buyers who are

reluctant to finance novel systems but are happy to lease them. Solar energy arrays are often provided as a service, with monthly payments covering the capital cost and delivering savings compared with previous grid supplies. Lighting as a service was pioneered by Philips, offering LED (light emitting diode) lighting installations to rent before the end of life of the existing system and saving on current power bills. BMSs (building management systems) are available as a service from Siemens, amongst others, justifying their subscriptions by improving the performance of other building systems. Elevators are an obviously servitisable system, as Mitsubishi demonstrates.

The digital twin concept fits the servitisation model well. Embedded sensors in the asset deliver data to the supplier to enable them to understand how the asset is performing. A digital model of the asset is connected to the real asset to form a cyber-physical entity. Software based controls can be used to adjust the real asset when necessary. Upgrades can be delivered down the line. Need for maintenance can be perceived before breakdowns, avoiding service interruption. The model is established in advanced industries, notable aerospace and high-speed rail. We now cross the Atlantic on two servitised, digitally twinned engines rather than four purchased ones. Twinning is advancing in electric car applications also as self-driving nears. Building systems seem a logical next market area. The UK is the leading country for building information management use and is well advanced in sensor-laden smart buildings. Digital twin based-servitisation might be an export opportunity for the UK.

Buildings are systems of systems. They also sit within corporate, urban, national and global systems. Systems thinking is an essential element of the second horizon ideas changing the industry. The present silo approach treats each component of design and construction as a world of its own whilst system thinking sees them as connected and interacting. Digital twins can connect to each other, to leverage data shared to improve delivered performance and understanding. Artificial intelligence/machine learning feeds on the data and can progressively automate control.

Buildings are not yet wholly made of servitisable elements. Structures are generally unlikely to benefit from the approach, nor will much of the envelope be made of such elements. But up to 40% of the capital cost of a typical non-residential building is made up of engineering systems, using or harvesting energy and delivering controlled climate, lighting, hygiene, transport, security, fire safety, space management, communication, catering and more. The capital, operating and maintenance costs of these systems dominate the building's whole-life cost.

These systems were typically provided by different companies and used hard-wired controls which were incompatible with each other. The move towards smart buildings and digital twinning overcomes this by enabling systems to connect via the IoT (internet of things). BMSs currently link some systems to each other, but IoT-linked digital twin systems may not need an overall BMS to act collectively, using distributed intelligence. Similarly, within any system there are elements which are also systems, often supplied to the primary system provider. These components need to act in concert to function as a collective digital twin.

The servitisation model suggests that the many firms supplying systems and subsystems to a built asset each deliver their part to meet a prescribed service level agreement. Payments are made as defined in the agreement when target availability and performance is achieved. Additional payment may flow if useful additional performance occurs. Data flow from each digital twin to allow its control and to signal needed maintenance but also to support the commercial process.

This commercial model is well suited to being supported by smart contracts on a public blockchain and potentially a blockDAG to handle scalability and low throughput. Tokenisation would be a useful way to record and track transactions so that commercial

confidence is retained whilst transparency is available to show that the service has been delivered and payments made. Utility tokens are suggested, substituting non-sensitive data for the original. This is safer than encryption in the long run and provides a Zero Knowledge Proof. A verified audit trail is created. What we need to see now is research to develop the overall integrated concept.

3. Conclusion

Built environment is a set of industries on the cusp of transformation. Many of the good ideas now being developed suggest a move away from transactional trading towards long-term supply-chain relationships which encourage high performance, productivity growth, sustainability and service quality. Servitisation is the label used for this conversion from product sale to service supply. Data will drive the transformation, flowing from connected cyber-physical systems. Smart contracts and tokenisation on a blockchain can underpin this arrangement commercially handling payments and by recording all activities in a secure but transparent setting.

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