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Smart or Intelligent Assets or Infrastructure: Technology with a Purpose

Will Serrano

The Bartlett, University College London, London WC1H 6BT, UK; w.serrano@ucl.ac.uk

Abstract: Smart or intelligent built assets including infrastructure, buildings, real estate, and cities provide enhanced functionality to their different users such as occupiers, passengers, consumers, patients, managers or operators. This enhanced functionality enabled by the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Mobile Apps, Virtual Reality (VR) and 5G does not only translate into a superior user experience; technology also supports sustainability and energy consumption to meet regulation (ESG, NZC) while optimising asset management and operations for enhanced business economic performance. The main peculiarity is that technology is standardised, ubiquitous and independent from the physical built assets whereas asset users including humans, machines and devices are also common to different assets. This article analyses the atomic differences between built assets and proposes an asset omni-management model based on micro-management of services that will support the macro-functionality of the asset. The proposed key concept is based on the standardisation of different assets based on common and specific functionality and services delivered by the technology stack that is supporting already the transition to Industry 5.0 based on Web 3.0 and Tokenisation.

Keywords: multipurpose assets; asset management; smart infrastructure; smart buildings

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Citation: Serrano, W. Smart or Intelligent Assets or Infrastructure: Technology with a Purpose. *Buildings* **2023**, *13*, 131. https://doi.org/10.3390/buildings13010131

Academic Editor: M. Amin Hariri-Ardebili

Received: 6 October 2022
Revised: 8 December 2022
Accepted: 30 December 2022
Published: 4 January 2023

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1. Introduction

Infrastructure is essential to an operational organization, society and country. Assets are of crucial relevance in the day-to-day life of different societies providing substantial social, environmental and economic impacts in terms of capital investment, employment, quality of life, resources, energy, and services.

Traditionally, assets have been designed and built with independent purposes that met specific business and user needs. This physical siloed approach is adapting to a trend that combines different functionality or purposes into the same physical infrastructure. The main reason is the diversification of business and investment to generate autonomous clusters of services. Offices and hotels are converging in their work-hospitality offers, likewise to factories and warehouses in their use of industrial space and robots. Transportation also presents a similar approach with railway stations providing dining and shopping services for passengers whereas airports include cinema and other leisure facilities within their facilities. Buildings are transforming into vertical cities with hotels, gardens, residential flats and commercial units scattered on different floors and public transport underneath. Homes and hospitals are also blending based on the pre and post treatment of human patients.

This fusion of functionality and purpose of the built asset makes its users to have different roles at once as the same user can be a passenger, patient, office occupier or diner. However, its interaction with the built asset, user experience and the journey will be different according to their specific needs. In addition to human users, the Internet of Things (IoT) and Artificial Intelligence (AI) bring devices, machines and robots as additional users with different needs from the smart asset. The ultimate physical asset digitalisation or virtualization is the metaverse where physical restrictions are suppressed.

Technology provides services to the different users of the asset, not just connectivity but also enhanced functionality, control and management. The digital computing approach based on fog, edge and cloud computing is also being emulated into the physical asset user experience. Users make decisions and interactions on different assets to provide or receive the required service before physically travelling via mobile apps or VR. Although the services are specific, technology itself is standardised, ubiquitous and independent of the physical assets. Examples include common standards for 5G, Wi-Fi 6 and Local Area Networks (LANs) transmit information between users and systems. Security, building and information systems that enable the functionality of the different asset users are also independent of the asset as different assets can also have the same systems and devices.

The multipurpose asset Whole Life Cost (WLC), from business case, design and procurement to management and operation of multipurpose assets are delivered following a combination of service models, either directly by the asset owner or outsourced to third parties. Normally, asset ownership, procurement, management and operations are performed by independent organisations specialized in the service based on the market of scale based on servicing numerous clients during a specific time to be competitive. Key challenges for asset owners, management and operations include regulation based on Environmental, Social, and Governance (ESG), Net Zero Carbon (NZC), business economic drivers, market competition, supply chain management, and cybersecurity. In addition, the long- and short-term objectives of an organisation do not necessarily support each other or align with the different department targets or budgets, such as cybersecurity vs. budget. The different decisions to address these challenges balance the complexity of the organisation against the maturity of the business based on the balance between costs, service performance improvements, safety and risks.

Asset Management (AM) provides complex multidisciplinary services due to it is based on standardised and controlled processes, dedicated leadership, skilled human resources, efficient information management, and organisational integration between management, operational, and technical departments that balances long- and short-term targets. Organisations have been adopting ISO 55000 series Asset Management standard to enhance the efficacy and use of the assets, addressing the sense of value to organisations, their shareholder and stakeholders.

Based on multifunctional assets, with standardized technology and common users where ownership, procurement, management and operations have equivalent targets and objectives, the main question is what makes these assets different or what defines an asset; equivalent to what defines a human.

1.1. Research Proposal

This article proposes an asset omni-management model based on micro-management of services where the atomic functional peculiarities between different built infrastructure or assets are incorporated into the model. These functional distinctions cover users, spaces, management and technology. The key concept is based on the standardisation of different assets or infrastructure based on common and specific omni functionality and micro-services that will support the macro-functionality of the asset. This standardisation is delivered by the technology stack that is supporting already the transition to Industry 5.0 based on Web 3.0 and Tokenisation. Distributed Ledger Technologies (DLT) and their generated new business management models place humans and machines at the centre of the economic asset transformation. The proposed asset-management model is based on a Decentralized Autonomous Organization (DAO) with the repercussions for the role of intermediaries in asset management.

1.2. Research Structure

Section 2 of this article presents the literature review for the different Asset-management models including applications of digital technologies, data models, artificial intelligence, blockchain and sustainability. Section 3 presents an overview of asset management.

Section 4 defines the omni-management functional model based on micro-management of services for the users, spaces, management and technology. Section 5 provides a detailed insight of the smart or intelligent assets or infrastructure from a technology perspective. Section 6 shares a general discussion of the Requirements, Decisions, ESG and NZC. Cybersecurity, hybrid working, in-house vs. outsourced services, premise vs. cloud technologies. Finally, Section 7 presents the conclusions of this article.

2. Research Background

2.1. Models

Modelling in AM broadly covers methods that support the decision-making process and holistic taxonomies that divide the asset into different functional components (Figure 1).

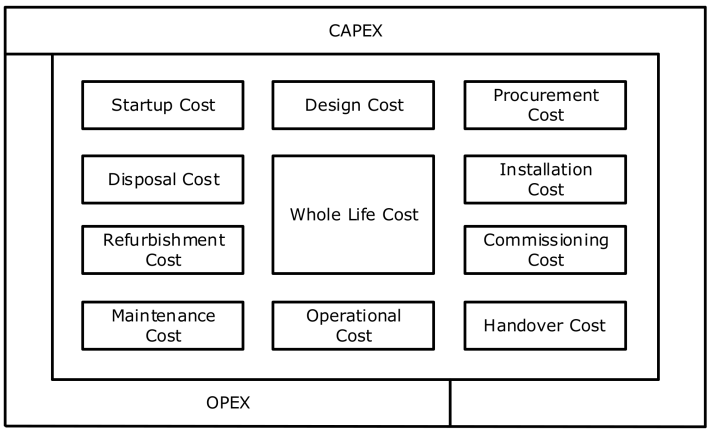


Figure 1. Whole Life Cost.

The WLC of engineered assets including its role within an organisational and competitive strategy comprises control and planning tasks to maintain a control process and a relationship with the strategy-making method where omitted or deficient elements of the model develop in undesirable effects on cost, productivity, quality and business achievements [1]. AM and business performance models support organisations to take improved decisions in infrastructure investments and bring better returns to the business by developing a relationship graph between AM systems, AM main processes and AM maturity models with Asset Performance Indicators (API) and Business Performance Indicators (KPIs) [2]. A Regulation-Oriented Model for Asset Management (AM-RoM) based on standards ISO 31000:2018 (guidelines to risk management) and ISO 55001:2014 (Asset Management) supports decisions based on compliance against regulatory framework [3]. A high-level conceptual model for decision-makers in infrastructure organisations is based on a structured understanding of value; the model considers the influence of mental and motivational biases, such as organisational objectives and stakeholders' needs and expectations, in addition to the intricacy of operational and business contexts [4]. A service assessment for AM and decision-making distributes a limited budget for a long-term maintenance and rehabilitation plan based on the assessment of the level of service [5]. A dynamic analytical framework for resilient AM extends the established conventional AM to future proof the WLC functionality and aligns maintenance, repair, or rehabilitation tasks associated with resilience enhancement retrofits [6]. An empirical framework supports production companies to implement value-based AM by committing to operational excellence where the key decision criteria is the value delivered by assets to the organisation [7]. An AM decision-support model prioritises assets that require supplementary maintenance or whole replacement by predicting their outstanding lifetime and failure effect [8].

A metamodel for multi-utilities assets manages the entire asset and defines the entities, their relationships and the evolution flow through its WLC [9]. The complex system of AM is analysed from time and space dimensions to assure every aspect and control in the three layers: organisational structure, rules, and regulations [10]. An integrated approach for AM

includes the entire scope of interrelations and interactions among three functions: temporal, organisational, and spatial to develop a capability and maturity model that include a strategic perspective and a framework for governance, policy, tactical and operational functions [11]. An integrated maturity AM model combines best practices and competencies including operational and technical strategy, policy and governance levels in addition to social and human resources to present an effective method to assess the capability of organisations to manage their assets [12]. An AM framework provides the link between asset performance measures (safety, value creation, reliability, cost), AM performance measures (planning, implementing, monitoring, review, enablers), and organisational performance measures (KPIs) based on the return of investment, customer satisfaction, profits, and employee for three perspectives financial, performance, and risk [13]. WLC models are categorised into three levels [14]: the operation level identifies the condition of an asset; the planning level includes maintenance plans; the strategic level forecasts expenditures and budgets. A practical approach for managing risk in infrastructure AM provides a reference model that fulfils the different requirements in different standards via three aggregations based on events versus location, similar events and system risks [15].

2.2. Digital

Different digital solutions have been proposed to optimize the AM process in terms of users, functional components, information and processes. A business dependency network supports investments in digital technology by linking objective business drivers and their resulting benefits and value throughout the WLC of an asset [16]. A general infrastructure AM system is developed in Python as an open-source, extensible, free accessible and modular platform [17]; the modules are developed based on an object-oriented approach that prioritises assets based on optimised maintenance, rehabilitation, reconstruction plans and optimised structural health monitoring schedules for the asset's WLC. An integrated decision support system for AM addresses the systematization and coordination of lifecycle data via Building Information Models (BIM) and database management systems where a lifecycle work breakdown structure facilitates the integration of the WLC phases for AM and presents a unified hierarchy to classify and arrange building assets [18]. An intelligent maintenance system based on Industry 4.0 and asset monitoring techniques enables information, data management, system analysis, knowledge management, online digital model and automatic decision [19]. An intelligent AM platform is divided into the platform itself, modules with different applications and data models based on the design, operation, maintenance, spare parts and materials [20]; whereas another intelligent AM platform links business priorities in maintenance work and investments [21].

A university fixed asset database information management system based on the Internet of Things (IoT) uses an SQL database server where the information management system is composed of four layers: subsystem, base, business layer and decision making [22]. An advanced AM project (Analytics 4 Assets) leverages data and analytical models to improve the calculation of health indexes and probabilities of failure based on minimum viable products, analytical algorithms and health indexes [23]. A conceptual model of the IT ecosystem applied to general AM is based on three functionalities: operational control for the day-by-day activities, tactical control for the coordination and planning of tasks and strategic control for the analysis and evaluation [24]. A genetic-algorithm-based asset resource management integrates machine learning for predictive maintenance in fog computing for an optimised decision support system within a production line [25].

2.3. Data

As AM relies on information, several data models and applications and models have been proposed. To facilitate incremental and iterative enhancements in the understanding of structural behaviours for methodologies in data interpretation, models need to respond to transparently changes and need to be updated accurately at minimal additional cost as more information becomes available [26]. A conceptual model based on agents supports

AM via the development of data infrastructures that generate trusted data while providing organisations with the capability to make the right decisions at the right time [27]. A holistic requirements view of a big data technology application and its analytical system architecture consists of three layers that cover data ingestion, analytics and visualization [28]. An extensible model of data infrastructures supports are capable of evolution and aids the successful adoption of IoT and new technologies [29]. A data framework covers information management and the integration of information into an AM decision-making to provide value-oriented decisions for the asset WLC [30].

2.4. Artificial Intelligence

The integration of AI into the AM provides benefits through its WLC. This includes the deployment phase for the design, procurement, installation and commissioning; the service phase for asset operation and maintenance; finally, the asset disposal for circular economy and recycling [31]. AI brings value in the asset acquisition phase in terms of technical and financial analysis, planning, and monitoring. Most state-of-research and machine learning tools focus on the tracking, exploration, and retrieval of assets to address development integration whereas the state-of-practice machine learning tools also offer functionality for collaboration and workflow execution. Directions for new machine learning tools and techniques include asynchronous collaboration and asset reusability [32]. An integrated decision tool applies machine learning algorithms to predict demand and mathematical optimisation for centrally planned asset management and allocation [33].

Deep learning supports sustainable asset management by learning complex functions and mapping systems providing the scalability required to extract hidden representations of significant features and automatic learning at several levels of abstraction from raw data [34]. Examples include equipment maintenance, inventory and supply chain applications, anomaly detection and prediction of future states. Deep learning management clusters supports search for information in complex data models simulating the way our brain takes decisions [35,36]. Finally, Deep reinforcement learning algorithms learn, predict and adapt to the different intelligent infrastructure variables emulating a living biological organism [37].

2.5. Blockchain

Blockchain and Distributed Ledger Technologies (DLTs) also provide new services and applications to AM. A global asset management system unifies permissionless and permissioned blockchains [38]. The permissioned blockchain authenticates the registration of end-user assets through smart contract deployments on a permission-less blockchain. An application for the management of cross-organisational business processes as well as assets uses a blockchain and methods for fungible/non-fungible asset registration, escrow for conditional payment, and asset swap [39].

2.6. Sustainability

Sustainability is becoming more relevant within asset management strategies. A sustainable asset management framework conceptualized by risk, performance assessment lifecycle, policy and strategy positively influence the sustainability performance outcomes, including economic, environmental, and social performance [40]. A sustainable model measures digital twin maturity for asset management forming a systematic view of digital twin development and implementation based on three dimensions of the maturity model: purpose, function and trust [41].

3. Asset Management

Asset management refers to an organised methodology and systematic process for the governance of the different elements that compose the asset over its Whole Life Cost (WLC). The main purposes are the delivery of organisational objectives and the maximization of the value generated by the assets. The preservation and extension of the service life for

long-term infrastructure assets are crucial underlying elements in supporting the quality of life in society and economic efficiency. WLC value realisation requires the optimisation of both life cycle costs and the value obtained from assets over the organisation's period of responsibility. This is accomplished by balancing a budget between an enhanced functionality against an optimised cost that prioritizes risks, performance, services, and sustainability via a combination of practices such as management, finance, and engineering (Figure 2).

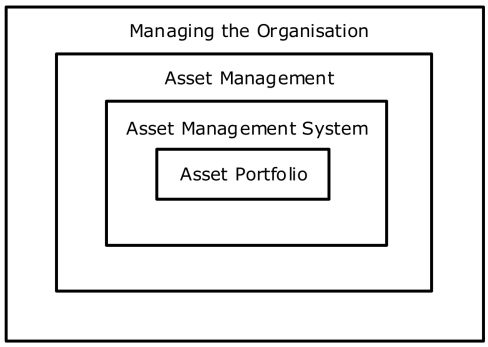


Figure 2. ISO 55000.

The process is normally divided into several stages across the WLC mainly design, construction, commissioning, operation, maintenance, upgrade, and final asset disposal of assets following a circular economy. The key components of Infrastructure Asset Management include [42]:

- Definition of a standard of service.
- Establishment of measurable specifications for the asset performance.
- Definition of a minimum condition grade.
- Development of a whole-life cost approach to managing the asset.
- Specification of an asset management plan.

The main asset taxonomy considers its physical properties that differentiate them between tangible and intangible whereas digital assets as the borderline between them. Infrastructure assets include physical elements with a social purpose such as the components of property, power, water, industrial, and transport distribution systems. IT assets normally correspond to the hardware, and software owned by an organisation to perform its business.

Normal tasks for an asset manager include stakeholder engagement, demand management, supplier relationship management, risk management, capability development, financial control and knowledge management. Successful asset management supports the delivery of business strategic objectives, performance service, optimised client and owner value from assets while mitigates risks, ensures that investment is justified by quantitative and qualitative analysis, enables agreement of funding with stakeholders, supporting staged and prioritised expenditure assigned to capital availability, and ensuring asset performance is under control. Essential processes and activities for infrastructure asset management comprise [42]:

- Maintaining a systematic record of individual assets.
- Developing a defined program for sustaining the aggregate body of assets through deterioration modelling, planned maintenance, repair, and replacement.
- Implementing and managing information systems in support of these systems.
- Defining current and expected levels of service and linking them to maintenance and capital planning.
- Calculating life-cycle cost of assets and possible sources of finance for maintenance actions.

- Defining the standard of service that describes asset performance in objective and measurable terms against a minimum condition grade, which is established by considering the consequences of a failure of the infrastructure asset.

4. Asset Omni-Management Model

This article presents an innovative asset Omni-management model different from previous defined asset management approaches. Specifically, the proposed omni-management model is based on the combination of the several functionalities provided by the assets instead of their definition or physical boundaries (Figure 3).

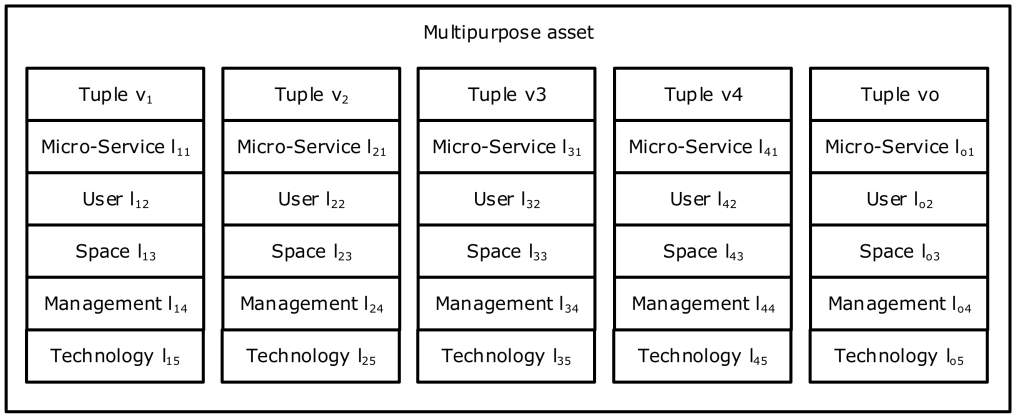


Figure 3. Asset Ommi-management model.

The universe of micro-services is a relation U that consists of a set of X M-tuples, $U = \{v_1, v_2 \dots v_X\}$, where $v_i = (l_{i1}, l_{i2} \dots l_{iM})$ and l_i are the M different attributes for i = 1, 2, . . . , X. Each possible asset in the universe is a subset of Y M-tuples $A = \{v_1, v_2 \dots v_Y\}$ where $v_o = (l_{o1}, l_{o2} \dots l_{oM})$ and l_o are the M different attributes for o = 1, 2, . . . , Y where the attributes l_{oM} correspond to the micro-service definition, user, space, management and technology, respectively. The overall combination of every specific dimension l_{oM} enables the provision of a micro-service and its combination will support the macro-functionality of the asset v_o. Therefore, the asset omni-management model is based on the micro-management of services that define the asset's intrinsic atomic properties. The concept is that micro-services (tuples) can dynamically be added or removed to the asset adapting to variable macro-functionality. The presented model emulates the genome as the root of structured information that codifies and develops more complex organisms or structures. A high-level example of the omni-management model is represented in Table 1.

Table 1. Asset Omni-management model.

Tuple	Micro-Service l_{o1}	User l_{o2}	Space l_{o3}	Management l_{o4}	Technology l_{o5}
v_1	Check in visitor	Visitor	Reception	Outsourced Public cloud	Visitor Management System
v_2	Check in visitor	Client servicers staff	Reception	Outsourced Facilities Management provider	Visitor Management System
v_3	Lease collection	Asset management staff	Office	In house asset owner	Asset Management System
v_4	Cleaning	Facilities management staff	Washrooms	Outsourced Facilities Management provider	Smart washroom
v_5	Parking digital wayfinding	Asset staff	Car Park	Outsourced Public cloud	Parking Management System
v_6	Catering	Client Services staff	Kitchen	Outsourced Facilities Management provider	Food stock management system
v_7	Investor reporting	Asset management staff	Office	In house asset owner	In house asset owner
v_8	Energy optimisation	Asset energy performance manager	Office	Outsourced engineering services provider	Energy management system
v_9	HVAC maintenance	Asset maintainer	Asset back of house	Outsourced engineering services provider	Enterprise asset management
v_{10}	Network provision	Office occupier	Office	Outsourced Network services provider	Local Area Network
$v_{\dots}$	...	...	...	...	...

4.1. Micro-Services

Micro-Services is the most atomic or indivisible activity with a purpose for any stage of the asset WLC. Examples of high-level micro-services are shown in Table 2.

Table 2. Asset Omni-management model—microservices.

Micro-Service l_{i1}		
Provide return to asset investors	Design an asset	Pay electricity bill
Collect rent from tenants	Deliver an AM economic plan	Decide asset function
Collect lease from leaseholders	Maintain the HVAC	...
Commissioning a new asset	Change floor plan	

4.2. Users

Users of the infrastructure or asset include humans, machines and robots that provide or receive a service during any stage of the WLC, from the business case to construction. Different users interact with the asset differently and therefore have specific functional requirements or use cases. Examples of users are shown in Table 3.

Table 3. Asset Omni-management model—Users.

User l_{i2}		
Office occupier	Asset owner	Designer
Visitor	Asset manager	Cooker
Passenger	Facilities manager	...
Customer	Energy performance manager	

4.3. Spaces

Spaces within the asset are linked to the users, management and technology to physically host its specific functionality based on services. Some spaces will be almost identical for different physical assets, however, specific spaces such as guest rooms, desks, platforms, boarding gates, flats and hospital beds provide specific functionality to the asset. Examples of spaces are shown in Table 4.

Table 4. Asset Omni-management model—Spaces.

Space l_{i3}		
Office space	Bicycle rack	Washrooms
Reception	Retail space	Kitchen
Entrance	Common area	...
Car Park	Equipment room	

4.4. Management

Management includes the demarcation of responsibility within the asset in terms of ownership, design, construction, tenancy, property management, facilities management, operations or maintenance. Traditional management for each of the mentioned aspects is performed as a centralised or outsourced service based on traditional legal contracts. Web3 based on decentralization of data and services, marketplaces, smart contracts and tokenization provides the framework to provide services directly and autonomously without a central authority or management. Users and devices can publish values and metadata in a data marketplace [43,44] where decentralized service providers can automatically agree on terms and conditions with their associated performance. Examples include the automatic report of a fault from a device in a data marketplace with additional information included such as operation and maintenance manuals, previous maintenance, and geolocation where different maintainers can quote directly their services in a legally binding smart contract.

The main challenge is the definition and description of services between clients and service providers without human intervention where one key growth area for Artificial Intelligence is the automatic quantification and scope of work for different services. Examples of management are shown in Table 5.

Table 5. Asset Omni-management model—Management.

Management l_{i4}	
In-house	Internal smart contracts
Outsourced to a third-party service provider	...
External data marketplace	

4.5. Technology

Technology enables smart functionality to the different users in the associated spaces and management of the asset or infrastructure. Technology is further divided into four categories: sensor, network, server and workstation. Examples of management are shown in Table 6.

Table 6. Asset Omni-management model—Technology.

Technology l_{i5}			
Sensor	**Network**	**Server**	**Workstation**
Camera	Wi-Fi	Local Area Network	Display
Occupancy	5G	Security System	Mobile App
Environmental	Local Area Network	Building Management System	Tablet
...	...	...	...

The specific components of the technology attribute are specified within the next section.

5. Smart or Intelligent Assets or Infrastructure

Smart or Intelligent Assets or Infrastructure rely of technology to deliver its services and functionality. Technology is further divided into four categories: sensor, network, server and workstation.

5.1. Sensor

Field devices embedded into the asset provide specific functionality such as video surveillance, access control, intercoms, environmental, location, and occupancy. These field devices can be powered via a dedicated power supply, the network Power over Ethernet (PoE) or batteries. IoT devices are normally battery-powered based on simple hardware with limited computing power designed to perform simple computing operations and transmit data quickly at low bandwidth while consuming as little energy as possible.

Sensors transmit information via open standard protocols to the server layer located at the edge or in the cloud. HyperText Transfer Protocol Secure (HTTPS) is designed for the transmission of documents in client-server applications rather than IoT data communication from mobile devices or sensors. Message Queuing Telemetry Transport (MQTT) and Constrained Application Protocol (CoAP) are the main OSI Application Layer IoT protocols for constrained networks defined as low bitrate, high packet loss and high asymmetric links. Both are designed as client/server models via the transmission of TCP/UPD IP packets with mechanisms for asynchronous communications with binary data messages for small payloads therefore low RAM memory and power consumption.

MQTT protocol transmits mainly binary live data via TCP connection data stream to a detached broker as a client-sensor/server-broker model. Every message in MQTT is a discrete piece of information published to an address, denominated as a topic where the broker transmits every message published to the topic to the various subscribed clients and

clients can subscribe to various topics. The main issue with MQTT is the topic string can be composed of large strings, therefore, inhibiting its low power, low computing, and low bandwidth features. COAP transmit information via UDP connectionless datagrams with an inbuilt functionality for content negotiation and discovery that allows devices to validate each other and to discover different methods for exchanging data. CoAP is primarily a client-to-server protocol for transferring state information rather than events that integrates with the HTTP and RESTful protocols due to its packet fragmentation mechanism. CoAP performs better than MQTT in terms of bandwidth usage and round-trip time, therefore, reducing network utilization, device memory and power, on the other hand, MQTT is more reliable with congestion control mechanisms and Quality of Service (QoS).

Lightweight M2M (LwM2M) aims to simplify and standardize device management and data transfer between sensor and server in the IoT based on TCP, CoAP and REST architecture.

5.2. Network

The fast and large increment of mobile devices and content coupled with server virtualization and cloud services where users access applications anywhere and anytime are the main reasons traditional network architectures are adapting to changing traffic patterns. The network transmits information between the sensors and the server for machine and human communications.

5.2.1. Software Defined Networks

A software-defined wide area network (SD-WAN) over the public Internet creates virtual private networks and simplifies the management and operation of a WAN by decoupling the networking data plane hardware from its control plane software. Bandwidth is shared without an established Quality of Service (QoS). Secure Access Service Edge integrates networking and security functions into a cloud solution. Software-defined networking enables controlling and optimizing the routing of data packets through a centralised server.

5.2.2. Internet Connectivity

Fixed wired Internet Service Providers (ISP) provide external connectivity between the different users of the assets and infrastructure, including datacentres. Technologies include Asymmetric Digital Subscriber Line (ADSL) and Integrated Services Digital Network (ISDN) based on the 2-wire copper telephone line, Fibre to the Cabinet (FTTC), or Fibre Broadband where the telephone line connects the cabinet to the property. Hybrid Fibre-Coaxial is the same as a Fibre to the Cabinet (FTTC), however, Coaxial Cable is used instead of phone lines. Fibre to the Premises (FTTP) the connection is via a fibre optic cable from the exchange to the asset at speeds up to 2 Gbps per connection.

Wireless Internet Service Providers (WISPs) deploy solutions including Wireless Fidelity (Wi-Fi-IEEE 802.11), Worldwide Interoperability for Microwave Access (WiMAX-IEEE 802.16) or Satellite. Low-cost Wi-Fi connectivity is designed with coverage of around 100 m and 150 m. WiMAX normally delivers the last mile/kilometre wireless broadband access as a substitute to fixed DSL and cable at speeds (approx. up to 1 Gbit/s with 2.3–3.6 GHz). Satellite Internet access provides data rates ranging from 2 kbit/s to 1 Gbit/s downstream and from 2 kbit/s to 10 Mbit/s upstream at 1–40 GHz. Satellited can be in Geostationary Earth Orbit (GEO) with a total latency between 0.75 to 1.25 s that affect real-time applications. Satellites in low Earth orbit (LEO) and medium Earth orbit (MEO) require more satellites at variable positions above the Earth although they provide lower latencies (125 ms, and 7 ms), respectively, with associated higher speeds.

5.2.3. Mobile

The 5G mobile infrastructure provides low latency services for large data streams within very short, unobstructed transmission links to enable applications based on mobile

broadband, IoT, and mission-critical applications; 5G is designed to provide up to 10 Gbit/s therefore with competing services Internet Service Providers (ISPs). Furthermore, 5G provides higher transmission speeds and bandwidth; therefore, it is able to connect more devices, improving the quality of service (QoS) in crowded areas. Additionally, 5G can be implemented in low-band, (600–900 MHz, 30–250 Mbit/s), mid-band (1.7–4.7 GHz 100–900 Mbit/s) and high-band (24–47 GHz, 1–10 Gbit/s. The 5G Radio Access Network (RAN) is supported by macro-cells based on Multiple Input, Multiple Output (MIMO) antennas and millimetre waves (mmWave). In addition, small-cell base stations with edge computing capabilities complement the macro network are distributed in dense clusters supported by indoor distributed antenna systems. Normally, the lower frequency of the radiofrequency spectrum provides the widest coverage and presents lower penetration losses. On the other side, the higher frequency the higher the bandwidth although requires a line of sight.

5.2.4. Wi-Fi

Wi-Fi 6 (802.11ax) provides higher bandwidth wireless connectivity with greater throughput at lower latency enabling connectivity to more IoT and mobile devices in the network in the frequency range between 1 and 7.125 GHz. The main two technologies that support Wi-Fi 6 are Multi-User, Multiple Input, Multiple Output (MU-MIMO) permit communication from multiple devices to the access point at the same time. Orthogonal Frequency Division Multiple Access (OFDMA) enables a higher spectral efficiency via the transmission of information to multiple devices at the same time.

5.2.5. Radio

Private Radio Systems (PRS) mostly support the communications of emergency services, public safety organisations and asset operators via VHF or UHF bands that transmit power typically limited to 4 watts to provide a reliable coverage between 5 to 30 km depending on terrain. Private Radio technologies include Private Mobile Radio (PMR), Trunked Radio System (TRS) such as Terrestrial Trunked Radio (TETRA) (Bandwidth-25 kHz Frequency: 380–430 MHz) or P25 (Frequency 136–859 MHz, Bandwidth: 12.5 kHz), Digital Mobile Radio (DMR) (12.5 kHz, 66–860 MHz). Due to PRS being privately owned with its associated additional OPEX and CAPEX and the low bandwidth provision that does not support Big Data applications such as Virtual Reality, BIM or video calls, the trend is the outsourcing of its services to 5G or replacement by Wi-Fi.

5.2.6. Low Power Wide Area

A Low Power Wide Area (LPWA) is a wireless Wide Area Network with long-range coverage up to 10 km at a low bit rate (0.3 kbit/s to 50 kbit/s per channel) designed for the IoT based on low-cost lightweight protocols, reduced hardware complexity and low power normally via battery or directly harvested. The network itself is also low cost based on a simplified design: star topology device to a gateway, reduced expensive infrastructure requirements, and the usage of license-free bands. Low power low bandwidth devices transmit long-range data to a gateway mainly via LoraWAN, and EnOcean wireless communication protocols, the gateway provides edge computing and forwards relevant information to the cloud via a fixed or wireless network. Due to its extensive coverage, LPWA includes smart city applications such as air-quality data, waste-management data, parking-availability data, or smart meter readings.

Long Range WAN (LoRaWAN) is considered the equivalent to the OSI Layer 2 datalink and OSI Layer 3 network layers (863–928 MHz and 2.4 GHz). Typically, LoRaWAN operates on top of LoRa which is the equivalent of Layer 1 physical OSI Layer. LoRaWAN is mostly designed for outdoor applications with battery powered sensors. On the other side, the EnOcean wireless protocol (868.3 MHz, 125 kbit/s) was designed for self-powered devices that transmit very low data and use very reduced amounts of power. The required power can be locally harvested via thermal differences or equipment vibration to recharge batteries

and expand their autonomous working life for many years with no maintenance. EnOcean supports low latency suited for mission critical applications and short range (30 m) for indoor applications such as building or transport automation.

5.2.7. Local Area Networks

A local area network (LAN) interconnects devices within one limited physical location or area (1 Gbps–10 Gpbs) via twisted copper pairs or fibre optics. LANs enable access to centralized applications such as servers, sharing resources including printers and access to the Internet; therefore, it can enhance communications and flexibility while holistically protecting the network from external attacks. Local Area Networks in access, distribution and core configuration for the asset converged network provides connectivity and power to fixed sensors based on the OSI Layer 2 Ethernet (IEEE 802.11) based on 48-bit MAC addresses.

5.2.8. Wide Area Networks

In contrast, a wide area network (WAN) or metropolitan area network (MAN) covers larger areas by interconnecting several LANs together via the OSI Layer 3 IP protocols. Several technologies support a WAN. Private circuit mechanisms typically are delivered over Synchronous optical networking (SONET)/synchronous digital hierarchy (SDH) and have been widely utilized for the past several years. The reliability inherent in SONET/SDH is due to the automatic protection switching element, which provides recovery within 50 milliseconds. However, the lack of bandwidth flexibility makes private circuit services less adaptable to current network and traffics demands. Asynchronous Transfer Mode (ATM) circuit and packet switching protocols via asynchronous time-division multiplexing are used in the SONET/SDH backbone of the public switched telephone network (PSTN) and the Integrated Services Digital Network (ISDN) based on the transmission of a fixed size 53-byte cells for real-time, low-latency content such as voice and video at approx. 135 Mbit/s. Frame Relay (FR) is a standardized packet switching methodology designed for transport across ISDN infrastructure. Multi-Protocol Label Switching (MPLS) is a key protocol for delivering voice, video, and data services on IP networks, it operates at OSI layer 2.5. Metro Ethernet involves circuits with Ethernet interfaces where assets can subscribe to high bandwidth at rates of 1 Gbit/s or higher.

5.2.9. Personal Area Networks

Personal Area Networks (PANs) provide wireless data transmission among devices replacing the serial cables or "RS" protocols based on low power (mW), and low range (10 m) communications. ZigBee protocol targets self-powered IoT sensor solutions in the 2.4 GHz IEEE 802.15.4 standard (868 MHZ–20kbits 2.4 GHZ 50 kbits/s). Bluetooth (IEEE 802.15.1) uses UHF radio waves in the ISM bands, from 2.402 GHz to 2.48 GH with a transmission power limited to 2.5 milliwatts for a range of up to 10 m.

5.3. Server

The server element collects data from the sensors and performs specific actions according to the required functionality or service. Server or computing can be distributed at the device level (fog computing), at the gateway level (edge computing) or at the datacentre level (cloud computing) to balance the triangle between power consumption, latency and bandwidth.

5.3.1. Systems

The specific functionality of the server function for assets or infrastructure includes security systems (video surveillance, access control, intrusion detection), Building management systems (HVAC, energy, lighting, fire, public address voice alarms) Building monitoring systems (environmental conditions, occupancy, energy), user experience sys-

tems (visitor management systems, resource and space booking, lockers, wayfinding), asset management (devices, facilities, property, space, leases, maintenance, project management).

Specific asset management systems also reside in the server layer such as Integrated Workplace Management System (IWMS), Computer Aided Facility Management (CAFM), Computerized Maintenance Management System (CMMS), and Asset information for asset register and maintenance. These systems enable functionality including maintenance, project, lease, rent, cost, auditing, investment, and space management supporting cost efficiencies and expenditure effectiveness while reducing human interventions that lead to time consuming and prone-to-error inefficient operations. One of the main challenges of asset management solutions is the alignment between daily activity and short-term plans between individual departments and the longer-term objectives of the organization while keeping accountability or placing undue constraints on individual departments. This alignment includes other management aspects such as maintenance. Costs are normally reduced with routine maintenance; however, unnecessary planned maintenance also intensifies expenses. Timing these decisions support extending an asset's life cycle at a reduced cost.

Asset accounts management systems are used by a variety of stakeholders to assess the financial and business performance of the organization, supported by consistent and robust evidence with the alignment of technical and financial data. Accounts are subject to auditing and policies such as expenditure, revenue recognition, capitalisation, valuation, depreciation policy, asset impairment, capital rationing policy or tax treatment policies. Finally, asset financial models include financial requirements, capital investment requirements, capital and revenue investment streams, projects, maintenance, energy, utilities, and operational and facilities management.

5.3.2. Open Standard Protocol

The asset middleware combines the individual functionality of the different system servers for advanced functionality via system integrations based on open protocols and standards. This overarching middleware removes organizational or team silos as different users' access and benefit from a single interface.

Digital Addressable Lighting Interface (DALI) is designed for the interoperability of lighting control in the IoT (IEC 62386). Each device is assigned a unique logic address between 0 and 63 where devices can also be programmed to operate in groups devices, report a failure, or answer a query about its status or other information. A single pair of wires generates the bus used for signal and power. Data are transferred between devices via asynchronous, half-duplex, serial protocol over a two-wire bus with a fixed data transfer rate of 1200 bit/s.

KNX is developed for commercial and domestic building automation mostly in Europe (EN 50090, ISO/IEC 14543, ANSI/ASHRAE 135). KNX supports devices to form distributed applications or decentralized topology via a twisted pair bus. This is implemented via interworking models with standardised datapoint types and objects that model process and control variables in the system. KNX can connect up to 57,375 devices using 16-bit addresses distributed in areas lines and segments.

BACnet is mostly used in building automation and control (BAC) networks (ANSI/ASHRAE 135-2016, and ISO 16484-5). BACnet was designed to allow communication of devices regardless of the particular building service or systems. It is normally applied in commercial HVAC control and Building Energy Management Systems (BEMS).

Modbus is a network communications protocol suited for industrial automation systems. It connects electronic equipment over serial lines in a master (requesting information)/slave (transmitting information) arrangement in building automation, transport, and energy such as metering.

5.3.3. System Integrations

Two separate applications communicate information via an intermediary bridge called Application Programming Interfaces (APIs) that enable one system to access the information

or functionality of another via standardised protocols. The most widely used APIs are SOAP (Simple Object Access Protocol), REST (Representational State Transfer), GraphQL, and Remote Procedure Call (RPC).

Remote Procedure Call RPC defines a remote execution of a function into a separate environment. The process consists of the client invocation of a remote method, the serialisation of the parameters and additional information into a message, and finally the transmission of the message to the server. After the server receives the message, the process consists of the deserialization of its content, execution of the requested operation, and the transmission of a result back to the client. RPC uses GET to collect information and POST for everything else based on a high message rate and very low overheads. With its tight coupling, RPC is normally applied in internal microservices.

SOAP makes data available as Web-based services based on an XML-formatted, highly standardised Web communication protocol language and a platform-agnostic environment. A SOAP message consists of an envelope tag that starts and finalises every message, a body that contains the request or response, a header to determine any specifics or extra requirements, and a fault that reports any errors from the process of the request. Due to SOAP presenting a static structure coupled with security and authorization features it enforces formal software contracts and complies with legal contracts between the API provider and consumer. SOAP applications include billing, booking, and payments for private or enterprise distributed applications between heterogeneous platforms.

Representational State Transfer (REST) is architected for developing high-performance, scalable services based on Web services. It is based on the concept of resource-oriented architecture, where resources are identified by their URI (Uniform Resource Identifier). REST makes server-side data available and represents them in simple formats, often JSON and XML, that decouple client and server via HTTP Communication between the client and server.

GraphQL is based on building a schema aiming to make precise JSON data requests to retrieve data from multiple sources. GraphQL messages are self-describing for distributed environments and therefore suitable for mobile devices to load data from multiple APIs.

5.3.4. Data Structure

Data or information have their own life cycle and management, similar to the asset that supports monitoring, audit, assurance, and performance benchmarking. Information requires maintenance to comply with legal and other statutory requirements, this includes change management, storage, retention and final. Information Lifecycle, processes physical and functional requirements. Raw asset data automatically retrieved from the different sensors are stored in a data lake following specific naming conventions such as Brick Schema, Haystack, OSCRE and Google Digital Buildings. Data ontologies are based on the Semantic Web principles and provide a uniform schema and toolset for representing structured information and model systems and components relationships. This standardisation enables its portability and consistency between multiple assets independently of individual inputs from the different users through the asset's WLC. Data ontologies support the management and operations of very large, heterogeneous asset portfolios in a scalable way. Data models support advanced functionality based on energy audits, automated fault detection and diagnostics, asset automation, the complex search of information and analytics and optimisations.

BIM Standards based on ISO 19650 [45] structured information management applied to the entire WLC of a built asset to support collaboration and procurement competition. Specifically, ISO 19650 is based on Information Requirements (Employer's Information Requirements, Organisational Information Requirements, Asset Information Requirements, BIM Execution Plan), Information Models (Project Information Model, Asset Information Model), Collaborative Practices(Common Data Environment, Interoperability, Industry Foundation Classes and COBie).

The Digital Building Logbook [46] is a proposal aiming at establishing a common European approach that aggregates relevant building data and ensures that authorised people can access accurate information about the buildings. Users are intended to be the market players such as property owners, tenants, investors, financial institutions and public administrations.

5.3.5. Data Formats

Different data formats support the digital creation of information and document in terms of the content, as the displayed information, structure as how the information within the document is structured and finally the formatting as the visual appearance. The first data standard was Hyper Text Markup Language (HTML) which structures the content of the document in tags and provides formatting rules to display data. HTML is a rendering protocol for Web browsers that lacks structure within tags. As a consequence, Extensible Markup Language (XML) was developed to encode the information structure of the document, or the representation of arbitrary data structures and transmit data readable for humans and machines. XML sends structured data within a web-based system and does not include a programming syntax. As Web pages become more dynamic or interactive via Web applications developed via software such as Javascript, rather than just displaying content via markup languages JavaScript Object Notation (JSON), structures information as key-value pairs to support data storage and interchange between software applications, although still hierarchical and human-readable. Geography Markup Language (GML) models geographic features via the Web Feature Service (WFS) Interface Standard.

5.3.6. Artificial Intelligence

Artificial Intelligence (AI) provides different applications to asset management based on classification, and regression algorithms for the different asset management functions. By analysing different sources of data, AI reduces asset risk under several predicted scenarios such as political, economic, social, technological, legislative and environmental. AI analyses and refines the Big Data stored from the different sensors to find patterns and detect anomalies supporting applications that optimize variables such as energy consumption or space utilization or predict the growth of demand, trends in customer behaviours, analyses of market conditions, and long-term resources. AI has the potential to expand the asset life cycle via the learning of the right intervention at the right time for its rehabilitation, reparation and replacement based on preventive and proactive maintenance.

5.3.7. Tokenisation

Web3, based on Distributed Ledger Technologies (DLTs) enables the movement of asset information between parties transparently where every asset transaction is auditable and verified without the need for a third-party central authority. DLT has the potential to disrupt ingrained legacy operating models based on the manual reconciliation of "Book of Records" or ledgers that are the barrier to change with an almost real-time solution. The time between trade date and settlement date is still from two to three days in most markets where the risk of counterparty default is often mitigated with collateral, which adds unnecessary transaction costs. DLTs enable a single version of truth between investors, managers, and sellers. Different users can share asset information and transaction history without compromising trust or confidentiality or human error. The tokenization of the asset supports a faster resolution of issues related to dispute resolution and improves the time to find information and solve discrepancies in data while enabling new digital parties to deliver new or traditional services. Smart contracts or tokenisation enhance the ease of asset management and the respective supply chain by prescribing the terms and conditions of the service which must occur for transactions to take place and making the communication of such conditions being reached irrefutable. These applications have the potential of reducing costs and processes time, increasing operational efficiency, improving transparency and facilitating a series of innovative investments. As services become digitally managed,

Artificial Intelligence can draft automatically smart contracts based on Natural Language Processing and make autonomous decisions via Big Data analytics and decision trees. Tokenisation supports also regulatory compliance, information security rules, privacy laws and investor reporting. New services include asset tokenization, or tokenized ownership, as the securitization of high-value goods that broadens the investor base, increases liquidity, and decreases resell risks where parties trade and settle directly within minutes at low cost.

5.4. Workstation

Workstation identifies the different interfaces or channels users of the smart asset or infrastructure have for its management, operations, or usage. As the access to the servers and information is performed via a Web Brower, there is no need to have a dedicated workstation, laptops, mobile phones and tablets also can be used where functionality can be bundled into mobile apps that aggregate different services and functionality into a common user channel. Although users have the information via their mobile phones, digital signage in fixed locations is still relevant to easily show relevant information, such as train, flight timetables or asset conditions including occupancy and environmental conditions. Digital signage can the updated in real-time and used to visually reinforce messages from the Public Address/Voice Alarm in emergencies.

Dashboards support asset managers and operators to visually group, analyse and filter information to make data-driven decisions for asset and portfolio levels. These decisions seek the enhancement of the asset performance in terms of energy consumption, environmental conditions, maintenance, or space utilisation. Dashboards support longer strategic decisions on longer-term strategic decisions by specific criteria such as Key Performance Indicators (KPI) based on value generation whereas balancing the asset's performance, service, capacity, expenditure, risks, operational constraints, compliance to regulatory safety or another statutory requirement and environmental. Decisions in asset management include the time dimension from day to day for operational delivery to yearly tactical planning and provision for longer-term life cycle considerations.

The digital model representation of the physical asset as the single source of truth via Geographic Information Systems (GIS), Building Information Models (BIM) and Digital Twins support asset manager, operations and maintenance to find relevant asset information within a 3D model where different dimensions or layers can be added such as time, financial, sustainability, facilities management, utilisation. Real-time device information can be embedded within the Digital model supported via IoT networks.

BIM models have the potential to include the asset information through its lifecycle, from design and construction to its operations and final decommissioning. In addition to the traditional 3D BIM, more dimensions have been added: 4D includes time and construction sequences, BIM 5D adds CAPEX and OPEX cost; 6D provides facilities management information; 7D is for sustainability information; 8D brings health and safety considerations. Geographic information places the asset to the earth coordinates within a spatial and cartographic landscape. Augmented Reality provides an interactive experience of real-world environments for training in terms of operations and maintenance.

6. Discussion

6.1. Requirements

Smart assets must be specified with atomic SMART requirements Specific, Measurable, Achievable, and Relevant, to define the solution. Requirements include financial, business, functional, organisation technical, integration, and cybersecurity operating models of the smart asset. Clear atomic requirements, in terms of conciseness, consistency and simplicity that holistically and independently and non-overlapping cover the different aspects and users guarantee a successful asset. Adequate requirements specify necessary, verifiable, and achievable within a budget and programme constraint elements. Due to requirements that need to be verified, it is important to address the verification process when writing the

requirements. Common issues with requirements include wrong assumptions, incorrect or ambiguous terms, specifying the how rather than the what and over-specification.

6.2. Decisions

Decisions about technology must be based on a well-defined business case with criteria and policies, made by the right people, information and methodology. Decisions shall be consistent with longer-term strategic decision-making based on value generation balancing asset's performance versus costs and service vs. capacity. Time is a fundamental dimension for decisions due to its influence on obtaining funding and the effects outcomes of the decision. Time includes day to day operational delivery and yearly tactical planning and provision longer-term life cycle considerations.

6.3. New versus Renewal

Currently, new or additional functionality of assets is generally enabled by ubiquitous technology, therefore independent from the physical asset itself. There is a viable case that supports the repurposing of existing physical assets and modifying them to their new functional use adapted to evolving human and social needs. This strategy supports ESG, NZC policies, and the circular economy while reducing project costs. An equivalent renewal approach also applies to digital assets where the additional functionality enabled by the new asset needs to support either its associated Return on Investment (ROI) via additional profits made or cost reduction in terms of efficiencies or maintenance.

6.4. ESG and NTZ

Current policies force the assets to meet Environmental, Social and Governance (ESG) and Net Zero Carbon (NZC) commitments. This includes circular economy, reporting NZC and the three different scopes. There are numerous regulatory initiatives that force asset managers to include ESG risks, disclose information and have a more proactive role in policy making implementation. ESG and NZC impact asset management due to the increased investor and occupier demand for regulation compliant assets. These initiatives do not address addressing environmental damage and climate change, their objective is also the opening access to investment opportunities and services to different clients to enable social equality and financial inclusion.

There are numerous technology solutions that support sustainability and NZC such as API system integrations, building management and lighting management systems for energy optimisation, delivery and waste management for resource tracking, IoT sensors for proactive maintenance and asset management for performance. In addition to sustainability, the democratization or inclusion of services will not be achieved only via enabling data access to otherwise closed systems, but also due to lower the cost of market entrance via fintech solutions, larger scalability and digital accessibility such as mobile apps or tokenisation. Subsidies also promote ESG in terms of environmentally friendly asset purchase, preferential tax, lower interest rate, and potential utilization of capital market such as green bonds.

However, data remains the obstacle. Evidentiary information requires data quality that includes its access, collection and aggregation at the right frequency, validity, and consistency. Another data challenge is their standardisation in terms of ESG scoring for a common benchmark. Different evaluation criteria of ESG magnify the difference between various data sources. Natural language processing and machine learning to extract value from big unstructured data, the main challenge is in the data access, collection and quality. As data become a valuable source of evidence, they need to be governed for their maintenance and security. These algorithms provide the outcome; however, ethics in AI or explainable AI are required to validate how the outcome was reached.

6.5. Cybersecurity

The IoT with additional connectivity and cloud services increases the risks for cybersecurity as attackers have additional coverage. Successful cybersecurity attacks not only impact business disruptions with their associated economic impact but also the asset manager's reputation and eventually asset value if there is a perception some assets are more vulnerable than others.

Cybersecurity for asset management is the process of proactively identifying, on a continuous, real-time basis, the technology elements and networks in the asset and assessing their potential security risks or vulnerabilities. Once the hardware, software, virtual infrastructure, information, and online accounts are identified and risks are identified, these risks and vulnerabilities need to be managed on a day-to-day basis. Free assets and services such as cloud storage or mobile apps shall be included as they may hide intentional threats due to their low price. In addition to on-premise asset elements, cloud resources need to be identified and protected. In the likely event of a cybersecurity incident, such as a resource violating security policies a proactive incident response investigates the root causes and provides remediations. Finally, continuous policy enforcement assures new devices added to the network are added with the established active policies.

Asset management in terms of discovery and provision of a single, accurate, available, accessible, automated, complete and authoritative source of information provides the foundation for most other areas of cyber security in terms of managing risks, legacy components, identity and access, changes, classification, vulnerabilities and patches, real-time monitoring, human factors, incidents, response and recovery [47]. Examples of data sources for asset management include procurement and billing records, mobile device manager, system/device management tools, logging and monitoring platforms, vulnerability management platforms, information from development and engineering teams, public key infrastructure.

6.6. Hybrid Working

The nature of work is gradually changing with the hybrid workplace model were working from anywhere is gradually becoming the norm, this behavioural change affects the design of assets in terms of their functionality and capacity. The workplace is transforming the purpose of the asset as work only into a physical-virtual hybrid space with a purpose or intention that provides a corporate identity for individual work, socialisation and collaboration designed to enhance staff productivity and business growth supported by technology. The collaborative technology for physical and virtual attendees includes audio–visual approaches, meeting/conference room videoconferencing, and room and desk booking, eventually, virtual reality will make meeting rooms virtual. In addition, there is an increasing focus on the provision of wellbeing facilities based on a pleasant and healthy environment to work in will make staff more productive via better ventilation, natural lighting, cycling facilities and showers. Occupiers are demanding a more flexible office hotel experience worth the commute that requires a larger space with more quality per occupier.

6.7. Services: In-House/Outsourced

Services for the management, operations and maintenance can be performed by the asset owner or outsourced to third parties based on a balance between cost and quality and control. Outsourcing services hire external specialized resources to work on tasks or projects ideally to reduce cost and increase delivery speed, on the other hand, in-house services use the internal operational infrastructure of the organization to deliver the same activities.

Outsourced services provide quickly exceptional expertise and skills and reduce salary costs if the tasks or projects are not required full-time. Outsourcing is the option to address peaks of service demands or growth with a faster project delivery where it also removes the need for in-house training and reduces the in-house team's workload. Additionally, if specific tasks are becoming too time-consuming or to better focus on the core aspects of

the business to improve efficiency and productivity. In-house overtime is both expensive and energy exhausting. Outsourcing also requires additional management effort in terms of contracts, scheduling reporting and communications. Overall, outsourcing reduces the control in terms of methods, quality and security on the task or project, although it also mitigates the risks via legal contracts, and service level agreements.

In-house services are preferred if the required task or project is not well defined or clear as in-house service is preferable to get a better understanding. Additionally, long-term commitment such as support, or maintenance is needed. Handling sensitive and confidential information or strategic or business critical services. In-house services build up reputational/brand value, expand the team's skills and enhance its performance, bringing motivation and commitment as part of career progression as a result of the project outcome and company values with the associated intellectual property control and innovation. Although in-house generally places new operations and processes within the organization at an additional expense.

6.8. Technology: Premise/Cloud

Technology also presents different service models based on ownership and maintenance. Cloud computing is based on the virtualisation of computing, network and storage, although this principle can also be applied to on-premise configurations. A cloud service provider hosts and offers on-demand computing services to individuals or businesses, including infrastructure as a service (IaaS), platform as a service (PaaS) or software as a service (SaaS). IaaS is the virtual equivalent of a traditional datacentre that includes servers, virtual machines (VMs), storage, networks, firewalls/security and operating systems. PaaS targets software development including testing, delivering, and managing software via IaaS and operating systems, development tools, database management and business analytics. SaaS covers subscription-based software accessed from the internet via IaaS, PaaS and hosted applications.

Cloud service providers offer private, public, or hybrid cloud computing solutions that provide high availability platforms designed to assure business control, security, privacy and continuity. A private cloud consists of cloud computing resources physically deployed on the client datacentre or hosted by a third-party service provider exclusively by one business or organization. Public cloud services are owned and operated by a third-party cloud service provider and delivered over the internet and accessed via a Web Browser. It is a more economical option but offers limited customization. Benefits of public services include lower cost, no maintenance, high scalability and reliability. Multiple customers or tenants share resources even though the service provider segregates the data. Examples of public cloud include: Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP). A hybrid cloud combines on-premise cloud services for sensitive applications that require security and regulatory compliance and private and/or public cloud services for less sensitive applications and benefit from high flexibility, and scalability.

Product manufacturers are evolving to a device-as-a-service (DaaS) model in which customers purchase a subscription to the products that cover the initial hardware purchase, software and future maintenance costs. The success of this model depends on the connectivity of the devices for external monitoring and software upgrades.

6.9. Metaverse

Assets in the metaverse are detached from the real physical world into a completely virtual environment based on an open platform for economic purposes. The metaverse enables its users to create and share content and applications modifying the assets and the environment itself. This feature supports interaction and collaboration at different levels while making it a highly customisable environment. Virtual assets and ownership in the metaverse are traded as non-fungible tokens via cryptocurrencies such as Bitcoin or Ethereum. Although the main functionality of the metaverse is already delivered via

Digital Twins or Virtual Reality, it provides a higher level of customisation and economic trade. While the metaverse provides a complete digital service, it still relies on physical assets such as headsets and datacentres which need to be managed.

6.10. Datacentres

Datacentres are the new physical asset developed as a consequence of Industry 4.0, cloud computing, IoT, DLTs and AI. The asset which the main user or tenant is data based on computers, storage and network components. Datacentres design is a trade-off between high availability, modularity and flexibility, security, and energy consumption. This user-centric approach based on data makes datacentres detached from human areas to locations that optimise their performance.

6.11. Regulation

Regulation plays a crucial role in technology adoption as it provides legislation from which consumers and organisations can protect their interests, agree terms, and assure compliance. The legal framework based on a common ground, provides stability and insurance services bringing extra costs due to the additional third parties involved in the process.

6.12. Real Estate Data Challenges

Real estate is very conservative about digitalisation due to the threat of technology disruption to a sector where information is the main value provided. The big data challenges are the reluctance to share, different formats, naming conventions, governance and ethics beyond the scope of GDPR and ESG. Large and essential asset information is still held as documents, this causes information barriers between asset owners and occupiers. Data models need to include property rights, leases, and events such as rent reviews, dilapidations, property management around rent collection, and disputes.

7. Conclusions

This article has proposed an asset omni-management model based on micro-management of services where the atomic functional peculiarities between different built infrastructures or assets are incorporated into the model. These functional distinctions cover users, spaces, management and technology. The key concept is based on the standardisation of different assets or infrastructure based on common and specific omni functionality and micro-services that will support the macro-functionality of the asset. This standardisation is delivered by the technology stack that is already supporting the transition to Industry 5.0 based on Web 3.0 and Tokenisation. Distributed Ledger Technologies (DLT) and their new generated business management models place humans and machines at the centre of the economic asset transformation. The proposed asset-management model is based on a Decentralized Autonomous Organization (DAO) with the repercussions for the role of intermediaries in asset management. The main challenge is that this model is based on these new unregulated technologies that may limit its complete implementation and reach. In addition, AI needs to excel in delivering autonomously fit for purpose smart contracts. Finally, the main limitations of the adoption of this technology lay in its user adoption, and its organisational and business integration.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Will Serrano, the author of this article, would like to express gratitude to Tim Broyd @UCL for his personal and academic support writing this challenging article. Jing Jia @UCL for her comments on asset management regulation. Jiayin Meng @ UCL for her comments on asset management finance. Andrew Knight, Global Data & Tech Lead @ RICS for his comments on real estate data challenges.

Conflicts of Interest: The author declares no conflict of interest.

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