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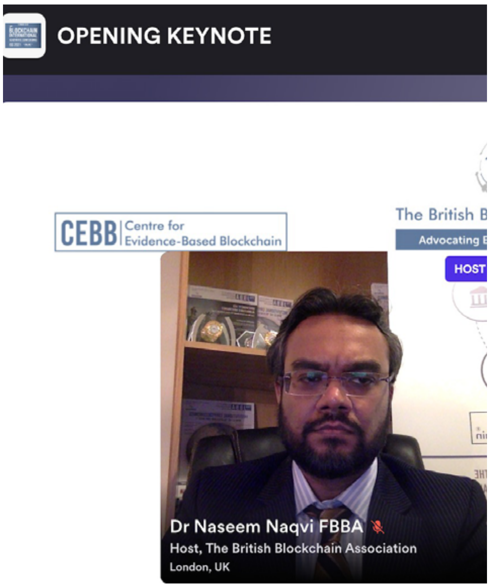

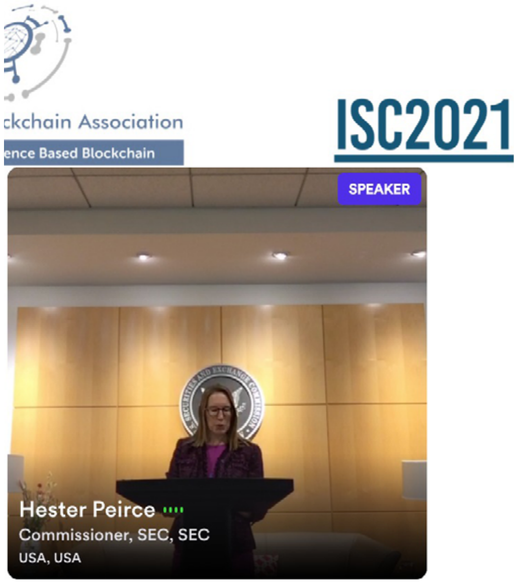

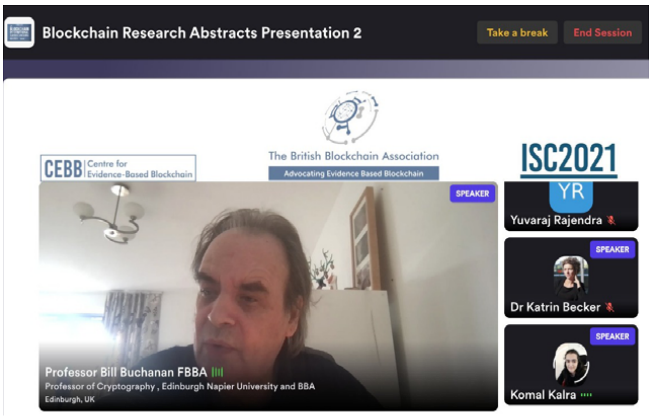

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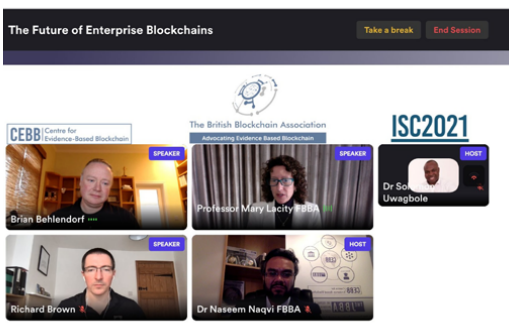

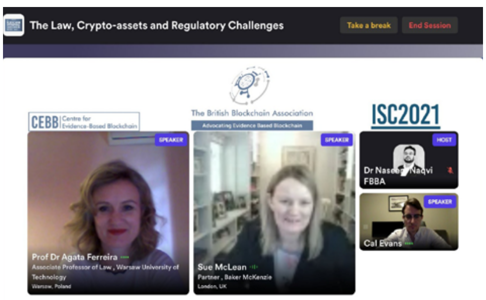

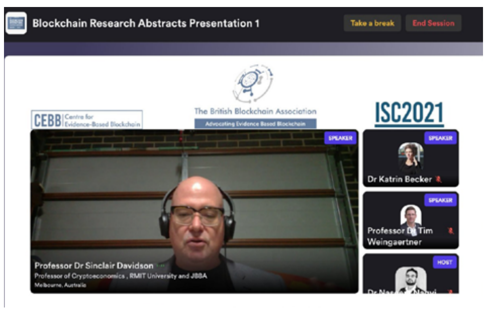

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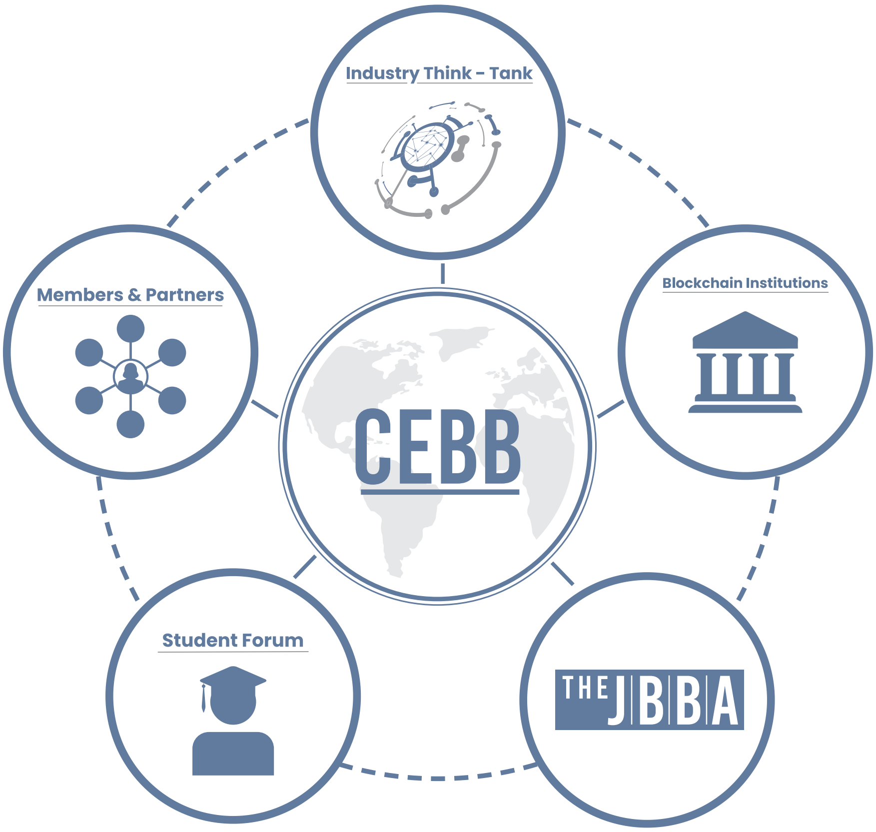

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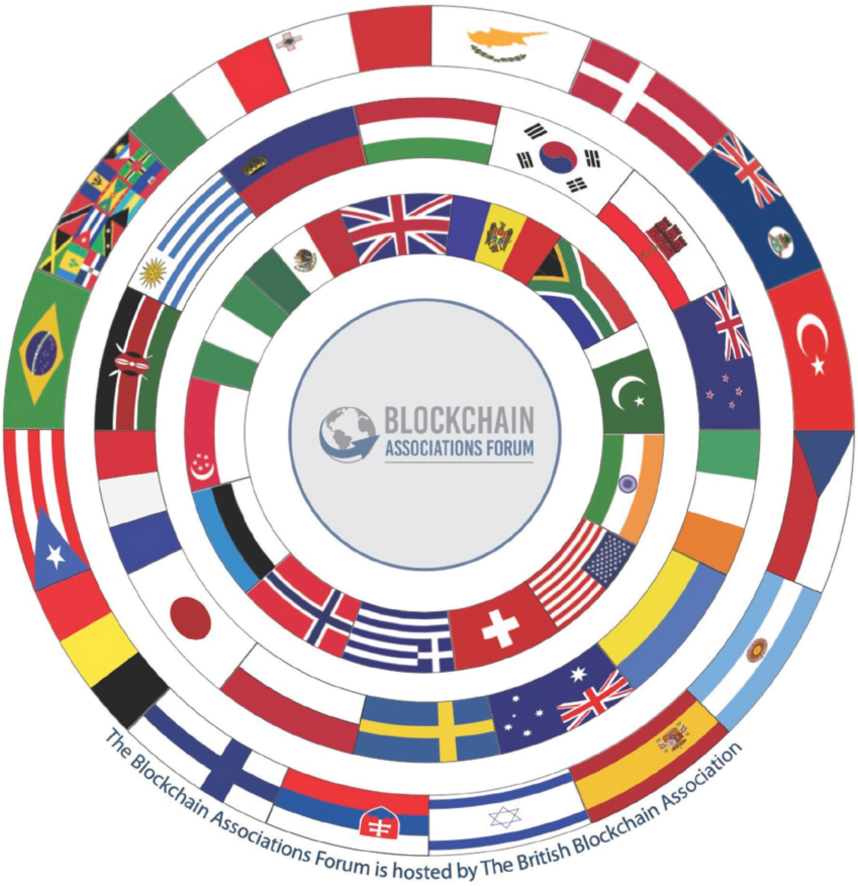

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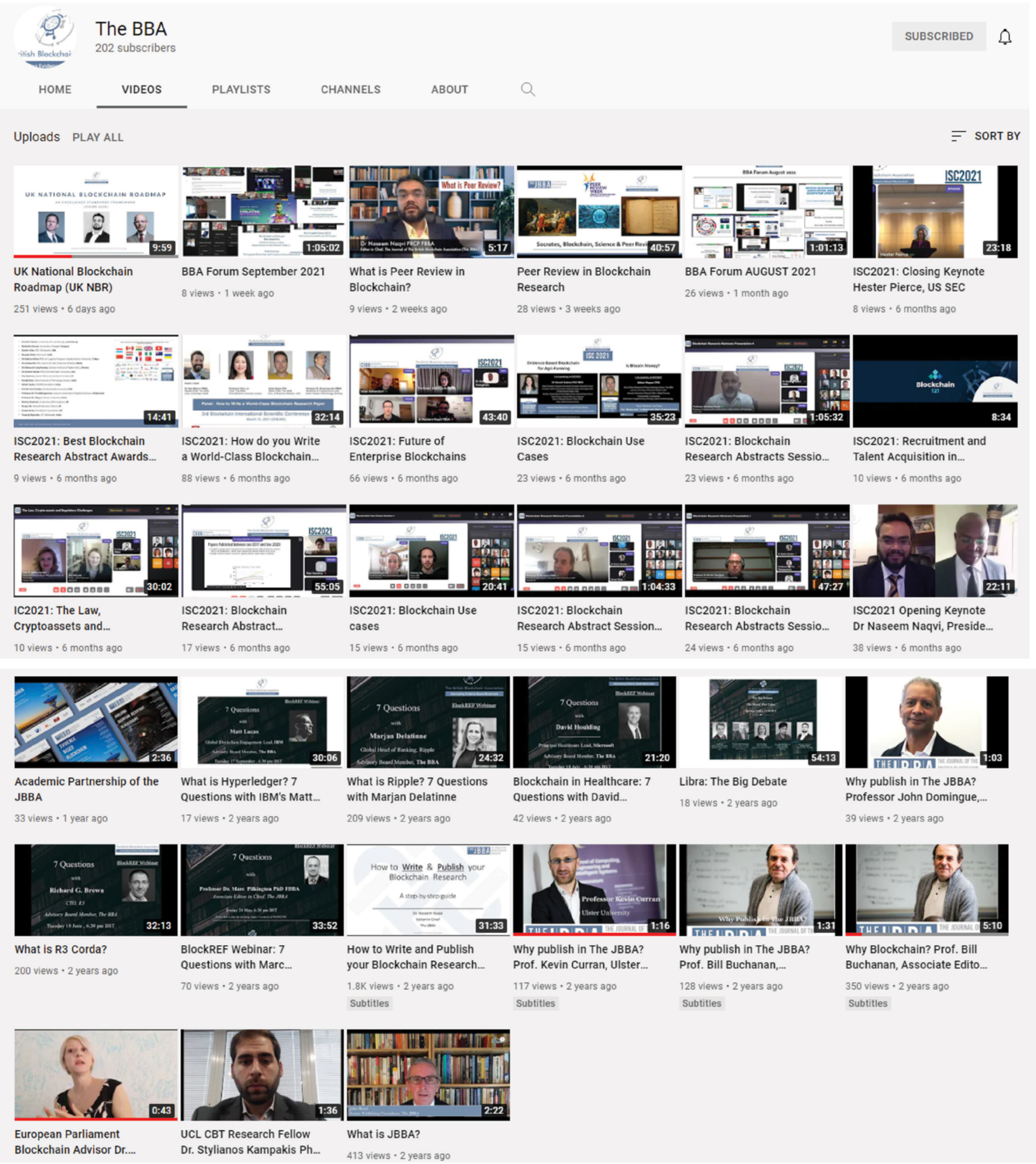

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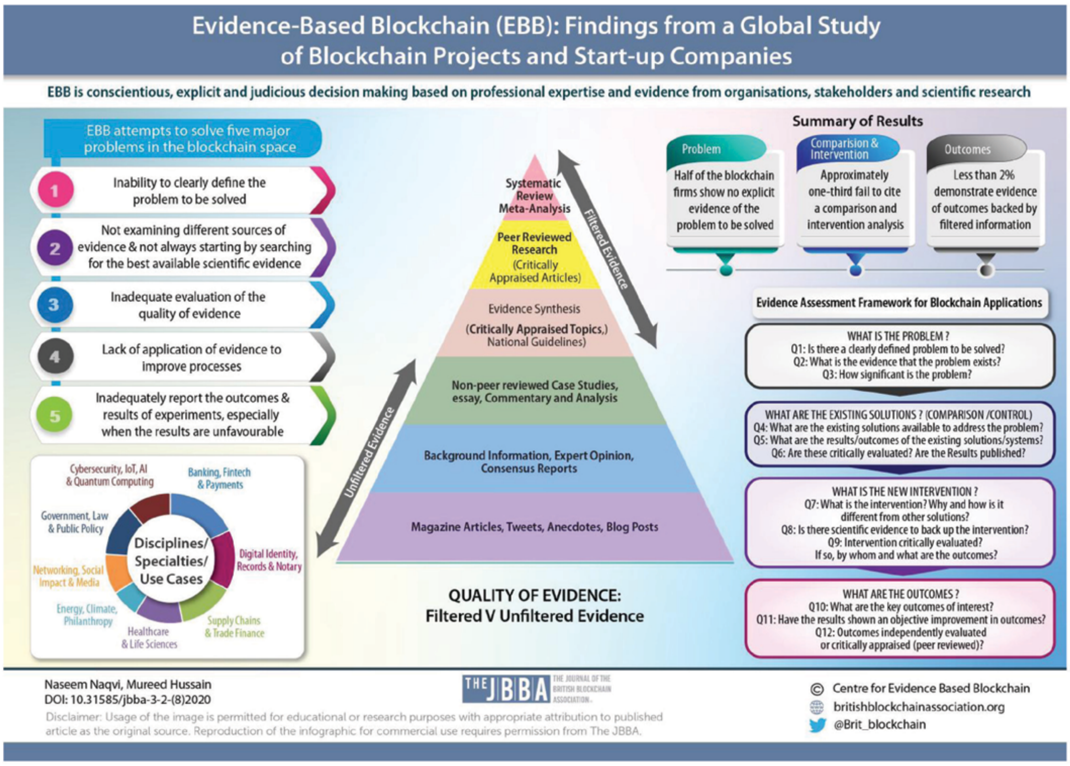

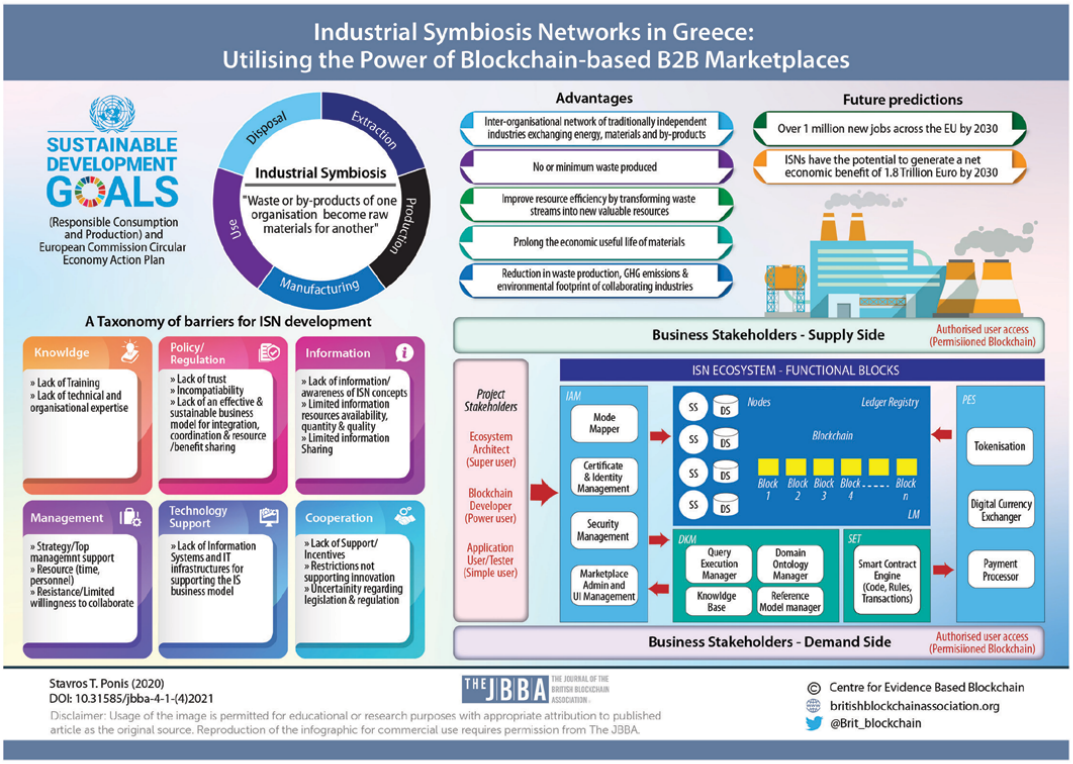

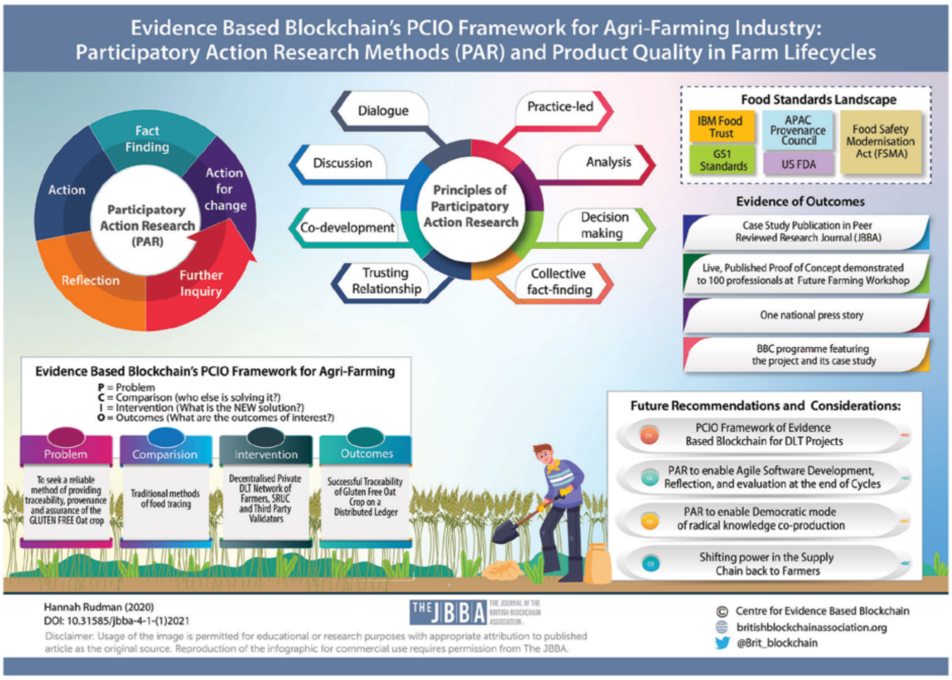

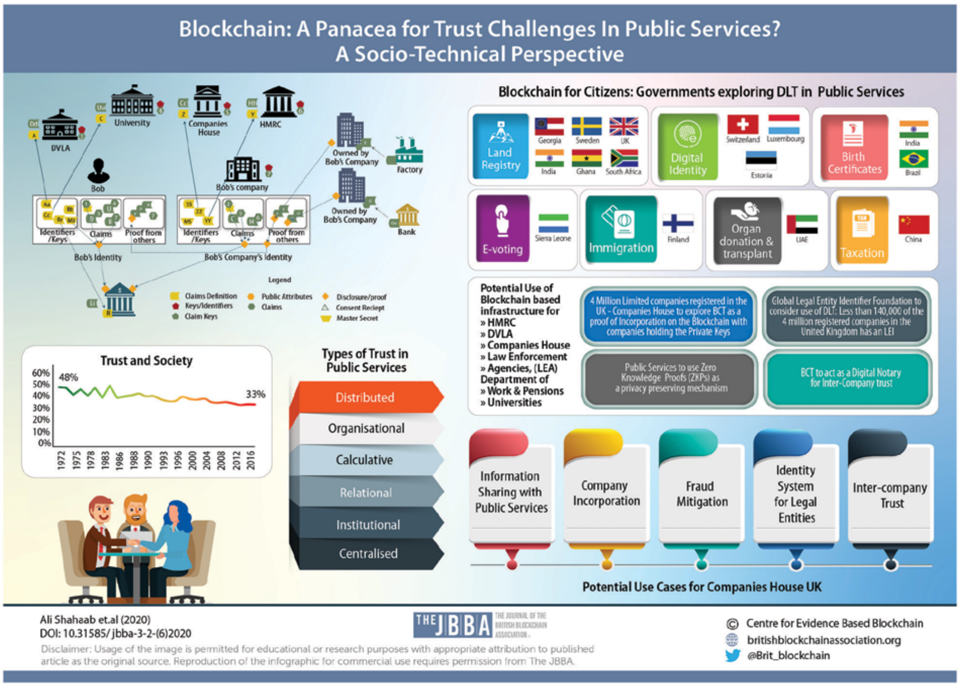

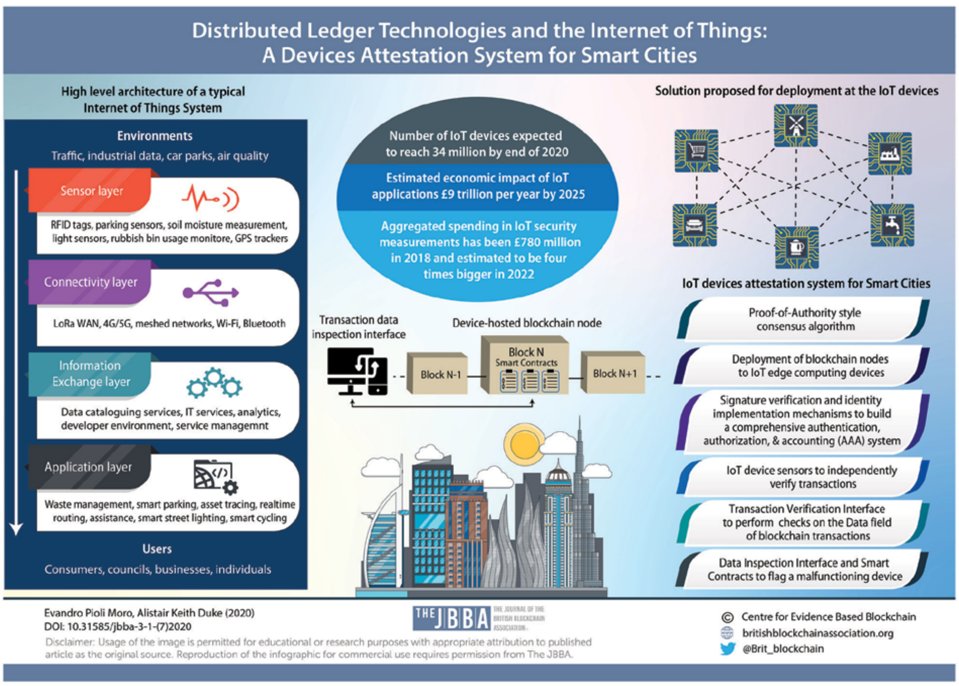

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EDITORIAL

It gives me great pleasure to present to you the 8th issue of *The Journal of the British Blockchain Association* (The JBBA).

This is a special edition featuring the *Excellence Standards Framework of UK's National Blockchain Roadmap (NBR)*, published by the Centre for Evidence Based Blockchain (CEBB) in July 2021. As countries around the globe begin to work on their national DLT strategy, it is paramount that policies are made based on high quality evidence, backed by peer reviewed scientific research. To put together this roadmap, the Centre for Evidence Based Blockchain undertook an analytical review of over 5000 blockchain research papers, evidence synthesis of more than 2000 DLT case studies and multi-stakeholder, strategic consultations with enterprises, academics and the policymakers over an 18 months period.

The journal continues to publish cutting-edge research on topical issues related to crypto assets and distributed ledger technologies. The papers featured in this issue are:

1. Consortium Capabilities for Enterprise Blockchain Success
2. Blockchain-hosted Data Access Agreements for Remote Condition Monitoring in Rail
3. Principles of Natural Resource Economics for Bitcoin
4. Blockchain Network as a Platform: Conceptualising its Adapted Layered Architecture Design

Cryptocurrencies' Proof of Work energy consumption has been a topic of significant interest to environmental activists, policymakers, and green energy advocates. The paper from Goorha on Bitcoin mining attempts to establish principles of natural resource economics for bitcoin and should hopefully provide an impetus for further exploration. I believe the question here is not that Bitcoin consumes energy; the question is, "Is the bitcoin energy consumption appropriate and fair for its operations, being one of the world's largest digital asset infrastructure that is securely maintained without a trusted third party?"

The challenges of establishing an effective blockchain consortium is an important debate. What makes a DLT consortium successful? How do we know it has been successful? The paper by *Koffman* et.al, sheds some light on the capabilities for the formation of an effective blockchain consortium.

Supply chain, transport and logistics have been one of the best explored use cases for Blockchains. The paper by *Alzahrani* et.al, on Blockchain hosted data access for remote rail monitoring is an exciting new area for further research in the use of DLT for transportation.

Blockchain applications are often a multi-layered stack and it is essential for a DLT solution to conceptualise its layered architecture design in order to understand the synergies among different layers and the external adaptability to business systems – something that is explored in the research from *Runyu Shi* of University of Warwick.

One of the most pressing questions in the DLT space right now is: "What ethical values do we uphold as a blockchain professional?" - British Blockchain Association has recently put forward the "Standards Charter" outlining the 12 'Codes of Conduct' for a blockchain professional. It is our moral, ethical, and legal obligation to act honestly with the stakeholders, be accountable to the society, and have a life-long commitment to highest standards of professional competence and excellence.

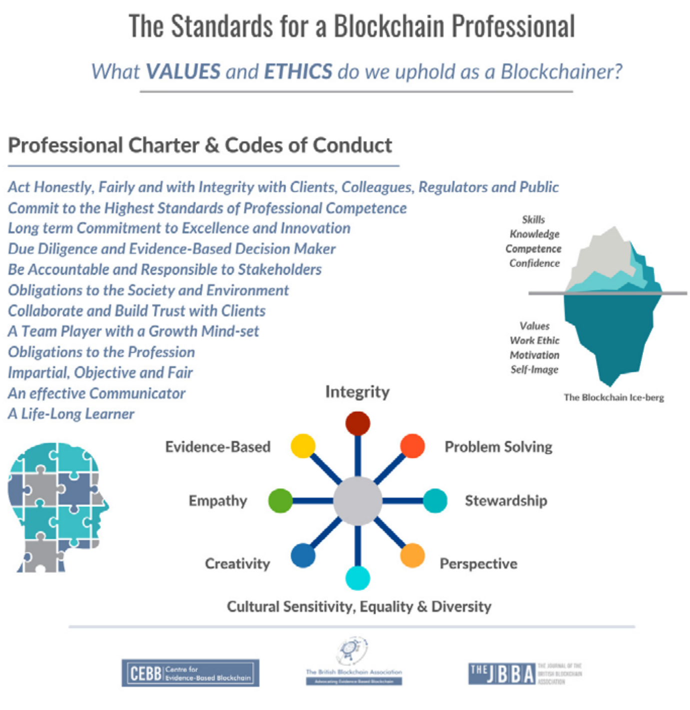
The journal continues to expand its global operations and editorial board. In the past three months, we have added over a dozen external reviewers as well as contributing to the global dialogue on evidence-based adoption of blockchain. Our plain language infographics have become so popular that they are being discussed during university lectures and policy meetings around the globe!

On this note, I would like to thank all our editors, reviewers, authors, readers, managerial staff, PR and communications teams, journal's academic partners – as well as JBBA's friends and well-wishers for their continued support of the journal.

I would very much welcome your feedback – please do write to us at editorial@thejbba.com with your suggestions on how to improve the quality and reach of the JBBA.

Yours truly

Dr Naseem Naqvi FRCP FBBA
Editor in Chief
President, The British Blockchain Association
Chair, Centre for Evidence Based Blockchain (CEBB)



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" The JBBA has an outstandingly streamlined submissions process, the reviewers comments have been constructive and valuable, and it is outstandingly well produced, presented and promulgated. It is in my opinion the leading journal for blockchain research and I expect it to maintain that distinction under the direction of its forward-looking leadership team.

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" The JBBA has my appreciation and respect for having a technical understanding and the fortitude for publishing an article addressing a controversial and poorly understood topic. I say without hesitation that JBBA has no equal in the world of scientific Peer-Review Blockchain Research.

Professor Rob Campbell, Capitol Technology University, USA "

" I had a professional experience of publishing my work in The JBBA. The feedback from reviewers and editors certainly helped to turn my manuscript into a better publication. JBBA's cross-disciplinary publishing platform is crucial to enable the blockchain sector to flourish. The journal strongly advocates evidence-based outcomes, essential to differentiate sound research papers from those that are not.

Dr Joshua Ellul PhD, Chair, Malta Digital Innovation Authority "

" The opportunity to interact with JBBA's expert reviewers and their valuable feedback helped us greatly in our project. I feel honoured to have my paper featured in the JBBA. Peer reviewed research is the foundation to build best-in-class Web3 platforms.

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" I would like to think of the JBBA as an engine of knowledge and innovation, supporting blockchain industry, innovation and stimulate debate.

Dr. Marcella Atzori PhD, EU Parliament & EU Commission Blockchain Expert, Italy "

"Very professional and efficient handling of the process, including a well-designed hard copy of the journal. Highly recommend its content to the new scientific field blockchain is creating as a combination of CS, Math and Law. Great work!

Simon Schwerin MSc, BigChain DB and Xain Foundation, Germany"

"Our group submitted a paper to ISC2021. The paper was reviewed, accepted and subsequently published in The JBBA. We were quite impressed by the speed of the review cycle and submission to publication time. JBBA has become an important journal in the field of Blockchain, given its efficient reviews and timeliness in the publication of research articles."

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"I had the honour of being an author in the JBBA. It is one of the best efforts promoting serious blockchain research, worldwide. If you are a researcher, you should definitely consider submitting your blockchain research to the JBBA.

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"It has been a pleasure working with the JBBA's editorial team. The submission process was transparent and the reviews were accurate and meaningful, adding great value to the manuscript.

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"The articles in the JBBA explain how blockchain has the potential to help solve economic, social, cultural and humanitarian issues. If you want to be prepared for the digital age, you need to read the JBBA. Its articles allowed me to identify problems, find solutions and come up with opportunities regarding blockchain and smart contracts.

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"The whole experience from submission, to conference, to revision, to copy-editing, to being published was extremely professional. The JBBA are setting a very high standard in the space. I am looking forward to working with them again in future

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"The JBBA is an exciting peer-reviewed journal of a growing, global, scientific community around Blockchain and Distributed Ledger technologies. As an author, publishing in the JBBA was an honour and I hope to continue contributing to in in the future

Evandro Pioli Moro, Blockchain Researcher, British Telecommunication (BT) Applied Research"

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Blockchain Network as a Platform: Conceptualising its Adapted Layered Architecture Design

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Correspondence: mandyshiry@gmail.com
Received: 26 March 2021 **Accepted:** 19 April 2021 **Published:** 6 May 2021

Abstract

Digital platform as an organising logic has prominently reshaped the innovation activities in many sectors. Previous studies have extensively investigated the digital platforms from two views: economic view (i.e. as a sided marketplace) and engineering view (i.e. as an innovation infrastructure). Blockchain – a digital artefact that connects the distributed ledgers – resembles great overlaps and specifics to digital platforms. Building on this aspect, I first demarcate the Blockchain Product as a Platform (BPaaP) informed by the economic view and the Blockchain network as a platform (BNaaP) inspired by the engineering view. Given the scant of research around BNaaP, this research aims to depict the BNaaP's architectural design by drawing on the layered design of digital technologies. Using Ping An Group as a case, this research applies the thematic analysis method in analysing online open data. As the main contribution, this research proposes the Adapted Layered Architecture of BNaaP that consists of (1) three design layers (foundation layer, interaction layer, and application layer); (2) adapted business scenarios; and (3) environmental factors. The suggested architectural design implies the BNaaP's internal synergistic collaboration among layers and the external adaptability to different business contexts. Overall, this research provides a novel angle to understand the Blockchain phenomenon and brings insightful implications to Blockchain practitioners.

Keywords: *digital platforms; Blockchain platforms; Blockchain network; case study; thematic analysis*

JEL Classifications: *M15*

1. Introduction

Digital platforms that enable the value co-creation of multiple parties that are otherwise not connected have prominently reshaped our economy and daily life [1] [2]. Blockchain, as an emerging digital solution, resembles great similarities and distinctiveness to digital platforms. Specifically, past studies on digital platforms have well established two salient views: platform as a marketplace (i.e. economic view) [3] [4] and platform as an innovation infrastructure (i.e. engineering view) [5] [6]. The economic view emphasises the platform's effectiveness in enabling transactions among multiple parties that are otherwise disconnected. Blockchain echoes this view through its collaborative nature of the distributed ledgers and its subject to the network effects. Alternatively, the engineering view discusses how a platform can incorporate heterogeneous innovation while maintaining unity [7]. In this regard, establishing a Blockchain platform requires synergistic co-creation within its design structure and entails high adaptability to different contextual scenarios.

Informed by the economic view and engineering view are two possible pathways of studying Blockchain. The first strand considers Blockchain as a marketplace that enables value exchange among multiple parties. Very often, participants in the Blockchain market have a certain degree of a joint agreement on Blockchain product's value. This article defines this stream as Blockchain Product as a Platform (BPaaP). Examples include cryptocurrencies such as Bitcoin, Facebook's Libra, digital tokens, and the Initial Coin Offering (ICO). Platform participants are bounded by the common recognition of the digital product's exchange value and the collective objective to continually grow the value of Blockchain product.

The other stream proposes that the Blockchain's usefulness is not embedded in its transaction value but more emerged from its architectural design as an organisation logic. Shedding light on Blockchain's enablement of building and sustaining a network, this article defines this type of Blockchain as Blockchain Network as a Platform (BNaaP). Instead of focusing on digital asset transactions, BNaaP grants more efforts in articulating the overarching design of the Blockchain network. In other words, despite what products are transmitted through Blockchain, BNaaP emphasises on how Blockchain platform is established with multiple levels of complexity and is adapted to different business scenarios where platform participants may have diverse value exchange expectations.

Motivated by the importance of BNaaP as an organisation logic, this article aims to establish the fundamental ground of the architecture design of BNaaP. The case understudied is Ping An Group's Oneconnect Blockchain solution. I use the thematic analysis method to analyse online data and obtain some humanistic insights on BNaaP. The proposed Adapted Layered Architecture serves as a starting point that inspires future research on BNaaP specifics. It also provides insightful implications to practitioners who wish to utilise Blockchain to ignite business transformation.

2. Related literature

2.1 Digital platforms

The platform has been widely recognised and applied as an organisation structure that enables multiple parties to exchange value and incorporate external parties' innovation [8]. The different sides of participants, governance rules and regulations, and various platform resources form the platform ecosystem [1] [9]. Prior studies on platforms have been mainly built on two streams. The first stream is founded on the market nature of platforms. This economic view considers the platform as a mediator that facilitates transactions among multiple types of otherwise not connected users. Such user connection tradition is widely revealed by the two-sided or multi-sided organisation of platforms [3]. Catalysed by such sided-platform organisation is the network effects, which indicate the reinforced traction of growing one side of the platform users (e.g. app users) in attracting the other side (e.g. app developers). The platform's usefulness to each user is most likely to increase as more people join from the same side or the other side [4] [10].

Another popular stream of platform research is built on the engineering view. Unlike the economic tradition that highlights the transactional feature, the engineering view discusses how platforms can be a resource pool that facilitates external parties' innovation activities [6] [1]. In this regard, platforms often consist of a core product, on top of which are a set of platform resources (e.g. Application Programming Interfaces, Software Development Kits, and development guidelines) that aim to enable innovation from heterogenous developers [11]. The arm-length distance between platform owners and platform participants enables platforms to grow in generativity that extends the platform core product's usefulness. For example, to augment the Android operating system's generativity, Google has issued many platform resources to different participants such as the Google APIs and SDKs to developers, the hardware-abstraction layer, compatibility test suite, and MADA (mobile application distribution agreement) to Android device manufacturers, and some other user tools such as Android studio. In this regard, a platform can be viewed as a digital infrastructure that fulfils the core requirements of its intended users and entails flexibilities to be modified, updated, and adapted [12].
Digital platforms, as a design hierarchy, are greatly dependent on and enabled by the capabilities of digital technologies. Yoo, Henfridsson, and Lyytinen [13] suggest that different from the integral design hierarchy, which entails closely binded interdependency among different components and in between the product's functionality and its physical embodiment, the digital technologies are featured by reprogrammability and data-homogeneity. First, the reprogrammability implies the possible separation of the technology's functional logic and its physical embodiment. As long as the users agree on the digital resource's general meaning, they have much freedom to decide how they would like these resources to produce and perform. Users can combine different types of digital recourses to serve their user cases. Alternatively, they may re-engineer the usefulness of digital assets by modifying source codes. Second, the data-homogeneity ensures the consistency of digital data across devices and networks. It means digital data that was installed and altered on one device can be seamlessly synchronised in multiple places. The data-homogeneity enables the wider transmission of digital information and ensures the unrestcited user innovation on multiple devices.

The objective of exploring the Blockchain platform's design architecture brings the engineering view more relevant to this study. Inspired by Yoo et al. [13], this research will depict the Blockchain platforms' architecture design by drawing on the layered architecture design of digital technology. The layered architecture lays the foundation to view the Blockchain network as an integrated digital artefact formed of multiple functioning layers [14]. Inside each layer are many sub-systems and modules that correspond to different types of utilities.

2.2 Blockchain platforms

Since the debut of Bitcoin, Blockchain technology has gradually influenced business activities in many different sectors such as finance, manufacture, and public management. Widely known as a database formed by the distributed ledgers, Blockchain in nature resembles several common attributes to platforms regarding its features of connecting isolated entities and facilitating digital exchange [15]. However, Blockchain also exhibits many features that make it go beyond the scope of a sided-platform.

First, as a distributed ledger organisation, Blockchain presents the dissolved boundary of the same-side and cross-side network effects. Participants who contribute a new block to the existing chain are also users who benefit from the chain's increased usefulness. Because the ledger records all types of participants' activities (e.g. add transactions and modify information) on the network and publish these records to each participant [16], adding a new member or a new block to the chain network always implies a higher degree of information richness to each node [16]. More conservatively speaking, though some cross-side leverage relationship may exist (e.g. block contributor and block beneficiary), its significance on a Blockchain platform is much less than that on a typical sided platform.

Second, different from digital platforms where governance rules and practices are mostly performed by a central party, that is, platform owners, Blockchain allows decentralised governance [17]. The modification and alteration of Blockchain must pass the authentication of all members on the chain. There is no single entity that can enforce the dominant power to decide what can or cannot be done [18]. Besides, because participants in a chain network have a common agreement on disclosing information in return for a collective efficiency, a single entity can rarely manipulate the information asymmetry and make the entire Blockchain to privilege its own business. Such distributed governance and eliminated central dominance highlight the Blockchain platform's distinct differences from the conventional digital platforms.

Third, following decentralised governance, another benefit realised by Blockchain is digital trust. All data shared on the Blockchain network is encrypted. Members' rights to read and modify can be classified with classified deciphering keys. Therefore, participants, in general, have fewer concerns in hiding or manipulating the data integrity. Also, with the full records of the chain activities, the Blockchain entails high traceability which means that any intentional sabotage of chain integrity can be traced to its sources.

Upon establishing the overlaps and different features presented by digital platforms and Blockchain platforms, this article has introduced two meaningful Blockchain pathways: BPaaP and BNaaP. The BPaaP relies on the transaction nature of Blockchain platforms; the BNaaP offers an early emphasis on the value of Blockchain architecture as an organising logic. With ample empirical examples around BPaaP (e.g. Bitcoin and Facebook's Libra), this research aims to shed light on the unique value of BNaaP. To offer some fundamental groundings to this research stream, I will investigate the architectural design of BNaaP. The depicted framework aims to open new venues for future research and offer blueprint guidance to practitioners.

3. Methodology

To investigate the architecture design of the BNaaP, this research will conduct a case study. As an explorative research, the data used in this research mainly consists of internet-based qualitative data. The thematic analysis method will be applied to gain insights from online data.

It is noted that the case study "is not a methodological choice but a choice of what is to be studied" [19]. Given the early spread of Blockchain and the scant empirical evidence, doing a case study has substantial usefulness to acquire new experiences, humanistic understanding, and knowledge about this theme [20] [21]. In this regard, an in-depth exploration of the single case helps understand the Blockchain architecture's complexity and particularity [22] [23]. The case selected in this study aims to constitute a representative member of larger organisation groups [24]. And the knowledge gained from this single case is deemed to provide naturalistic generalisability [20].

This research follows Braun and Clarke's [25] thematic analysis method to analyse online qualitative data. By definition, the thematic analysis "is a method for identifying, analysing, and reporting patterns (themes) within data" [25]. In other words, it offers the possibility to capture the meaning of data by identifying different themes and their associations from the data. Adopting the thematic analysis method fulfils the objective of this study in the following two ways:

First, the thematic analysis does not hold a committed subscription to the development of a theory. According to Braun and Clarke [25], for an under-researched area, rather than theory building, the thematic analysis can capture predominant and important themes in relation to the available dataset. Applying this method may sacrifice the depth of analysis, but the overall description and articulation will be well captured and maintained [25] [23]. Second, the thematic analysis entails some allowance for the researchers to preconceive a certain degree of coding direction informed by other theories. This feature demarcates thematic analysis from the grounded theory, which often implies the delayed literature engagement [26]. In this research, some insights from the platform literature essentially help to sensitise themes and interpret the Blockchain network architecture. Therefore, applying thematic analysis with wide references to platform studies well fulfils the research objectives.

4. Data and analysis

Blockchain technology has received rapid development in the past five years in China. In line with digital technology's prominence, the National Strategic Development department strongly emphasises the Blockchain's vital influence on the future economy. To highlight, the National Plan for Information Technology during the Period of the Thirteenth Five-Year Plan (2016-2020) remarked Blockchain as a frontier weapon for the new wave of national development and competition. Over the years, some national authorities and relevant institutions gradually issued a series of documents, guidance, regulations, and industry standards to incentivise Blockchain innovation.

The case studied in this research is Ping An Insurance (Group) Company of China, Ltd. Established in 1988, it is one of the largest financial service providers in mainland China and ranked 29th in Fortune Global 500 in 2019. As a financial institution with a highly diversified business portfolio, Ping An Group has always adhered to the "finance + technology + ecosystem" principle. In recent years, Ping An Group has extensively innovated with different digital technologies. It revolutionized the bank operations using Artificial Intelligence technologies that helped to build an open banking system and connect bank users, clients, and business partners. This AI banking intelligently managed business operations and monitored risks at a larger scale. Besides, Ping An Group also launched its OneConnect subsidiary. With 161 patents, the OneConnect's Blockchain solution has seen successful deployment in many business sectors such as finance, cross-border trade, estates, automobile, healthcare, and smart-city. The OneConnect's Blockchain solution is designed as an infrastructure that facilitates business activities on a network basis, thus serving as a valuable empirical case to this study.

Guided by the thematic analysis method, this study primarily obtained data from Ping An Group's online official publications. The dataset includes (a) 12 annual and semi-annual reports from 2014 to 2019 published by Ping An Group – these documents precisely reveal the firm's trajectory of digital advancement over the years; (b) 27 newsletters and 4 "white page" documents published by Ping An's OneConnect Research Institution – these documents provide detailed insights, particularly on the development, deployment, and regulations around the Blockchain application; (c) multiple media data sources, including 7 online interviews and public speech clips from Ping An's Co-CEO and Chief Innovation Officer; and (d) 32 articles published by media and research organisations such as Bloomberg, OECD, China Academy of Information and Communications Technology, and International Data Corporation (IDC). These documents supplement an alternative angle to assess the Blockchain's application in different industries and its business impacts.

The thematic analysis of the collected data is applied with the six-step analysis suggested by Braun and Clarke [25]. First, media data in video forms are transcribed into scripts. All collected data are cleaned and saved into Nvivo software and are read twice by the researcher to gain initial sensitisation. Second, each document is analysed with open coding strategies. Nodes are coded to data blocks whenever they are implying "basic segment, or element of the raw data or information that can be assessed in a meaningful way regarding the phenomenon" [25]. This step results in 45 first-level nodes and 29 sub-level nodes. Third, the coded nodes obtained in the second step are reviewed and sorted into 14 potential themes, which can best capture coded data's core meaning. Up to this stage, a thematic map draft is made with relationships and associations of all themes. Before moving on to the theme refinement, two graduate students are involved as research assistants to read all documents independently and review all the nodes. Fourth, the researcher revisits all coded data and the proposed themes. This stage mainly investigates the internal homogeneity within each theme and the external heterogeneity among themes [24]. Besides, this stage also engages the evaluation of the theme's "accurate representation" of the entire dataset [25]. Fifth, each theme's essence and the thematic map are re-assessed with several iterations of data review. In the last step, the thematic map is finalised. Themes are defined, interpreted, and discussed with data extracts.

5. Results

Figure 1 presents the proposed architectural design of BNaaP. The term "layered" describes how the Blockchain platform is developed and managed. The term "adapted" implies its applicability and adaptability when implemented in different business scenarios. In the following, I will explain each conceptualisation construct with empirical evidence.

5.1 Foundation layer

The foundation layer describes the technical specifications that are necessary for establishing a Blockchain platform. Three subordinate layers are included. First, the technological layer deals with hardware and software solutions that substantially enable Blockchain functionalities. For example, the request-response module deals with the ongoing tension between the block size and processing transactions' speed. A larger block size enables high throughput. However, when transaction volume is low, such a large block design often leads to high latency. Ping An's "smart block" solution adopts the block-less structure, which can achieve almost real-time responses without reducing transaction throughput.

Second, the functional layer involves digital solutions that aim to ensure the integrity, authenticity, and accountability of chain functionality and operation. For instance, in the cryptography module, Ping An patents its 3D zero-knowledge proof technology, which can verify data and statements within three milliseconds without revealing the real information enclosed in the block. Besides, at the functional layer, the management of digital keys is also a critical task in sustaining Blockchain operation. It determines whether the Blockchain can maintain its operation quality with a high level of security.

Third, the operational layer deals with Blockchain's usefulness and effectiveness in supporting different user needs. This layer consists of some deployment tools and management tools. For example, OneConect's Blockchain invented many primary and add-on business-specific functionalities for a different category of users. Specifically, it enables customised asset record format, allows asset liquidation based on users' changing status, and monitors abnormalities with the user-defined Web interfaces. Compared to the technological and functional layers, the operational layer focuses more on the business operation aspect and the user-interface design.

5.2 Interaction layer

While the foundation layer ensures the well-functioning of the Blockchain, the interaction layer embodies the possibility of forming a Blockchain platform using some boundary resources. Three types of boundary resources are involved. The general APIs allow a chain to quickly incorporate some commonly used functionalities such as identity management and digital contract. The industry APIs are groups of interfaces that are designed to fit the needs of a specific industry. It allows some industry-level services to be incorporated instantaneously. For example, in the international trading context, such APIs may involve orders, invoices, and logistics. The third interactive element is the cross-chain APIs. This type of APIs is widely engaged when a Blockchain network wants to connect with an external Blockchain network. Overall, the foundation layer ensures the usefulness of the interaction layer. And the interaction layer extends the capabilities and scalability of the foundation layer.

5.3 Application layer

The application layer describes the possible means and complexity when deploying a Blockchain network. Companies and consumers can decide to join an existing Blockchain network by instantaneously attaching themselves to the Blockchain nodes. Alternatively, they can operationalise the foundation layer and the interactive layer to initiate a new Blockchain network. Depending on the business needs, joining an existing Blockchain network will benefit the joined party with pre-existed network value. Because the incumbent Blockchain network has already acquired a large number of relevant business partners, built relatively mature procedures, and tested its operational efficiency and security standards. Nevertheless, creating a new Blockchain network may be necessary if no existing chain fits the business requirements. Moreover, enterprises may also consider building a new Blockchain platform as a means of leveraging and re-engineering the network value of their business circles.

5.4 Adapted business scenario

Conceptualising the BNaaP architecture is not completely done if we omit the varying implementation business scenarios. The business scenarios indicate the purposes and contexts of the Blockchain network. Because the types of business activities, the potential capacity of the network, and the required standards and regulations will all affect the operation and management of the Blockchain platform. For example, Ping An Group helped Hong Kong Monetary Authority to establish an eTradeConnect Blockchain platform. This platform involved 12 international banks from the Hong Kong region and an independent trading platform (we.Trade) in Europe. The Blockchain platform's global orientation required Ping An to ensure that all designs at the foundation and interaction layer were complying with both parties' legal obligations. However, in the other case, Ping An's Blockchain platform was used by a Chinese local government to achieve faster document transmission and communication with those connected organisations. In such a context, the Blockchain's compliance to international legal obligations became less relevant. The Blockchain's flexibility in adapting to users with different levels of technical know-how and distinct habits of sharing documents became a central challenge.

5.5 Environmental factors

The environmental factor is a critical element that influences the establishment and growth of Blockchain platforms. This factor contains multiple parties that are either directly or indirectly engaged in the Blockchain development. Informed by the Ping An's Blockchain network, environmental factors' impacts can be grouped into four categories: (1) Monitor. While encrypted data is only readable for the trading parties on the chain, the national monitoring authority may have full access to view all the trading information. (2) Regulate. The Cyberspace Administration of China has issued a series of Blockchain-relevant regularities that have enforcement power to all Blockchain applications. (3) Arbitrate. On Ping An Blockchain, signing an electronic contract is under the supervision of the National Notarization and Judicial Departments. If there is any dispute, the notary department will intervene. (4) Certificate. The data security suite adopted by Ping An Blockchain has obtained the National Certification of Level 3 Information Security Protection provided by the Ministry of Public Security.

Besides, it is worth noting that the development and growth of the Blockchain platform also recursively feedbacks fresh insights into the environmental factors' alteration and improvement. For instance, Ping An's 3D zero-knowledge proof technology and its crypto-controlled data sharing technology significantly accelerate the modification of Blockchain security regulations at the industrial level.

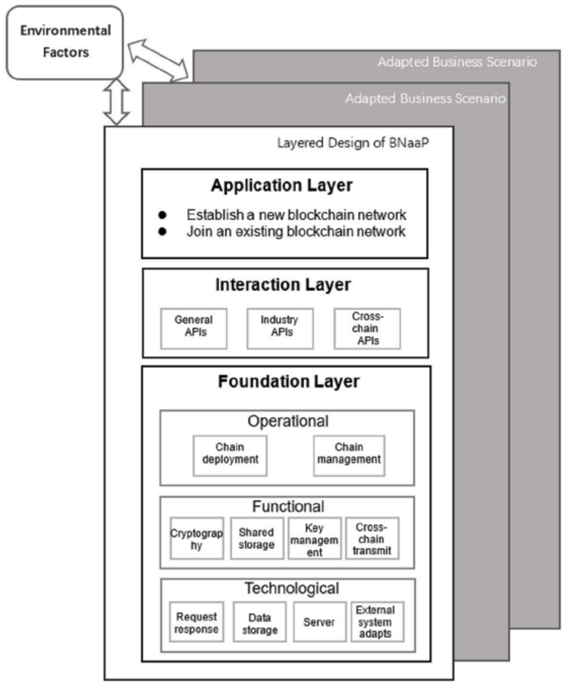

Figure 1: The Adapted Layered Architecture of BNaaP.

6. Conclusion

Inspired by the similarities and differences of digital platforms and Blockchain network, this study, for the first time, suggests two potential pathways of viewing and studying Blockchain phenomenon: BPaaP and BNaaP. Given the scant attention to the BNaaP, this research aims to arouse interests towards this stream by investigating its architectural design. The proposed Adapted Layered Architecture of BNaaP depicts a blueprint to practitioners who wish to leverage the power of Blockchain in igniting digital business transformation. Besides, it also serves as a starting point for future research to explore the formation and implementation of BNaaP from multiple aspects, including but not limited to the technical challenges, governance issues, business adaption considerations, and the bilateral relationship with environmental factors.

However, this research also presents some limitations. First, the data used in this research contains online open data published by the understudied case company. The officiality of these materials ensures data authentication and validity. Future improvement may involve an attempt to gain more first-party insights from interviews. Second, the aims of gaining knowledge on the overarching design of BNaaP neglect the importance and complexity of the "adapting" processes. Future studies can approach this aspect by adopting the process view to study Blockchain's adaption tactics and specifics in relation to different business factors.

References:

[1] M. G. Jockbides, A. Sundararajan and M. Van Alstyne, "Platforms and Ecosystems: Enabling the Digital Economy," World Economic Forum, Switzerland, 2019.
[2] A. Tiwana, B. Konsynski and A. Bush, "Platform Evolution: Coevolution of Platform Architecture, Governance, and Environmental Dynamics," Information Systems Research, vol. 21, no. 4, pp. 675–687, 2010.
[3] J. Rochet and J. Tirole, "Two-Sided Markets: A Progress Report.," RAND Journal of Economics, vol. 35, pp. 645–667, 2006.
[4] M. Armstrong, "Competition in Two-Sided Markets," RAND Journal of Economics, vol. 37, pp. 668–691, 2006.
[5] A. Gawer, "Bridging Differing Perspective on Technological Platforms: Toward an Integrative Framework," Research Policy, vol. 43, pp. 1239–1249, 2014.
[6] K. Clark, "The Interaction of Design Hierarchies and Market Concepts in Technological Evolution," Research Policy, vol. 14, no. 5, pp. 235–251, 1985.
[7] K. Karhu, R. Gustafsson, B. Eaton, O. Henfridsson and S. Carsten, "Four Tactics for Implementing a Balanced Digital Platform Strategy," MIS Quarterly Executive, vol. 19, no. 2, pp. 105–120, 2020.
[8] G. Parker, M. Van Alstyne and X. Jiang, "Platform Ecosystesm: How Developers Invert The Firm," MIS Quarterly, vol. 44, no. 1, pp. 255–266, 2017.
[9] A. Tiwana, "Platform Synergy: Architectural Origines and Competitive Consequences," Information Systems Research, vol. 29, no. 4, pp. 829–848, 2018.
[10] M. Rysman, "The Economics of Two-Sided Markets," Journal of Economic Perspectives, vol. 23, no. 3, pp. 125–143, 2009.
[11] M. Meyer and A. Lehnerd, "The Power of Product Platforms: Building Value and Cost Leadership," New York: Free Press, 1997.
[12] S. Wheelwright and K. Clark, "Creating Project Plans to Focus Product Development," Harvard Business Review, vol. 70, no. 2, pp. 67–83, 1992.
[13] Y. Yoo, O. Henfridsson and K. Lyytinen, "The New Organising Logic of Digital Innovation: An Agenda for Information Systems Research," Information Systems Research, vol. 21, no. 4, pp. 724–735, 2010.
[14] D. Teece, "Economics of Scope and the Scope of the Enterprise," Behavior and Organization, vol. 1, pp. 223–247, 1980.
[15] Z. Zheng, S. Xie, H. Dai, X. Chen and H. Wang, "An Overview of Blockchain Technology: Architecture, Concensus, and Future Trends," Honolulu, USA, 2017.
[16] M. Nofer, P. Gomber and O. Hinz, "Blockchain," Business & Information Systems Engineering, vol. 59, pp. 183–187, 2017.
[17] R. van Pelt, S. Jansen, D. Baars and S. Overbeek, "Defining Blockchain Governance: A Framework for Analysis and Comparison," Information Systems Management, vol. 38, no. 1, pp. 21–41, 2021.
[18] R. Beck, C. Muller-Bloch and J. King, "Governance in the Blockchain Economy: A Framework and Reseach Agenda," Journal of the Association for Information Systems, vol. 19, no. 10, p. Article 1, 2018.
[19] R. Stake, "Qualitative Case Studies," in The Sage Handbook of Qualitative Research, Thousand Oaks, CA: Sage, 2006, pp. 433–466.
[20] R. Stake, "The Case Study Method in Social Inquiry," Educational Researcher, pp. 5–8, 1978.
[21] R. Boyatzis, "Transforming Qualitative Information: Thematic Analysis and Code Development," Thousand Oaks, CA: Sage, 1998.
[22] R. Stake, "The Art of Case Research," Thousand Oaks, CA: Sage, 1995.
[23] H. Simons, "Case Study Research in Practice," SAGE Publications, 2009.
[24] M. Patton, "Qualitative Evaluation and Research Methods (2nd ed.)," Newbury Park, CA: Sage, 1990.
[25] V. Braun and V. Clarke, "Using Thematic Analysis in Psychology," Qualitative Research in Psychology, vol. 3, no. 2, pp. 77–101, 2008.
[26] Urquhart, "Grounded Theory for Qualitative Research," SAGE Publications, 2013.

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Principles of Natural Resource Economics for Bitcoin

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Abstract
To assess claims such as Bitcoin is 'digital gold' it makes sense to examine whether Bitcoin exhibits features common to other exhaustible natural resources that are the concern of natural resource economists. We therefore present some foundational ideas in the economics of exhaustible resources and examine their relevance to Bitcoin. There are several useful similarities but also some key differences, chiefly with respect to how miners manage inventories, or their 'inventory policy'. Therefore, to highlight this aspect, we use a simple model for any physical natural resource and introduce sensitivity to a capital-to-energy ratio. The resulting policy for Bitcoin miner over a halving cycle is not unlike a traditional miner in that optimal inventories are determined by optimal capital investments over the entire duration of the cycle.
Keywords: *Bitcoin, miner, exhaustible resources, inventory policy*
JEL Classifications: *Q3, D21 and G31*

1. Resource Economics and Bitcoin

The claim that Bitcoin is 'digital gold' rests first and foremost on the soundness of the idea that Bitcoin behaves like a traditional exhaustible resource[1]; that it is more akin to gold than any other depletable resource relies further on the premise that it is relatively scarcer than gold. To that end, it is significant that Bitcoin has been programmed to mimic the essential characteristics of an exhaustible resource: its extraction rate approaches 0 over time and the total yield feasible from 'mining' is limited to 21 million bitcoins. It is, therefore, worth examining what analytical value the economics of exhaustible resources provides for the case of Bitcoin.

The economics of exhaustible resources has one rather simple and compelling analytical premise. It is that the opportunity costs incurred from current extraction and consumption of an exhaustible resource must be weighed against the fact that limited supplies ought to generate returns over time. A miner must, therefore, consider both the market value of a resource and the opportunity costs of current extraction in its investment decisions. The price of any such depletable resource should exceed its marginal cost of extraction to capture any logic of an exhaustible resource being used in the present rather than the future, the 'excess' representing the opportunity cost of intertemporal substitution in consumption.

While the market value of the natural stock of an unextracted resource depends on the prevailing market price and the attendant costs of bringing the resource to the market, the opportunity costs depend on trading off future consumption possibilities with present use as well as considerations on the present value of the rent that is destroyed by extracting in the present rather than leaving the resource in situ for the future.

The difference between marginal extraction costs and the price is often called the *Hotelling rent* in recognition of Hotelling's seminal 1931 paper [2]. It further follows from the preceding observations that the rate of change in price of the depletable resource must equal the interest rate that a miner uses to discount the future, and this is known as the *Hotelling* r *-percent growth rule.* Whenever marginal extraction costs are zero, the price of the resource in stock and that of the unmined resource are equivalent and the Hotelling rule applies equally to both. If, however, extraction costs increase over time, the price of the resource rises at less than the discount interest.

Thus, all things being equal, an increase in the discount rate implies a higher price for the unextracted resource and would incentivise a faster rate of extraction. In Bitcoin, while the rate of extraction is algorithmically fixed for any given halving cycle, mining *effort* can readily be increased. Further, miners arguably discount hyperbolically for the simple reason that the total remaining in situ stock is known in advance as well as the fact that extraction costs are likely to rise exponentially into the future as all miners increase efforts.

A relationship between Bitcoin and the economics of natural resources has been examined in a few other papers. [3] presents a continuous-time model for the inventory policy of miners in Bitcoin that permits examining how miners optimise over the income generated from transaction fees, while also accounting for risks that emanate from demand-side shocks. By contrast, the ambition of this chapter is to present a simple model that places emphasis on highlighting the parallels in Bitcoin with natural resource mining and examines the inventory policy of Bitcoin miners over the course of a halving cycle. In this ambition, a notable contribution is the empirical analysis presented in [4]. The authors discuss the importance of the Hotelling rule to natural resource and energy economics, provide a useful review of the literature and, using Bitcoin as a case study, show strong support in the data that mining rents in Bitcoin are associated with the market rate of return.

1.1 Some Slight Differences

The Hotelling *r*-percent growth rule is sensitive to several factors in practice that have useful analogies in Bitcoin.[2,3] These include: (a) the marginal cost incurred by the miner in exploration and extraction of the resource, which in the case of Bitcoin depends on the network difficulty and the requisite hashrate[4]; (b) the perceived scarcity of the resource, i.e. the point on Bitcoin's overall trajectory of bitcoins mined relative to its absolute cap or total depletion; (c) the level of competition in mining, or, for Bitcoin, the relative hashrate of a miner to the overall hashrate being deployed by other miners across the network.

Being a digital resource, the size of the resource 'field' to be explored in Bitcoin over time can, in theory, increase *or* decrease in proportion with the exploratory effort of the miners. The miners deploy the hashpower of their mining rigs in order to increase the probability that their efforts to solve the cryptographic problem[5] are successful, thereby earning them the right to add their block to the Bitcoin blockchain and receive the block reward. The more hashpower that is brought to bear across the network, the higher the difficulty[6] of the cryptographic problem and vice versa, essentially adjusting the size of the resource field for miners based directly on their efforts. This isn't very different from any exhaustible natural resource that has increasing extraction costs over the long run with periods of falling costs that eventuate from new discoveries of resource sites or cost-saving technologies.

In contrast with any other natural resource, Bitcoin's exhaustion trajectory is *far* more deterministic. Many of the other features immanent to Bitcoin are, as a matter of fact, similar in nature to the assumptions made by Hotelling [2] in that Bitcoin mining is competitive,[7] the overall stock of bitcoins *is* known exactly and that, while technology for mining does improve, it does so in lock-step with the algorithmically adjusted difficulty for mining. Thus, the Hotelling rule ought to provide at least a useful starting point for the case of Bitcoin.

As opposed to exhaustible natural resources, where the Hotelling rent depends on whether the resource is left in situ, decisions on timing when to mine bitcoin, however, isn't a free variable. While miners frequently do pool their resources into one of several larger mining pools to maximise their chances of finding a block, in general, mining cannot be unitised in Bitcoin in any meaningful way. Thus, bitcoins *are* mined competitively and with a *strictly* decreasing yield over time – a block reward that halves roughly every four years. Further, with Bitcoin, there is no possibility of unexpected discoveries or new technologies making currently inaccessible reservoirs of resources suddenly available for exploitation.

1.2 And a Key Point of Difference

It is well established that excessive competition in the rapid exploitation of a resource leads to social waste; a common property problem of restricting access drives the familiar tragedy of the commons. Bitcoin, however, expressly relies on and exploits the incentives that create the common property problem. While the mining of bitcoins is governed by an algorithmic mechanism that encourages 'excessive' competition, the value of the resulting waste that accrues from this mad rush of mining is internalised to the security of the Bitcoin network, since higher network hashrates directly result in commensurate difficulty increases.[8]

Since bitcoins are not perishable, a miner's decision on production efforts over the extraction time path is interlinked with its policy over inventory levels. In contrast to a miner that mines a perishable natural resource competitively, a miner in Bitcoin selects a time path for the rate at which it adds to its inventory rather than the rate of extraction, which is exogenous. The reservation demand of miners – or the mined bitcoins that are held in inventory by miners – is influenced, in equilibrium, by the return that their stores generate, which must be equal to the return that the miners can achieve from alternate assets.[9]

So the available supply of bitcoins, b_t , during period t depends on the coins mined during t , $\mathbf{m}_t$, and the stock of bitcoins sold by miners from their inventory, $\mathbf{v}_{t-1}$. 'Consumption' of bitcoins during t must equal the available supply net of the number of bitcoins that miners hold back in their inventory. Thus, $b_t = \mathbf{m}_t + \mathbf{v}_{t-1}$ and $\mathbf{c}_t = b_t - \mathbf{v}_t$. The inventory level is drawn down if the mining costs incurred between periods exceed the expected return from bitcoin as estimated by miners, r_b. Thus, the price of the bitcoins held in inventory by the miners must be greater than or equal to the costs they incur to store the coins, w , and the rate of return that they expect to receive on their inventory. In other words, for $v_t < 0$:

$$P(b_t - v_t) = {}^{1}/_{r_b}\, E[P(v_t + m_{t+1} - v_{t+1})] - w$$

The Hotelling growth rule suggests that, within each halving period for Bitcoin, prices would have to rise *at least* by the rate of interest for miners to be indifferent about whether to increase mining effort or to delay it. The difference between the rate of growth of the spot price and the interest rate modulates mining effort. Note that this is a different consideration for miners than their incentives to deploy costly hashrate in response to extant difficulty levels.

With high capital costs for mining, short-term supply is inelastic, adding a secondary factor to inventory levels, besides planned reservation demand; the more inelastic shorter-term supply is, the more price volatility we ought to expect from changes in demand. On the other hand, there are two countervailing effects that arise on market prices from a natural resource being stored in inventory, especially in the presence of speculative capital. While increasing inventories during periods of declining prices results in price depressions becoming less severe, disposing stocks from inventories curtails price spikes during periods of relative shortages in market supply. Figure 1 illustrates these effects for Bitcoin over the course of a year beginning in March 2020, using the metric of miner rolling inventory (MRI), which exceeds 100 when miners sell from inventories at a faster pace than they mine.

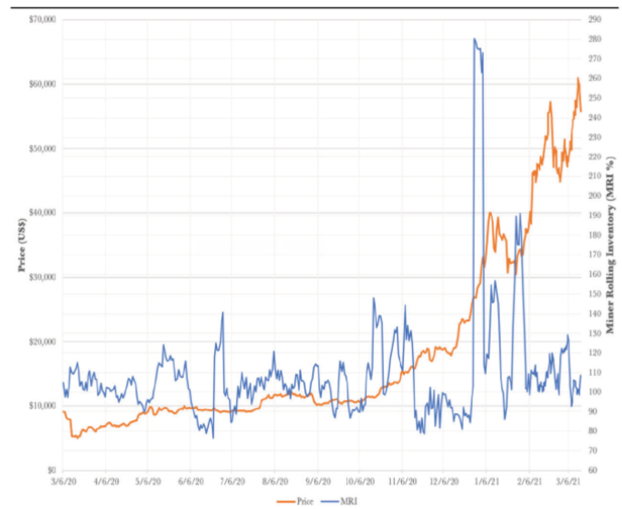

Figure 1: Miner Rolling Inventory and Price (Data Source: ByteTree*)*

In addition to reservation demand by miners, demand for bitcoins is often as a hedge against inflation and systemic risks; an increasing fraction of its consumers, be they individuals or institutional entities, use it as a store of value. As such, the asset is removed from active circulation and becomes the numeraire for measuring intertemporal wealth. Growing long-term inventories have the effect of modulating the Bitcoin market into even more of a traditional exhaustible and non-renewable scarce resource. In other words, when selling from inventory becomes *the* predominant source of supply in the market, the optimal time-path of production of traditional exhaustible resources becomes more applicable to the time-path of Bitcoin inventory depletion. For example, as demand becomes more inelastic with high levels of supply-side market concentration, the propensity to sell reduces. An increasing rate of resource depletion over time, coupled with the prospect of decreasing elasticity, *requires* the rate of growth in price to keep outstripping the discount rate. For a non-perishable good like Bitcoin, this creates a situation for intertemporal arbitrage and *increases* the marginal propensity to save in earlier periods. Indeed, both these patterns – price

growth rates far exceeding the discount rate and a high marginal propensity to save – have been characteristic of the majority of Bitcoin's history.
However, as the stock of a durable good increases, demand must grow at a faster rate than the discount rate for price to increase, regardless of the costs and rate of resource extraction. This can be seen as the minimum threshold for the rate of growth in demand for a stock-to-flow ratio to have a secular effect on price. The price profile has a U-shape for partially durable resources with growth in demand when mining is competitive. [5] Whether the logic applies to Bitcoin depends on whether it can be seen as partially durable. To the extent that the prospect of adverse regulation, elastic rehypothecation, lost wallets and hacked accounts decreases the fully durable characteristic of Bitcoin, this becomes more relevant.

2. Modeling the Bitcoin Miner's Inventory Policy

Given the particular importance of inventories, it is worth considering a stylised model for inventory policy in Bitcoin that underscores the relationship of the policy to optimising capital investments. As a digital resource, mining in Bitcoin depends most critically on the hashing power of the mining 'rigs' and their energy efficiency. Thus, the model gives scenarios for which inventory levels can vary between 0, 1 and some fraction between for a given cycle, depending directly on the optimal capital-to-energy ratio.

Assume that at time *t* a miner uses capital, $K(t)$ and energy, $E(t)$, as inputs in mining Bitcoin, $B(t)$. To simplify the analysis, assume that energy costs grow at a steady rate of $\alpha > 0$.
Thus, the rate of bitcoins extracted is given by the miner's production function $B(t) = F(K(t), E(t))$, where F provides constant returns to scale. The miner reserves some of the output as inventory $V(t)$ for investment and sells the rest to the market, $C(t)$, at prevailing prices to cover expenses. Thus, $B(t) = V(t) + C(t)$.

If the share of mined coins reserved for inventory is $v(t); v \in [0,1]$, we can write $C(t) = (1 - v(t))B(t)$.

Now assume that the deployed mining rigs become out of date at a rate $\zeta > 0$, governed by difficulty adjustments as well as exogenous improvements in technology. Therefore, the growth rate of capital for the miner is given by:

$$\dot{K}(t) = v(t)B(t) - \zeta(t)K(t)$$

In terms of units of energy expended, we can redefine these variables so that we have $\frac{B}{E} = b, \frac{V}{E} = v, \frac{C}{E} = c$ and $\frac{K}{E} = k$. Permitting $f(k) = F(k, e)$ allows us to state Bitcoin's average energy requirement in market consumption, $c(t) = (1 - v(t))f(k(t))$. We assume that $f(k)$ is concave, so that the marginal product of capital increases at a decreasing rate.

Logically, the capital deployment path for the miner depends on both the amount that is invested, in terms of capital's energy requirement, and through considerations over its obsolescence and associated considerations on the availability of energy. Therefore,

$$\dot{k}(t) = v(t)f(k(t)) - (\zeta + \alpha)k(t)$$

Crucially, the halving cycles for the block reward plays a key role in Bitcoin. It is, therefore, useful to consider a miner's benefit from a given halving cycle $[0, H]$ as $\int_0^H c(t)dt$, which then also determines the miner's strategy over inventory, $v(t)$, where $0 \le t \le H$.

In other words, the miner's optimisation problem can be stated as,

$$\text{Max} \int_0^H (1 - v(t))f(k(t))dt ,$$

$$\text{subject to } \dot{k}(t) = v(t)f(k(t)) - \beta k(t) ,$$

where $\beta = (\zeta + \alpha)$, $f_k(k) > 0$ and $f_{kk}(k) < 0$.

Choice over optimal inventory levels, $v^* \in [0,1]$ over the halving cycle for the miner is a function of the dynamics of the optimal capital-to-energy ratio, $k^*(t)$, over the period. We can assess the trajectory of the optimal inventory level, v^* , by appealing to the Pontryagin maximum principle *(PMP)*. To do so, we define a function, g^* , for which we assume $g_0^* > 0$ at $t = 0$, such that $\dot{g}^*(t) = -g_0^*(1 - v^*(t))f_k(k^*(t)) - g^*(t)(v^*(t)f_k(k^*(t) - \beta))$ and $g^*(H) = 0$.

The *PMP* then says that the Hamiltonian, H :

$$\text{H}(t, k^*(t), g^*(t), v) = (1 - v)f(k^*(t)) + g^*(t)(vf(k^*(t)) - \beta k^*(t))$$

is maximised by the optimal inventory trajectory.

- As the cycle approaches its completion – i.e. for *t* nearing H– g*(t)<1. With $g^*(t) < 1 \forall t < t[0, H]$, we would have $\dot{k}^*(t) = -\beta k^*(t)$ and optimal inventory over the entire halving cycle would just be zero and the optimal capital-to-energy ratio would simply be given by $k(0)^{-e\beta t}$.
- However, it is also possible for there to exist some time, $\hat{t}$, within the cycle where $g*(\hat{t}) = 1$, while $g^*(t) < 1$ for $t<H$. For the cases where the optimal inventory is positive, the situation is governed by whether k is above or below the steady-state rate of k , or the level of $\bar{k}$ that satisfies $f_k(\bar{k}) = \beta$. So, if at $t < \hat{t}$, $g^*(t) > 1$, it is the case that $k^*(\hat{t})$ is less than $\bar{k}$ and then $k(0)$ was less than $\bar{k}$, and we should expect $v^*(t) = 1$ for all
- Between these two extrema for the optimal inventory strategy, over the halving cycle there may be some positive spans of time for which $g^*(t) = 1$ or, in other words, $\dot{g}^*(t) = 0$. This suggests that $f_k(k^*(t)) = \beta$ and $k^*(t) = \bar{k}$ for that span of time. In turn, during that time $\dot{k}(t) = 0$ the optimal inventory policy is thus given by $0 < \beta\left(\bar{k}/f(\bar{k})\right) < 1.$

The model could be usefully extended to allow for a determinate time path of extraction in Bitcoin, since miners are often faced with additional considerations for their inventory policy. First, miners can readily adjust their optimal capital stock upwards in reaction to a bull market. They cannot, however, reduce capital stock swiftly in a bear market. While inventories can certainly help offset the costs of overcapitilisation in a bull market, they can also build during the bear market in anticipation of the next upward swing in prices and demand. Thus, rather than permitting obsolescence from higher difficulty adjustments in the network, miners are forced to be forward-looking in their inventory policy. Second, to the extent that a determinate extraction path forces the hands of miners in Bitcoin, the option value of investment can come from timing over selecting optimal capital levels (as in [9]) or from simply building up inventories.

3. Concluding Remarks

Examining Bitcoin as a digital resource not unlike a traditional natural resource permits us to seek some useful insights from natural resource economics. Indeed, as just another resource, the model presented above ought to seem intuitive, and miners of Bitcoin ought to behave largely like miners of any other physical resource.
The relevance of scarcity of a non-renewable resource to economic growth has largely only been muted on account of positive elasticities of substitution in production or by technological breakthroughs [10]. A contrary logic is applicable to scarce resources that are used as stores of wealth to the extent that they become effective additions to a diversified portfolio. It is particularly worth considering the effects of substitutability between Bitcoin and other physical stores of wealth, such as gold, rare collectibles and real estate.[10]

References:

[1] Fantazzini, Dean and Nikita Kolodin (2020) "Does the Hashrate Affect the Bitcoin Price?", Journal of Risk and Financial Management, Vol. 13, No. 11, pp. 263.
[2] Hotelling, Harold (1931) "The Economics of Exhaustible Resources", Journal of Political Economy, Vol. 39, pp. 137–75.
[3] Dai, Min; Wei Jiang; Steven Kou and Cong Qin (2021) "From Hotelling to Nakamoto: The Economics of Bitcoin Mining", NUS RMI Working Paper Series, No. 2021-01.
[4] Landry, Craig E; Dylan Turner and Jeffrey H. Dorfman (2019) "Hotelling Meets Crypto-Currency: Do Bitcoin Rents Follow Hotelling's Rule?", SSRN Working Paper.
[5] Devarajan, Shantayanan and Anthony C. Fisher (1981) "Hotelling's 'Economics of Exhaustible Resources': Fifty Years Later", Journal of Economic Literature, Vol. 19, No. 1, pp. 65–73.
[6] Goorha, Prateek (2020) "Bitcoinomics 101: principles of the Bitcoin market", Economics Bulletin, Vol. 40, Issue 1, 163–176.
[7] Hayes, Adam S. (2019) "Bitcoin price and its marginal cost of production: support for a fundamental value", Applied Economics Letters, Vol. 26, Issue 7, Pages 554–560.
[8] Levhari, David, and Robert S. Pindyck (1981) "The Pricing of Durable Exhaustible Resources", The Quarterly Journal of Economics, Vol. 96, Issue. 3, pp. 366–377.
[9] Arrow, Kenneth and Anthony C. Fisher (1974) "Environmental Preservation, Uncertainty and Irreversibility", Quarterly Journal of Economics, Vol. 88, pp. 312–320.
[10] Solow, Robert M. (2016) "Resources and Economic Growth", The American Economist, Vol. 61, Issue. 1, pp. 52–60.
[11] Cebrián-Hernández, Ángeles and Enrique Jiménez-Rodríguez (2021) "Modeling of the Bitcoin Volatility through Key Financial Environment Variables: An Application of Conditional Correlation MGARCH Models", Mathematics, Vol. 9, Issue 3, pp. 267.

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[1] See [1] for a recent comparison of Bitcoin (specifically, price and hashrate behaviour) in terms of established results in energy economics regarding the oil and gas industry.

[2] See [5] for a useful review of the literature inspired by Hotelling.

[3] We assume a basic familiarity Bitcoin; for the uninitiated, we suggest reading [6] and the literature cited in that paper.

[4] In this regard, [7] shows that the marginal cost of mining provides a strong support for the price of Bitcoin, making the analogy to natural resources stronger and to a pure speculative asset weaker.

[5] Recall that this involves using the SHA-256 hashing function twice, compressing arbitrary sized inputs into a fixed-length output in the process.

[6] Recall that the difficulty is adjusted by the Bitcoin code for every 2016 blocks, based upon whether the hashpower deployed over the network is trailing or leading a target of 10-minutes per block.

[7] The intuition is relatively straightforward. When an exhaustible resource is mined under conditions of monopoly, it will be extracted at a more gradual pace and price will remain above the marginal rate of extraction as it grows at a relatively more stable rate. Conversely, when the same resource is mined competitively, the rate of extraction will be higher, over a shorter horizon, and the price will grow faster over the entire period.

[8] This is not to say that, just like any other natural resource that is competitively exploited under rules of free access, mining in Bitcoin does not create social costs. Rather, the point is that competitive extraction creates an externality on network security in Bitcoin, which is an effect not seen with physical natural resources.

[9] To the extent that there are no real alternate uses for dedicated mining rigs, miners can really only engage in mining other proof of work cryptocurrencies to optimise their Hotelling rent.

[10] Most recently, [11] shows uncorrelation between Bitcoin and both gold and oil and correlation with stocks of companies associated with cryptocurrencies and electronic payment systems.

PEER-REVIEWED RESEARCH

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Blockchain-hosted Data Access Agreements for Remote Condition Monitoring in Rail

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Abstract

Advances in sensor technologies, remote authentication, and high-bandwidth data networks mean that Remote Condition Monitoring (RCM) systems are now an essential "Internet of Things" (IoT) resource for the efficient operation of railway infrastructure. However, the full potential of the big data generated by these systems has yet to be realised. RCM data within the industry is typically collected and used in silos, with limited possibility of exploitation across system boundaries. In 2013, the Rail Safety and Standards Board (RSSB), on behalf of the GB rail industry, established a cross-industry research programme, T1010, which aimed to build stronger cooperation between stakeholders and to enable sharing of RCM data. Building on the outputs of T1010, this work explores the use of blockchains and smart contracts (SC) in the automation, in an auditable and tamper-proof way, of commercial agreements for RCM data transfers in rail. By removing the limitations of paper-based agreements, we aim to enable innovation in shared business processes and stimulate the market for RCM data in rail. Leveraging existing smart contract-based schemes for trading and sharing IoT data over blockchain networks, we identify suitable methods for the enforcement of agreements and ensure fair cost attribution between stakeholders, without a trusted third party. The outline of a blockchain-based RCM data audit framework is presented, appropriate data access agreements and accounting models are specified in detail, and three permissioned blockchain platforms (Hyperledger Fabric, Sawtooth, and Iroha) have been analysed for their suitability for implementation. Finally, the chapter outlines planned future work around validation of the tools based on two industrial use cases: monitoring systems for unattended overhead line equipment and axle bearings.

Keywords: *big data, blockchain, Remote Condition Monitoring, cost attribution, process automation*

JEL Classifications: *L92, O31*

1. Introduction

The pursuit of higher quality services in the railway sector is a continuous process, and the availability in recent years of affordable, reliable, digitally enabled additions to traditionally mechanical-based infrastructure systems has provided a fruitful avenue for advancement. Remote Condition Monitoring (RCM) systems are one example of a tool that has been widely deployed to improve the standards of maintenance, reliability, and safety across the rail network. The advanced warnings of incipient faults provided by RCM data enable preventative maintenance to be performed before service-impacting failures arise, leading to reduced costs of disruption and increased passenger satisfaction. The perceived benefits of RCM have led the industry to install sensors on an ever-higher proportion of its assets, with a corresponding increase in the volume of data generated. In general, and according to [1], railway RCM operations can be divided into four major divisions (quadrants), which are defined by the location of the monitoring sensors and the assets being monitored: train monitoring train, infrastructure monitoring infrastructure, train monitoring infrastructure, and infrastructure monitoring train. In countries such as the UK, where the vast majority of the mainline rail infrastructure is maintained by a single Infrastructure Manager (IM), sensors that are mounted on assets belonging to one stakeholder but are being used to monitor assets related to another will, by definition, fall into the train monitoring infrastructure or infrastructure monitoring train quadrants; an example of this would be sensors mounted on the tracks that are used to detect wheel flats on the rolling stock [2]. Although this type of cross-interface monitoring of assets may be the most technically practical solution to many industry-wide problems, commercially they can prove complex as the business paying to install, maintain, and operate the sensing device is not the party benefitting from the data collected. As a result, it can be hard to generate business cases for the purchase, installation, and operation of cross-interface monitoring systems that would have recognised industry-wide benefits.

In order to address this issue, it is widely recognised within GB rail that either closer collaborations must be established between stakeholders to enable more effective cross-interface business cases to be developed or there must be a trusted audit process that can enable costs of data collection to be fairly attributed based on business benefits accrued by individual stakeholders. To investigate these issues the Rail Safety and Standards Board (RSSB) set up a Cross-Industry RCM (XIRCM) research programme, which in turn acted as sponsor to the T1010 research project [3] from 2013 onwards. The stated aim of T1010 was to overcome the barriers for rail companies to use RCM systems across company boundaries, with the first round of findings presented by RSSB and Network Rail at the IET RCM conference in 2014 [4].

A key component of business case generation for cross-interface RCM is the assignment of value to the data generated by one party but used by another. In order to address the cost issue, it was suggested in project T1010 that commercial agreements could be established between all the actors in a new condition monitoring workflow before installation of the system began [5]. However, there are issues with this approach; commercial agreements do not remove the need for a trusted third party (arbiter) to ensure compliance with the terms of the agreement, and they do not inherently include any ongoing audit mechanism that would act as evidence should issues arise. In combination, these two issues act as a barrier to the full exploitation of XIRCM data and cost sharing between stakeholders.

Distributed Ledger Technologies (DLTs) have several features which can be leveraged to address the issues outlined. The benefits offered to the industry through improved system-wide asset information and decision support are clear, but for those benefits to be realised in a privatised rail system where the separation of business functions is the main architectural driver, the commercial implications of the operation of cross-industry systems for each actor must be clear. Further to this, existing investments in specific RCM systems made by the industry are currently only in their mid-life stages, meaning a method to deliver a clear understanding of operational costs must be cognizant of, and compatible with, the methods of operation of these existing assets. DLTs are one possible solution to these issues, offering the potential for traceability of data flows between industry actors with a minimum restructuring of the current systems. By understanding the flows of data between actors, and the ultimate costs/benefits accrued by the installation and use of the system (for which mechanisms are already in place), it will be possible to accurately assign costs to the relevant parties, to cut down on the operational inefficiencies associated with manual attribution and trusted third parties, and to enable improved understanding of data provenance via the decentralised and immutable record in the ledger.

Blockchains are a specific type of DLT constructed from structured sequences of blocks connected via cryptographic hashes, providing a tamper-proof ledger that leads to a traceable and auditable log of all activities between stakeholders. In industrial environments, the implementation of this technology facilities greater integration of business processes and stakeholder data, with the blockchain delivering three major protocols: decentralisation, cryptography, and consensus [6]. Due to the censorship-resistant and tamper-proof digital networks of distributed trust created by this revolutionary technology, blockchain-driven technologies help to enhance transactions and make them more reliable and safer. Industrial deployments of the blockchain are still in the early stages of development, and further work is required to establish the full extent of the value the technology offers. However, substantial efforts have been made to investigate its applicability and future penetration in numerous industries, including the industrial sector, as the new technology continues to mature [7], [8]. The transformative potential of blockchain technology in industry settings has already been established in the literature [9], and in the rail industry specifically, blockchain-based applications for ticket sales, invoicing, and freight distribution, among others, have also been investigated [10].

In this chapter we present early findings from the European Union (EU)-funded B4CM project, a study commissioned to investigate the value that blockchain technology offers the rail industry as a ledger of RCM data transfers (section 2), along with a discussion of related work in the literature. The proposed blockchain framework will be presented in depth in section 3, with plans for future work and concluding comments detailed in sections 4 and 5, respectively.

2. Background and related work

Large volumes of data are generated daily by RCM systems installed on the GB rail network. While this data is already utilised to improve performance within the context for which the system was initially specified, in many cases, opportunities exist for the realisation of additional benefits by sharing this data between stakeholders and across system boundaries, enabling it to be used in problems that cross traditional industry interfaces (primarily the separation between the infrastructure and vehicles). The continuous improvement of system performance through RCM-informed operations and maintenance is a field of intensive research, and many projects focusing on this area have been initiated [11]. At present, the industry is still on an upward performance trend in this area, and localised sensor systems used in isolation are still providing operational benefits. However, moving forward, the industry is expecting these systems to coalesce into fewer, multiparty and sensor environments, essentially evolving the network's current RCM capability into an "Internet of Railway Things" (IoRT) [12] requiring new ways of managing, processing, and accounting for data. This amalgamation of the state-of-the-art IT, cloud computing, and big data, presented as an Internet of Things (IoT) paradigm, will ultimately lead to a viable "smart railway" fit for the next century [13].

Depending on the nature of the sensors deployed, the data produced by RCM systems takes many forms, including audio, video, pictorial, continuous analogue measurements, and digital signals. In order for the raw datastreams to have operational value, they must first be processed, cleaned, and aligned to the point where they can be reliably used as the basis for analytics. As shown in Figure 1[14], there are six recognised levels of data analysis in condition monitoring, ranging from raw data collection (at the lowest levels), through the generation of alarms in response to defined alert criteria, to a full diagnostic function that involves sending prognostic information to the operations and maintenance team to instruct them to repair a particular asset before it fails. The data used as the input to each level of the stack (or indeed the analytics process itself) may originate from multiple stakeholders, and as the level of data processing increases, the inherent value of data becomes higher as a result of the additional knowledge associated with it. According to [5], unless specific contractual provisions say otherwise, it is typical for the Intellectual Property Rights (IPR) to the data recorded by RCM systems to be held by the party that collected it, while the IPR for derived data (data the results from a processing chain and is considered "enhanced") belongs to the party who performed the processing.

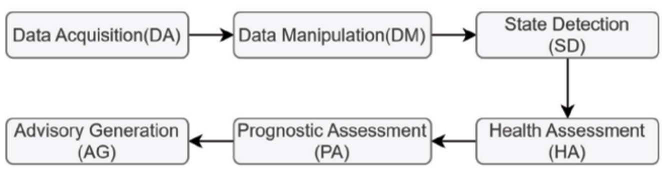

Figure 1: The six processing levels of ISO 13374. Source: [14].

As is the case in any trading environment, successful RCM deployments require that both the providers and the consumers of the data gathered comply with any contractual arrangements made around the system, and particularly when ensuring the quality and reliability of the data and advisory information produced. To this end, it is desirable for a traceable mechanism to exist within the system that monitors the provenance of the RCM data; this provenance information provides evidence that directly affects payment, compensation, or refund processing. In current RCM deployments, a Trustworthy Third Party (TTP) such as a bank, third escrow mediator, or conflict board may be a requirement to manage these needs.

DLTs, in the form of blockchains and smart contracts (SC), have the potential to offer great value to industry in this context enabling operators of RCM systems to dispense with the need for a TTP and inherently prevent the RCM data generated from being falsified, altered, or corrupted without the changes being evident. Further to this, in order to both quantitatively and qualitatively monitor and manage the flows of data between providers and consumers, SC may be deployed on the blockchain. Deployed SC are essentially distributed executable scripts running in the blockchain [15], and this combination of traceability (as provided by the chain itself) and transformation/transaction of data (as provided by the SC) provides an environment in which the whole value chain around items of data may be audited and understood. As pointed out by Christidis and Devetsikiotis [16], in a traditional relational database management system, an SC would essentially be used as a stored process, but by using an SC within the underlying execution framework offered by the blockchain, a wide range of applications can be created.

Within the literature, a range of examples of the use of blockchains in partial solutions to the problems seen in XIRCM may be found. Existing studies on the use of micropayments between stakeholders linked to IoT data exchange, for example, have suggested that SC-based frameworks would form an appropriate basis for that use case. In the Saranyu system [17], Nayak et al. created a cloud tenant and service management system using Quorum (a private blockchain network) as a platform but ultimately failed to capture appropriate information on charging tenants. A subscription-based model for trading data on cloud platforms was also introduced by Al-Zahrani [18]. In the proposed model, the ledger tracked all subscriptions and orders, and this included those on which the request has not been concluded and finalised, providing potentially useful information to forensic investigators should problems occur. A blockchain-based solution using Ethereum was launched in [19], which regulated both payments to and access by the owners of data-generating IoT devices. When subscribing to a particular IoT device and before accessing the data processed in the MQTT broker, which represented a single point of failure within the system, data owners paid a deposit in ether (the "currency" of the chain).

With the exception of [17], none of the work identified provided a mechanism for the suspension or revocation of malicious actors/account subscriptions, other than the removal of the associated data from the cloud platform used. Typically, the authors assumed that data providers acted honestly in all the systems surveyed, and did not address the issues raised by the presence of falsified or garbage data that may have been deliberately inserted into the platform to deceive customers. The payment companies BitPay [20], BitHalo [21], and DCSP [22] have considered the issue of dishonest actors, and all have previously proposed the use of double deposit escrow. In all three proposals, both the buyer and the supplier use SC to create an escrow for the deposited values, but the actual transfer of assets is made off-chain. Both parties must acknowledge the SC that the transaction is successfully made in order to unlock the escrow. Should confirmation not be given, both forfeit their deposits. A dual-deposit escrow mechanism identical to the previous three schemes was suggested by Asgaonkar and Krishnamachari [23] but offered a subsequent dispute resolution stage (potentially preventing deposit loss) and involving the main payment transaction. However, this system was only suitable for one-time usage scenarios, and the buyer was required to review every transaction and provide a reply to open the escrow and process the payment. The seller received no compensation if the customer did not respond (regardless of the presence or absence of malicious intent) and would forfeit their deposit and right to payment. A different data-sharing mechanism is proposed in [24], in which data hash values are encrypted with a symmetrical key and deposited in a secure location off-chain by the data provider before the transaction is actioned. In the cloud, all providers are able to promote their data services and public keys. To enable consumers to gain one-time access to the appropriate records, SC were generated on the fly and the activity was logged on the chain to be used in the resolution of any potential disputes.

In this chapter, the framework proposed will build on the escrow proposals discussed above but will additionally include litigation solutions that ensure escrow locking or payment/compensation loss do not take place.

There are several known limitations of blockchain technology; the blockchain trilemma [25], for example, states that the interrelated properties of scalability, decentralisation, and stability cannot be achieved simultaneously on the same chain, meaning that compromises must be made in terms of desired functionality based on the specific use case. Furthermore, all blockchain-based applications must make a trade-off between the size of any on-chain storage and operational performance; in practice this is manifested by a significant increase in processing time as the overall size of the ledger increases, a process that is naturally much more rapid if data being exchanged is recorded within a transaction alongside the record of the transaction itself. Scalability of storage has significant implications for the usage of blockchains in RCM contexts, and essentially enforces an architectural choice on the designer to use a hybrid approach that combines off-chain storage of data, with on-chain storage of provenance. Data integrity and immutability are ensured through the use of a checksum of the raw data, which when computed, stored, and verified within the blockchain record, can be used as evidence of data ownership, to automate integrity checks and to check latency claims.

3. Proposed framework

In this section, the authors present their proposed framework for the audit of RCM data in industrial systems. The framework replaces the TTP typically involved in these systems with a permissioned blockchain architecture, leaving data producers/data owners (providers), data users (consumers), and SC as the key actors in the system. Figure 2 illustrates this change; Figure 2 (a) shows a typical trust arrangement that would apply in a none DLT-based RCM network; in this case all parties must trust that the other producing/consuming parties will honour their obligations under the agreement defining the distribution of system costs; the TTP reviews local financial cost assessments provided by the other actors in order to confirm adherence to the applicable terms. This process will henceforth be referred to as "local cost monitoring." As the local cost monitoring of both providers and consumers is dependent on the data they report, even with the TTP in place there is no guarantee of strict adherence to the terms of the contractual agreements between the parties.

As an example of the requirement for trust, consider the Quality of Service (QoS) criteria placed on a data provider. Honest providers could choose to comply with the terms of the signed agreement and offer the requested level of service that they initially advertised; this would result in an estimated cost calculation for the data as delivered and an associated attribution of the cost to the consumer. The consumer, on the other hand, will have their own interpretation of the quality of the service they have received; this may tally with that of the provider, or may be impacted by external factors such as network latency resulting in a different view of the fair attribution of the cost from the consumer's side. To reinforce their point of view, both parties will provide evidence, but as there is no confidence between them, there will be no trust in the correctness of their evidence. The presence of the TTP goes some way to mediating these issues but still requires that the evidence as presented by the provider and consumer is fundamentally accurate, or that the TTP can identify when that evidence is incorrect and (ideally) who is in error. By comparison, the relationships and trust between actors required in the proposed framework are shown in Figure 2 (b). A trust relationship between the provider and the customer is no longer necessary, although both sides do need to trust the DLT and the SCs that implement the accounting logic, data access/delivery agreements, and cost allocations. Subsections 3.1 and 3.2 will explain these procedures in detail.

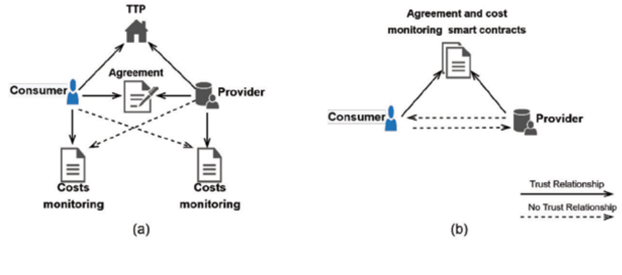

Figure 2: Trust relationship between actors.

3.1 Access agreement model

The commercial agreements originally outlined in project T1010 [5] have driven the definition of the components used in the SC for the access agreement and cost estimation process between provider and consumer as shown in Figure 3. Two new records, "DataAgreement" and "Escrow," will be automatically generated by SC and be appended to the ledger each time a new data access request is made by a consumer to a producer. The DataAgreement will hold information on the new agreement between the data consumer and data provider, including the data offered by the provider, the unit price, and the period of validity. The Escrow record will form the basis for enforcement of access to the data and exchange of payment on release.

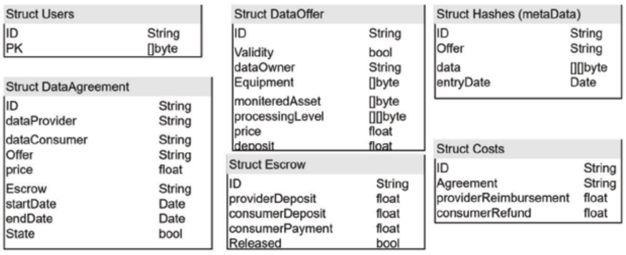

Figure 3: Data structure.

Recall that the IPR for the RCM data belongs to the provider, thus, no other party in the system will be able to advertise an offer for exactly the same data (although they may be able to advertise derivative forms) and this mechanism is protected by hash values. Both data providers and data consumers must be registered with the trustworthy authority (in this case the permissioned blockchain) in the set-up process of the system, and must have their IDs and public/private key pairs before participating.

The overall flow of the access agreement process is as follows:

1- The customer will submit a request to the SC in which they will specify the offer they are interested in, along with the subscription duration and all payments.

2- The authenticity of the submitted request will be tested by the SC. If it is not legitimate, so the request will be denied. A payment mechanism is triggered if the offer is still available; this process is addressed in depth in section 3.4.

3- After completing the payment process, the SC will automatically create a new agreement between the provider and consumer in addition to building an escrow to hold the payment. Both provider and consumer will be informed of the establishment of the agreement.

4- Prior to uploading the original data onto the external storage, the provider's private key and the consumer's public key will be used to sign and encrypt data respectively as follows: consumerPublicKey (providerPrivateKey (D)).

5- The consumer will decrypt the data they gain access to on the off-chain storage and compare its hash with the hash value provided in the on-chain record to validate its integrity.

In this proposed model, two types of malicious behaviour on the part of the data provider can be proven by the consumer:

a. Sending falsified or incomplete data;
b. Undue delay in uploading evidential hash values to the on-chain record.

If the QoS by either party is found to violate the terms of the agreement, both provider and consumer can revoke the agreement before the stated expiry date. This action is permanent, i.e., the agreement cannot be revived once revoked; instead, a new agreement must be entered into from the beginning. Figure 4 shows the sequence of creating the data access agreement.

3.2. Accounting model

Payments on any trading site may be realised using post-paid or pre-paid models. The post-paid model requires the provider to place trust in the consumer (buyer) that the payment will be made as agreed after the data is obtained correctly. The pre-paid model requires that the consumer places trust in the provider that the data will be delivered once the payment has been made as agreed. Neither model guarantees both consumer and provider satisfaction, and both bear some risk if the other party breaches the terms of the agreement. There is also a requirement for a TTP to provide both the provider and the consumer with an escrow service.

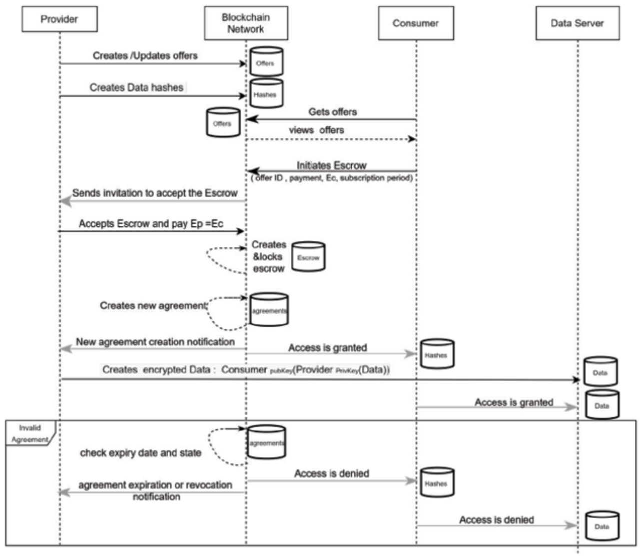

Figure 4: Data access agreement sequence model.

In the proposed framework, SC will be used to provide escrow, removing the need for a TTP and ensuring the payment is released to the provider after the data is delivered and the consumer agrees that it meets the stipulations of the agreement, assuming a revocation request is not made. The escrow SC is also responsible for managing any penalty payments required by the agreement, and these would be charged in advance of any data exchanging process by both provider and client.

The provider is expected to deploy the following attributes and values with the offer they are advertising as shown in Figure 3:

D_{price}: Denotes the data price of a certain offer in a specified period.

E: Denotes the deposit both consumer (Ecns) and provider (Eprd) should pay to build an escrow. The deposit will act as the penalty in case of any breach of the terms, and therefore must be set at a level that acts as a deterrent for both parties.

h(D): Denotes the hash value of the shared data.

The flow of the payment process is as follows:

1- An escrow SC will be initiated once the consumer responds to a published offer. The escrow details the offer being responded to and triggers payment of the corresponding charge and deposit by the consumer. On receipt, the

SC will then direct the request to the provider.

2- On receiving the request, the provider will check if the payment and deposit detailed in the escrow are matched with their offer. Then, in order to lock up the escrow, the provider must pay their deposit, which may not be less than the deposit of the consumer. If the provider determines that the size of the payment or the deposit does not match with the terms of their offer, the provider can reject the request and the consumer will get back their payment.

3- The process of locking the escrow will trigger an SC to initiate an agreement, in which the period over which the consumer has access to the provider's data is specified.

4- The cost of data consumption will be monitored via the SC when the escrow is released. The escrow will be released automatically if either of the two states below is realised:

a. The agreement's expiry date is reached, or
b. The agreement is revoked.

In both cases, if there is a claim of inappropriate activity from either side, it should be evaluated before calculating the final cost attribution. The deposits that have been charged would then be used in settling any penalties due if maleficence has been proven on either side. Figure 5 summarises all the possible outcomes of an investigation into QoS breaches between a provider and a consumer. Costs are calculated based on each scenario, which are outlined in equations 1–4. The terminology below is used in the equations:

$Cns_{Payment}$: Denotes the payment that the consumer should pay when initiating the offer request. It represents the total of D_{price} and E_{cns}.

$Act_{Payment}$: Denotes the actual payment of the consumed data based on the period of use; this value should be less than or equal to CnsPayment.

$Prd_{Reimbursement}$: Denotes the final cost that will be transferred to the provider based on the status of the agreement and the raised claims.

Cns_{Refund}: Denotes the refunds that will be transferred to the consumer based on the status of the agreement and the raised claims.

To calculate the $Act_{Payment}$ three different dates will be considered:

Rvc_{Date}: Denotes the revocation date.

$Start_{Date}$: Denotes the beginning of the agreement, as declared in the agreement.

Exp_{Date}: Denotes the end date of the agreement, as declared in the agreement.

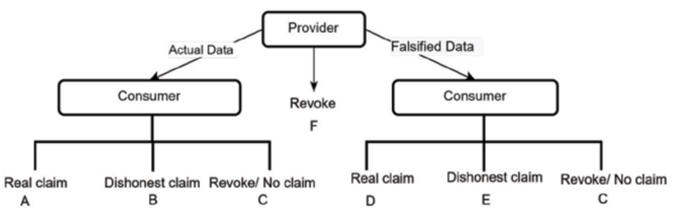

Figure 5: All possible scenarios in trading data.

Scenario A: The consumer receives the requested data as agreed but raise a genuine complaint about the latency in providing the hashes to the network. The cost SC will evaluate this claim by checking the dates of appended hash values on the chain, using the block's timestamp. As the consumer's claim is genuine, the agreement will then be revoked, triggering the calculation of costs as follows:

$$Act_{Payment} = D_p \times (Rvc_{Date} - Start_{Date})$$

$$Prd_{Reimbursement} = Act_{Payment} \quad (1)$$

$$Cns_{Refund} = (Cns_{Payment} - Act_{Payment}) + E_{prd} + E_{cns}$$

Scenario B: The consumer falsely claims the data is corrupted or incomplete, or that the hash values are not appended to the chain in a timely fashion. In this case, the cost SC will evaluate both cases to validate the claim. The former is evaluated by requesting the received data which is signed using the provider's private key that verifies the data source, and then the SC will perform a hashing process to the data, enabling it to be compared with the hashed value that is stored on-chain. The latency in appending hash values will be validated as mentioned before in scenario A. In this scenario, the consumer's claim will be found to be false by the SC, and as a result the agreement will be revoked and the cost will be calculated as follows:

$$Act_{Payment} = D_p \times (Rvc_{Date} - Start_{Date})$$

$$Prd_{Reimbursement} = Act_{Payment} + E_{prd} + E_{cns} \quad (2)$$

$$Cns_{Refund} = Cns_{Payment} - Act_{Payment}$$

Scenario C: The consumer revokes the agreement without raising any claim. In this case the agreement will be revoked and the cost will be calculated as follows:

$$Act_{Payment} = D_p \times (Rvc_{Date} - Start_{Date})$$

$$Prd_{Reimbursement} = Act_{Payment} + E_{prd} \quad (3)$$

$$Cns_{Refund} = Cns_{Payment} - Act_{Payment} + E_{cns}$$

A similar process will be triggered when the agreement reaches the expiry date without any revocation or complaints from the consumer's side:

$$Act_{Payment} = D_p \times (Exp_{Date} - Start_{Date})$$

$$Prd_{Reimbursement} = Act_{Payment} + E_{prd}$$

$$Cns_{Refund} = Cns_{Payment} - Act_{Payment} + E_{cns}$$

Scenario D: The provider sends falsified data to the consumer. In this case, the consumer raises a claim providing the received data to the SC, which compares it to the hash value stored on the chain. As a result of the provider's actions, the agreement will be revoked, triggering the calculation of costs according to equation (1).

Scenario E: The consumer raises a genuine claim against the provider, but attaches the wrong evidence leading the SC to evaluate the claim as false. Such a situation may occur if, for example, the provider uploaded the right hash values to the network at the right time, but sent the wrong data to the consumer on the external storage. When the consumer identifies the mismatch between the hash values, there is a risk of raising a latency claim rather than a claim resulting from the mismatched hash. Were the consumer to raise a latency claim in this situation then the SC would prove the claim false and process the cost according to equation 2. In this scenario, resolution and reimbursement of the consumer would be possible if the consumer provided the signed original data to a dispute board. The provider won't be able to show the hash value that matches with the provided signed data that has been uploaded to the network on the same date. This would of course require such a board to be in place and may reduce the overall financial benefit of the blockchain implementation. Scenario F: The provider chooses to revoke the request as they can no longer provide the data as advertised or are unwilling to provide the data for another reason. In this case, costs will be calculated according to equation 1. Such a scenario could arise if the consumer was suspected of data reselling, which is against the terms of the agreement with a provider. Proof of data reselling would be achieved by comparing hash values uploaded to the chain as part of a data offer. Such a case would require the intervention of the dispute board and may lead to legal action.

4. Future work

In this chapter, a proposed architecture for the delivery of a data audit chain for RCM in GB rail and other industrial contexts has been presented. The next step is for the proposed architecture to be implemented and trialled with real-world data. As there are no one-size-fits-all platforms for blockchain projects, identifying the most suitable deployment platform is critical to the success of this work. A trade-off study was carried out that compared four of the most commonly adopted blockchain platforms: Ethereum [26], [27], Fabric [28], Sawtooth [29], and Iroha [30], based on the parameters set out in Table 1.

Table 1: Trade-off analysis between Ethereum, Fabric, Sawtooth, and Iroha.

Criteria	Ethereum	Fabric	Sawtooth	Iroha
Supports SC	✓	✓	✓	✓
Consensus algorithm modularity	✗	✓	✓	✗
Built-in components for managing identities	✗	✓	✗	✓
Supports payment in fiat currency	✗	✓	✓	✓
Proficient in maintaining different privacy levels between users	✗	✓	✓	✓

Of particular interest was the fact that for any SC execution, the Ethereum chain incurred costs (gas) in its native payment currency (Ether), while the Fabric, Sawtooth, and Iroha Hyperledger systems are cryptocurrency-independent, and payment was possible in fiat currencies. Further to this, because of the voting-based consensus algorithms adopted in Hyperledger platforms, there is no requirement for time- and power-consuming consensus algorithms. The associated performance characteristic ensures quick access to provider information, which would be a key criterion for most RCM use cases.

The proposed framework requires differentiation between users to ensure the privacy of their transactions, i.e., not all agreements and payment processes are open to all network users. Any consumer may opt to have a private contract with a provider, and to keep the costs of sharing the data secret from those not participating in that agreement. The Ethereum chain treats all users identically, and all transactions are open and available to all network participants. Hyperledger networks by comparison are able to fulfil this criterion by one of several mechanisms; Fabric, for example, establishes a different channel to isolate parties requiring private agreements and cost allocations; changing the identity namespace in the transaction family on the Sawtooth chain would limit access to specific identities; and specifying guidelines for access management in Iroha would retain easy role-based access at different stages.

In the future, we seek to trial our proposal against representative use cases from GB rail and to evaluate its performance in terms of promoting trust, simplifying cost attribution, delivering a workable payment mechanism for RCM data, and implementing ad-hoc data access agreements between parties. To this end, two representative case studies will be developed, one around the Unattended Overhead Line Equipment Monitoring System (UOMS) and a second around RailBAM, an acoustic axle bearing monitoring system. Both case studies involve systems that require collaboration across the rail sector between multiple stakeholders, and the data generated is of interest to multiple actors, perfectly illustrating the cross-interface scenario that is the target of the system.

5. Conclusion

RCM is a critical technology in the evolution of the smart railway, enabling improved reliability at a reduced cost. As sensors attached to fixed and mobile assets are increasingly used to inform the operational decision making of the industry, it is becoming critical that the business processes that distribute the costs and benefits of such systems across stakeholders within the industry are aligned in a way that is fair to all parties. The ability to trade in RCM data offers a net market advantage to the industry, as this enables easy access to data by any party that believes they have a use case, while also ensuring that data providers are adequately reimbursed.

Traditional approaches to the management of costs associated with cross-stakeholder RCM deployments in rail have relied on specific business-to-business commercial agreements and predefined costs. These lack the flexibility required to fully exploit the data generated in the "big data" age, where automated model development often requires access to a wide range of data resources from across an industry. Furthermore, the specific use cases being investigated are unlikely to have been foreseen at the time the RCM systems were procured, meaning the initial agreements would need to be modified to support new usage scenarios, an expensive and time-consuming process. Some legacy collaboration arrangements are not wholly defined or explicit and are thus open to misinterpretation or may not be enforceable.

The B4CM project aims to provide the rail industry with an alternative to the traditional model for the attribution of RCM costs. This chapter has introduced a new architecture based on blockchain technology which ensures the rights to data are allocated to the data provider as long as they supply the blockchain network with evidential hash values. The architecture simplifies the mechanism for coordination between a data provider and data users, while also allowing automation of the underlying business agreements and cost distribution. A service quality agreement between provider and consumer is established enabling both actors to prove some violating behaviours; for example, a consumer may claim low service quality, prove their claim, and be paid for; otherwise, for making dishonest claims, the consumer would be fined. Fundamentally, the proposed system allows all stakeholders to contribute, and realise revenue from, their data while enabling cross-industry use cases that are currently not easily realised.

The next stage of the work is to validate the framework by trialling it with real-world industry use cases, and the results of these will be reported to the community in the near future.

References

[1] C. P. Ward et al, "Condition monitoring opportunities using vehicle-based sensors," Proceedings of the Institution of Mechanical Engineers. Part F, Journal of Rail and Rapid Transit, vol. 225, (2), pp. 202–218, 2011.

[2] A. Alemi, F. Corman, and G. Lodewijks, "Condition monitoring approaches for the detection of railway wheel defects," Proceedings of the Institution of Mechanical Engineers. Part F, Journal of Rail and Rapid Transit, vol. 231, (8), pp. 961–981, 2017.

[3] Sparkrail, Cross-industry remote condition monitoring (T1010). [Online]. Available: http://www.sparkrail.org/

Lists/Records/DispForm.aspx? ID=8096.
[4] G. J. Tucker and A. Hall, "Breaking down the barriers to more cross-industry Remote Condition Monitoring (RCM)," in 6th IET Conference on Railway Condition Monitoring (RCM 2014), Birmingham, UK, September 2014, pp. 1–6.
[5] Sparkrail, Cross-industry remote condition monitoring, Commercial, Final report Appendix E Standard Form (Template) (T1010 Report Appendix).
[6] M. Crosby, P. Pattanayak, S. Verma, and V. Kalyanaraman, "Blockchain technology: Beyond bitcoin," Applied Innovation, vol. 2, pp. 6–10, 2016.
[7] M. Friedlmaier, A. Tumasjan, and I. M. Welpe, "Disrupting industries with blockchain: The industry, venture capital funding, and regional distribution of blockchain ventures," in Proceedings of the 51st Hawaii International Conference on System Sciences, 2016.
[8] M. Risius and K. Spohrer, "A blockchain research framework," Business & Information Systems Engineering, vol. 59, (6), pp. 385–409, 2017.
[9] B. Biswas and R. Gupta, "Analysis of barriers to implement blockchain in industry and service sectors," Computers & Industrial Engineering, vol. 136, pp. 225–241, 2019.
[10] P. Mcmahon, T. Zhang, and R. Dwight, "Requirements for big data adoption for railway asset management," IEEE Access, vol. 8, pp. 15543–15564, 2020.
[11] D. Galar, D. Seneviratne, and U. Kumar, "Big data in railway O&M: A dependability approach," in S. Kohli, A. V. Senthil Kumar, J. M. Easton, and C. Roberts (Eds.), Innovative applications of big data in the railway industry. IGI Global, Hershey, PA, pp. 1–26, 2017.
[12] J. M. Easton. "Blockchains: A distributed data ledger for the rail industry," in S. Kohli, A. V. Senthil Kumar, J. M. Easton, and C. Roberts (Eds.), Innovative applications of big data in the railway industry. IGI Global, Hershey, PA, pp. 27–39, 2017.
[13] Q. Y. Li et al, "Chapter 14 – Smart railway based on the Internet of Things," in H.-H. Hsu, C.-Y. Chang, and C.-H. Hsu (Eds.), Big data analytics for sensor-network collected intelligence. Elsevier Inc., pp. 280–297, 2017.
[14] ISO13374-2: "Condition monitoring and diagnostics of machines – Data processing, communication and presentation – Part 2: Data processing," 2007.
[15] M. Alharby, A. Aldweesh, and A. V. Moorsel, "Blockchain-based smart contracts: A systematic mapping study of academic research," in International Conference on Cloud Computing, Big Data and Blockchain (ICCBB), Fuzhou, China, 2018, pp. 1–6.
[16] K. Christidis and M. Devetsikiotis, "Blockchains and smart contracts for the Internet of Things," IEEE Access, vol. 4, pp. 2292–2303, 2016.
[17] S. Nayak, N. C. Narendra, A. Shukla, and J. Kempf, "Saranyu: Using smart contracts and blockchain for cloud tenant management," in 2018 IEEE 11th International Conference on Cloud Computing (CLOUD), San Francisco, CA, 2018, pp. 857–861.
[18] F. A. Al-Zahrani, "Subscription-based data-sharing model using blockchain and data as a service," IEEE Access, vol. 8, pp. 115966–115981, 2020.
[19] A. Suliman, Z. Husain, M. Abououf, M. Alblooshi, and K. Salah, "Monetization of IoT data using smart contracts," IET Networks, vol. 8, pp. 32–37, January 2019.
[20] Bit-Bay, Double deposit escrow. [Online]. Available: https://bitbay.market/double-deposit-escrow
[21] D. Zimbeck, Two party double deposit trustless escrow in cryptographic networks and bitcoin. [Online], 2014. Available: https://bithalo.org/whitepaper_twosided.pdf
[22] G. Bigi, A. Bracciali, G. Meacci, and E. Tuosto, "Validation of decentralised smart contracts through game theory and formal methods," in C. Bodei, G. Ferrari, and C. Priami (Eds.), Programming languages with applications to biology and security. Springer, pp. 142–161, 2015.
[23] A. Asgaonkar and B. Krishnamachari, "Solving the buyer and seller's dilemma: A dual-deposit escrow smart contract for provably cheat-proof delivery and payment for a digital good without a trusted mediator," in 2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), Seoul, Korea (South), 2019, pp. 262–267.
[24] H. Desai, K. Liu, M. Kantarcioglu, and L. Kagal, "Adjudicating violations in data sharing agreements using smart contracts," in 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), Halifax, NS, Canada, 2018, pp. 1553–1560.
[25] T. Ometoruwa, Solving the blockchain trilemma: Decentralization, security & scalability. [Online]. Available: https://www.coinbureau.com/analysis/solving-blockchain-trilemma
[26] G. Wood, "Ethereum: A secure decentralised generalised transaction ledger," Technical report. [Online]. Available: https://gavwood.com/paper.pdf
[27] V. Buterin, Ethereum white-paper. [Online]. Available: https://ethereum.org/en/whitepaper/
[28] E. Androulaki et al, "Hyperledger fabric: A distributed operating system for permissioned blockchains," in EuroSys'18: Proceedings of the Thirteenth EuroSys Conference, April 2018, pp. 1–15.
[29] K. Olson et al, Sawtooth: An introduction – White paper. [Online]. Available: https://www.hyperledger.org/wp-content/uploads/2018/01/Hyperledger_Sawtooth_WhitePaper.pdf
[30] Hyperledger Iroha Community, Iroha handbook: Installation, getting started, API, guides, and troubleshooting. [Online]. Available: https://iroha.readthedocs.io/_/downloads/en/1.1.3/pdf/

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Author's contribution:
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Consortium Capabilities for Enterprise Blockchain Success

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Abstract

Enterprise blockchain projects have great promise. They can cut costs and promote efficiency through disintermediation, increase transparency for tracking intercompany transactions, expand knowledge through consortia databases, and improve workflows through shared business processes. Despite its potential, blockchain technology has failed to produce promised benefits for enterprise networks. While the underlying technology has advanced rapidly, managerial capabilities needed to form and manage blockchain consortia have lagged, and as a result, few consortia have succeeded. This chapter reviews the extant literature on blockchain consortia and provides a framework that identifies (1) foundational conditions that precede effective consortium formation, (2) capabilities required for effective consortium functioning and evolution, and (3) partner and ecosystem-level outcomes associated with successful blockchain projects.

Keywords: *enterprise blockchain, blockchain consortium, blockchain consortia, strategic capabilities, success factors*

JEL Classifications: *M15 IT Management*

1. Introduction

Blockchain technology has the potential to fundamentally change the way businesses collaborate and to solve business problems in ways not previously possible [1, 2, 3]. Promised benefits include streamlined processes, cost savings, risk reduction, and improved stakeholder relationships [4]. Despite its potential, the technology has not been widely adopted and early adopters have encountered problems and challenges [5]. While the underlying information technology continues to advance rapidly, the development of business capabilities necessary for creating and capturing value continue to lag [6]. This is particularly true for consortium blockchain solutions, which require the formation and governance of cooperative networks [7].

Consortium blockchains are interorganisational systems that enable organisations to integrate their business operations and data [8]. For such systems, the organisational component is critical because people, their ideas, and decision-making processes are all affected [9]. Networks of organisations and associated business workflows span supply chains or industries, and in some cases, external stakeholders [10]. Participants may include trading partners along supply chains that serve a shared base of end customers; they may be made up of competitors operating in the same industry sector; they may include a mix of public and private firms. Although participating organisations vary, the hallmark of consortia is that the partners collaborate to solve shared problems [11].

Blockchain projects require a broader range of business capabilities than do typical enterprise alliances [6]. Blockchain consortia are complex organisational arrangements where partners must collaborate on the purpose, operations, and desired outcomes of the project, which represent a new way of organising interfirm collaboration [1]. Member firms, and the consortium as a whole, must possess a variety of skills and attitudes. Because blockchain is typically treated as a technology problem, the business capabilities required for successful consortia are not widely recognised or discussed. While scholarly literature is beginning to emerge, it focuses primarily on technological issues and ignores or minimises organisational complexities [5, 12, 13].

In the remainder of this chapter, we review the extant literature on blockchain consortia and examine the capabilities needed for the successful formation and management of these solutions. Although several studies touch on consortium governance, we note a significant gap in research addressing criteria associated with consortium effectiveness. We build upon academic research and trade literature to propose a framework that identifies (1) foundational conditions that precede effective consortium formation, (2) capabilities required for effective consortium functioning and evolution, and (3) partner and ecosystem-level outcomes associated with successful blockchain projects. We believe that the ability to effectively form and manage blockchain consortia plays an important role in promoting value co-creation and capture and in supporting innovation. By presenting a framework based on systematic research, our aim is to contribute to these objectives.

2. Literature Review

To summarise current studies focused on blockchain consortia, we conducted a systematic literature review using the Web of Science academic database in June 2021. To ensure the broadest possible coverage, our search includes results for: enterprise blockchain or blockchain consortia or blockchain consortium. No date restrictions were used to ensure comprehensive results. Two important trends emerge from the 425 papers returned.

First, enterprise blockchain and blockchain consortia are a relatively new and quickly growing area of study. Results span an approximately four-year period, with the earliest published in July 2017 and the latest scheduled for publication in August 2021. Seven papers included in the results were published in 2017, while 135 (32% of the total) were published or available for early access during the first half of 2021.

Second, enterprise blockchain and blockchain consortia are of interest to a diverse set of academic disciplines. Figure 1 aggregates search results into a

Figure 1: Web of Science Search Results by Discipline.

visualisation comparing the number of results returned by discipline. The chart highlights the extent to which enterprise blockchain concepts are largely studied within disciplines that solve technical challenges preventing adoption and widespread use. A review of the results for various subdisciplines associated with computer science, telecommunications, engineering, and other hard science disciplines show rapid progress on technical challenges preventing adoption. While interesting and important, these findings are not the focus of this chapter.

Instead, we focus on the social and governance challenges that must be overcome to establish enterprise blockchains as a tool for strategic value creation. As such, we highlight the 71 results returned for various socialscience subdisciplines associated with business, management, finance, information science, operations, and law for additional analysis. Each of these articles was reviewed and categorised according to the paper's motivation and contribution. In all, we identified seven article categories.

Table 1: Analysis of Literature Results by Category

Topic of Article	Count	Percent (%)
Applications	39	55
Technical overview/proof of concept	9	13
Adoption challenges/ determinants/consequences	7	10
Privacy/security/regulation	6	8
Cryptocurrency	3	4
Literature review	3	4
Consortium formation and governance	*4*	*6*
Total	71	100

Web of Science Subdisciplines Included: Business, Finance, Information Science, Law, Management, and Operations.

Table 1 presents our categorisation of the motivation and contribution of papers selected for further analysis. The most common type of paper included within the subset is the application of blockchain technology to a specific task or market. Such articles make up 55% of the total. Each of these papers discusses how the application of blockchain technology could reduce cost or improve performance within a specific setting. Highly cited examples include the description of benefits to blockchain adoption in supply chain/manufacturing [14, 15, 16, 17], accounting/auditing [15, 18], financial services [19, 20], healthcare [21, 22, 23, 24], and utility markets [25]. While these papers make significant contributions to the general understanding and proliferation of blockchain technology, they do not focus on the unique challenges involved in consortium formation and governance.

The second most common type of paper included within the subset is a technical overview or proof of concept for a specific improvement to the blockchain ecosystem. Such articles make up 22% of those selected for additional analysis. Examples include summaries of technical developments in certain areas or within the blockchain ecosystem as a whole [26, 27], security/privacy [28, 29, 30], latency [31], error management [32], and consensus mechanisms [33, 34]. Technological issues have long concerned companies exploring blockchain adoption. Firms need to know that the solutions they invest in will continue to meet their needs over time. Such contributions help to overcome technical challenges within the blockchain ecosystem but do not focus on challenges related to consortium formation and governance.

Other categories within the identified subset include analyses of challenges, determinants, or consequences of blockchain adoption (10%) [35, 36, 37]; discussion of privacy, security, or regulatory challenges (8%) [38, 39, 40, 41]; a focus on cryptocurrency (4%) [42, 43]; or literature reviews (4%) [44, 45]. A final category includes papers that explicitly deal with the primary focus of this chapter: challenges related to consortium formation and governance (6%). As this category contains studies related to the primary concerns of this chapter, we will briefly summarise relevant examples.
Lacity [46] uses a series of cases to propose a set of questions organisations should consider when considering enterprise blockchain applications. The author provides an overview of circumstances where blockchain is preferable to other database solutions, and notes a variety of resources that could be used to develop viable solutions. Resources discussed include relevant standards, regulatory considerations, and shared governance models.

Zavolokina et al. [47] highlight trust, collaboration, and regulatory compliance as key inputs for blockchain consortium success. Their case analysis suggests a set of strategies that include initial membership of non-competing organisations, segregated platform/private and infrastructure/public benefits, and separate short- and long-term priorities.

Nathan and Jacobs [48] provide a brief overview of consortium strategy considerations alongside a discussion of blockchain applications in financial services. They emphasize the need for an overarching vision or strategy to guide consortium formation, membership criteria, technology supported, governance process, data management, and regulatory concerns. While discussion of each topic within the paper is of limited depth, each of the topics raised is important topics for future research and development.

Finally, Schwabe [49] examines the unique role public agencies can play within blockchain consortia. While the paper does not explicitly focus on consortium formation and governance, it does emphasise the need for data access, user trust, and data quality. Mechanisms for achieving those goals beyond public agency participation are not discussed.

3. Consortium Capabilities Framework

While technology continues to advance, the organisational factors that drive enterprise blockchain success need additional attention. Blockchains span technical, functional, social, and legal boundaries within business [50]. Consortia must harmonise diverse stakeholder views within companies and across the broader network in order to be successful [51]. As a result, blockchain solutions require consortium partners to share information and coordinate in new ways.

Process coordination and data sharing across organisations is an entirely new way of doing business for some participants [52, 53, 54]. Hurder [55] describes blockchain platforms as economic systems: "Blockchain-based consortia allow enterprises to share, buy, and sell valuable data and use that pooled data to create new goods and services which can then be monetized." The paper notes network effects that result from the number of partners in an ecosystem, driving growth in value as more members are added to the consortium network and as costs can be spread among them [55]. Despite the potential for such benefits, forming and operating consortia may require members to accept agreements that challenge long-held belief systems or underlying business models [56]. Such collaboration may require changes to workflows, business models, and corporate strategy at the highest level [46]. It demands strategic, organisational, and market coordination that is able to address all stakeholder interests [57].

The success of an enterprise blockchain project relies on the effective creation and management of consortia. This requires certain enabling conditions to be present prior to consortium formation and for the consortium to possess a number of core capabilities that enable it to effectively organise and govern activity [47]. Business leaders understand the potential benefits to blockchain consortia but remain concerned with issues around "co-opetition," or partnering with competitors or pseudo-competitors, even though such collaboration is critical [1, 50]. When collaboratively developed and managed, a consortium is positioned to benefit individual partners and the broader ecosystem [47]. When they are not, the blockchain project will likely fail to deliver anticipated benefits. Despite the importance of coordination and planning, Naqvi and Hussain [58] find that many projects fail to use high-quality evidence and critical appraisal to evaluate projects before they are implemented or after they are in operation.

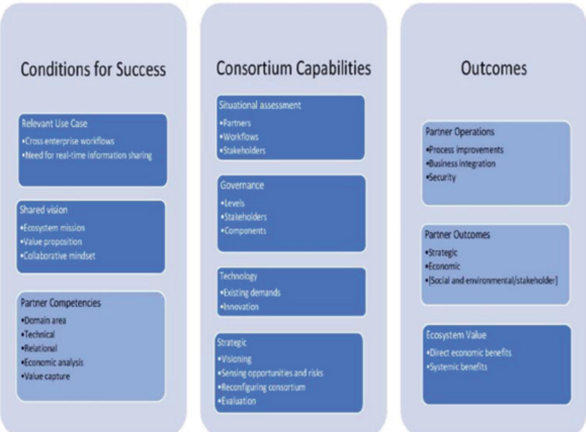

Figure 2: Consortium Capabilities Framework.

Figure 2 depicts a blockchain consortium capabilities framework that describes inputs, processes, and outputs associated with successful consortia. Partner-level factors are lightly shaded. Consortium-level factors are darkly shaded. Conditions for success are inputs and necessary antecedents to effective blockchain consortia. These conditions primarily refer to the blockchain's promise for addressing problems shared by the consortia, or factors driving member buy-in and fitness for participation. Consortium capabilities are processes or capabilities possessed by the consortium as a whole. Collectively, consortium participants must have the capacity to assess current functions and resources, govern the consortium effectively, maintain technological strengths, and act strategically to ensure the long-term effectiveness of the consortium. Outputs include intermediate and long-term performance improvements and value creation for both individual participants and the consortium as a whole.

3.1. Conditions for Success

The first section of the framework outlines the initial conditions necessary to form successful consortia. These conditions should be present or be developed before the consortium partnership is formalised. They include both consortium-level and individual-partner-level capabilities. A proposed use case should be one where a traditional system is not well-suited, blockchain offers superior performance, and initial participants share a vision for what the consortium can accomplish. Individual partners joining the consortium should possess or build the technical and administrative capabilities that will be needed to participate in and benefit from the network.

3.1.1 Relevant Use Case

The success of a blockchain solution rests on the development of an appropriate use case. There are many decision models for determining whether a particular use case can be best solved using blockchain. Wust and Gervais [59] suggest that a private permissioned blockchain is appropriate when the state of assets or agreements must be recorded by multiple, known parties and for which a trusted-third-party solution is unavailable or is more costly than a blockchain solution. PwC [60] adds the condition that transactions created by different participants are time-sensitive interactions, such that the ability to rapidly share information has business benefits. Naqvi and Hussein [58] through The Centre for Evidence Based Blockchain provide a more expansive analysis. They provide a comprehensive framework that can be used by organizations and consortia to anticipate and evaluate the probable outcomes of various blockchain use cases.

The existence of *cross-enterprise workflows* and multi-party transactions helps to develop a clear and relevant use case to drive successful adoption [61]. For example, supply chain consortia may include partners engaged in coordinated planning for material movement and handoffs or for shared regulatory compliance; finance industry consortia may share costs associated with customer verification and anti-money laundering requirements; cross-industry consortia may share scarce resources such as docking locations in a port or space inside a grain silo. The ability to share information in a validated, secure, and up-to-date format, or to automate actions through smart contracts, can create benefits for all parties [61].

The *need for real-time information sharing* presents a clear advantage for blockchain solutions. Traditional enterprise resource planning (ERP) and other enterprise systems do not share information easily, and in some sectors, rely on outdated electronic data interchange (EDI) systems or even on emailed spreadsheets [62]. This can result in delayed access to information, wasted time, and reconciliation difficulties due to error or fraud [63]. Blockchain systems allow partners to record, share, and aggregate data in real time. The result is greater visibility of activities and more immediate decisions.

3.1.2 Shared Vision

Prospective partners must have a shared vision for a blockchain project's purpose and benefits to attract the investment and commitment necessary for project success. Each individual participant may benefit differently, but the consortium must agree upon collective benefits from collaboration and share an understanding of how they will be realised through the blockchain network.

Participants need a shared *ecosystem mission.* This mission shapes the current and future contours and benefits for the jointly developed distributed system. Problems arise when a blockchain addresses important issues for its founding organisations but fails to provide the same level of benefit for future participants. This was a problem for the IBM Maersk Trade Lens blockchain as it sought to expand. German company Hapag-Lloyd would not join a consortium controlled by competitors Maersk and IBM until the platform made governance changes that benefitted the industry more broadly [64]. Ideally, consortia will be formed and they grow with a high-level ecosystem mission associated with transparency, security, provenance, and equality. While participants will have their own reasons for joining, the ecosystem as a whole should have a mission that supersedes the interests of a few powerful partners.

A positive *value proposition* for every blockchain participant is essential.

Blockchain participation and its associated process and technological changes make the technology costly and risky. These investments must be outweighed by the value created and captured by every current and future blockchain participant. While each initial participant in a consortium must weigh its own costs and benefits, many fail to anticipate the return on investment for future members. In many cases, network effects are realised when the value of the network for an individual participant increases as the network grows [65], so it is important to anticipate the likely business case for those who might join in the future.

Blockchain requires a *collaborative mindset* in which value is generated through cooperation. Strategic positioning and strategic advantage are based on the philosophy that companies achieve long-term success when they consistently outperform competitors, but such thinking can be counterproductive for blockchain consortia. Many large companies participate in strategic alliances that are built on cooperation, or often more aptly "co-opetition," but these are often short-term collaborations among a small group of partners. Blockchain consortia typically have no pre-determined endpoint and include tens, hundreds, or thousands of participants. Participants must collaborate to securely share processes, information, or other resources. Partners must govern the network in a manner agreeable to current and future participants. The World Economic Forum [66] states "it is critical to reach agreement on not just the initial value levers to be pursued by the ecosystem but also the longer-term vision to be pursued."

3.1.3 Partner Competencies

Partners in a blockchain collaboration can benefit from a number of competencies required to develop and manage a consortium that generates value. Individual competencies will strongly influence whether the partner will achieve a return from blockchain investment. Further, individual partner success is instrumental in the success of the consortium.

Blockchain participants benefit from prior *domain area* knowledge and expertise related to the blockchain solution in development. Companies typically collaborate in areas where they are already subject matter experts, such as financial services for R3 or track and trace for FoodTrust. In some cases, however, companies explore blockchain solutions that extend beyond current expertise. TaxChain, for example, enables importers to validate trade certificates and the Plastic Bank provides a way for companies to provide evidence that they are achieving claimed sustainability goals. Although some of the partners in these blockchains have domain area expertise, others need to develop expertise in order to maximise potential value from the blockchain project.

Distributed technologies are new and require significant *technical* knowledge and development expertise in participating organisations. While many blockchain projects are guided by SaaS providers such as IBM and Accenture [67], participants typically need a level of blockchain competence in their IT functions. Information stored on the blockchain will flow to, or be compared with, information in the company's ERP and other systems. IT staff will need to integrate these systems appropriately. Control and permissioning of blockchain access must also be managed, and technologists will need processes for key assignment and management. Many firms will need blockchain-specific skills, such as the ability to manage a validator node and maintain consensus with other partners.

Technology staff may also need the ability to understand, test, modify, and create smart contracts or to oversee those functions. Pre-audited contract templates are increasingly available, and contract developers and auditors can be engaged for idiosyncratic contracts. High-level applications facilitate the creation and testing of smart contracts and the use of pre-developed code libraries or domain-specific apps. IT staff may be tasked with using these solutions.

Relational capabilities allow firms to establish and maintain beneficial relationships with partner organisations. Relationships enable a firm to access information and resources necessary for project success that would otherwise be unavailable. Blockchain consortia may include companies that have no prior relationships, or have a past history of ineffective partnership. Individual blockchain participants need to form relationships with transacting partners that enable collaboration in transaction processing and governance decisions. For partners with whom they will transact directly, firms also need the ability to collaborate on restructured business processes to accommodate effective blockchain innovation and use.
Blockchain projects have been described as mini-economies [11], which suggest a need for platform-level economic analysis. Participants in these projects contribute numerous resources to system development and maintenance. Firms need the ability to evaluate the economic benefits associated with these investments. These systems are often designed to reduce inefficiencies and smooth frictions in marketplace interactions [68]. Their economic benefits may flow from coordination, the ability to immediately and economically share information, the ability to ensure execution and manage risk through smart contracts and control, and the ability to maintain data and regulate permissions.

Blockchain solutions provide numerous opportunities for value creation and *value capture* by consortia members [6]. Operational benefits from enterprise blockchains include reduced costs through disintermediation or enhanced reconciliation, improved processes through enhanced coordination and information sharing, and reduced counterparty risks. These solutions create opportunities for new sources of competitive advantage through the development of new products, processes, or business models. Companies with the capacity to sense and seize these opportunities will need to reconfigure their organisations in order to capitalise on them. Successful firms will be poised to extract value from their participation in enterprise blockchain consortia. Participants will also gain competencies that enable them to capitalise upon future blockchain projects should the opportunity arise.

3.2 Consortium Capabilities

Consortium capabilities are necessary competences for a consortium to survive, evolve, and continue to produce value for its members. These competencies exist at the consortium level rather than at the individual participant level. Some consortia are structured as stand-alone entities while others take the form of alliances between independent partners. No matter the structure, the consortium will need capabilities that differ from those of the individual partners. Participants possess diverse capabilities and differentially contribute to consortium success. Each organisation will have its own strategic expertise but will also benefit from consortium capabilities distributed across the network.

3.2.1 Situational Assessment

Situational assessment is an ability to monitor and assess the resources, assets, and other benefits possessed by or available to consortium participants. Because the framework addresses the consortium's strategic, technical, and governance capabilities separately, the focus here is on consortium operations. A consortium needs to regularly assess its resources and whether they are consistent with day-to-day needs. Resources include financial contributions by partners or generated by the consortium, the technology currently possessed, data owned and controlled, human resources dedicated to consortium operations, brand or reputation, relationships between the consortium and outsiders such as regulators or potential technology providers, and other tangible and intangible assets that could be used to create value.

Assessments will also examine current *partners* and their level of commitment to the consortium – including their ongoing commitment and support for the consortium's current and strategic goals. A consortium should monitor its ability to cultivate potential partners, attract new partners, and retain existing partners. As appropriate, the consortium might also assess the degree to which it is successful in attracting high-profile partners and partners that possess specific desired capabilities or resources.

Regular documentation and assessment of *workflows* is another opportunity to provide value. As partners move into and out of roles and committees, they will need to understand how the day-to-day work of the consortium is accomplished. Workflows associated with partner relationships should be documented and shared at the consortium level, as shared IoT and communications standards and workflows increase the consortium's value to partners [61]. A full shared knowledge base of past, present, and planned workflows can also be valuable.

Regular assessment of external actors' needs and expectations from a consortium is also important. All actors that affect or are affected by the consortium's operations should be identified, with inputs and impacts regularly evaluated. Examples include governing bodies, standards organisations, tax and customs authorities, financing organisations, non-partner suppliers and customers of the consortium, and media. Regular and thorough situational assessment and communication of this information among consortium partners lays the groundwork for ongoing work around strategy and governance.

3.2.2 Governance

Effective governance is perhaps the most foundational element in blockchain success. Managing governance among a group of partners can prove challenging as enterprises will differ in their priorities, profit and loss models, and business processes [69]. Aligning standards, designing consistent codes of conduct across industries, and ensuring stakeholders of all sizes have input [70]. Successful governance should encourage the continued development of industry standards, formal business processes, and other best practices.

However, governance is an expansive topic and there continue to be misconceptions about the core concept. Allen and Berg [71] argue that "blockchain governance relates to the way decisions are made, not the decisions themselves – who chooses and how choices are made, rather than what is chosen." Successful consortia require endogenous and exogenous governance mechanisms [71]. Endogenous governance refers to consensus mechanisms and other control procedures built into blockchain platforms. Exogenous governance refers to formal and informal agreements about the network itself, such as processes for admitting new participants or voting on platform changes. Tasca and Tessone [72] also recognise external factors affecting governance, including regulatory frameworks and industry policies. Van Pelt et al. [73] describe three layers of governance: on-chain protocol, which refers to rules encoded in the platform; off-chain development, which refers to the real-world processes related to governance of the protocol; and off-chain community, which refers to how the broader community defines and is tied to the blockchain.

Blockchain networks have many *stakeholders*, who pursue unique outcomes through participation in blockchain consortia. Governance helps coordinate the rights, responsibilities, actions, and incentives of diverse stakeholders with the overarching goal of network survival and growth. Blockchain governance agreements have the potential to support or even replace traditional forms of corporate governance such as legal contracts or behavioural norms [1]. Blockchain governance agreements therefore may be of interest to C-level executives and boards. Van Pelt et al. [73] provide a framework for blockchain governance based on extensive research and validation. The framework has six major *components*: formation and context reflecting the blockchain purpose and ideology, roles that determine responsibilities and accountability, incentives that motivate community members, membership processes for blockchain participation, communication relating to coordination and performance, and decision-making processes such as consensus and conflict resolution. Successful blockchain consortia must possess the capability to effectively enact and manage each of these six components, which will begin prior to the formation of the consortium and continue as it evolves.

3.2.3 Technology

Whether the consortium builds its own platform or relies on a software-as-a-service provider, technical expertise will be required to support normal platform activities and innovations to improve the functioning of the blockchain network. The consortium must possess the skills necessary to support the *existing demands* on a blockchain system, both at its inception and as the network grows, when partners join and leave, and platform functionality evolves.

The technological skills necessary to incorporate *innovation* through fundamental changes to the blockchain architecture is also a necessary consortium-level capability. Blockchain evolves rapidly. Improvements to core mechanisms of the underlying blockchain technology continue at a rapid pace. Examples include improvements to consensus mechanisms, data storage solutions, and protocols for interoperability that enable the sharing of assets and processes across networks. Technologists need the ability to stay abreast of these developments and to determine their appropriateness and compatibility with existing consortia structures and goals. When these innovations can provide significant benefits, technologists will need to plan and oversee system changes. Blockchain technology is still new, and innovations in the capacity and uses of these systems are continually introduced. A consortium needs the ability to understand how such innovation might enable or constrain the achievement of its strategic vision and develop plans to respond and adapt accordingly.

3.2.4 Strategic

Effective consortia need a shared strategic vision and mission to ensure success. Ongoing effectiveness requires the ability to manage and redesign the ecosystem's mission, respond to ecosystem learning, and adapt to environmental changes. Successful deployment of blockchain solutions "requires a shift to thinking in terms of the ecosystem" and a mindset that "allows organisations to move beyond what's traditionally possible for them within the confines of their own vertically integrated operations" [66]. A consortium must possess strategic capabilities to manage performance at the ecosystem level.

Strategic factors that influence the success of a blockchain consortium are many and varied. The consortium needs the capacity to *sense opportunities and risks*, which may include the introduction of competing consortia, partners joining and leaving the network, evolution of trade or industry standards, or new regulations. Consortia without the ability to respond to these risks will struggle to succeed within a rapidly changing marketplace. Working with IT, strategists can benefit from regularly scanning the environment for technological developments in blockchain and related technologies. The integration of IoT and artificial intelligence for writing and analysing records may promote the goals of the consortium and its stakeholders. Strategists should also foresee potential benefits that arise as the network scales and plan to translate into financial returns. Revenue-generating opportunities and new ways to monetise data should be anticipated and explored. Lessons can be learned from new use cases in related, or unrelated, contexts that have parallel sets of goals and constraints.

Successful consortia not only need to manage risk and seek out new opportunities; they need to be able to reconfigure the consortium accordingly. Effective digital transformation and dynamic learning capabilities enable blockchain participants to effectively form and execute strategies to capitalise on emerging risks and opportunities. Effective change management will require collaboration and coordination with consortium stakeholders about shifts in situational assessment, governance, and

technology. Communication with consortium stakeholders will be crucial as changes are proposed with shifts in responsibilities and impact [74].
The success of a consortium hinges on its ability to create value for its participants, the broader ecosystem, and its partners. A consortium's ability to evaluate both network and individual member outcomes is of crucial importance. While the value proposition is addressed before a company decides to participate, evaluation mechanisms must be in place to determine whether the project lives up to expectations for costs and value creation. These evaluations inform the need for changes in governance and direct collaboration with other partners. Naqvi and Hussain [58] outline a process for blockchain evaluation based on widely accepted, evidence-based research and evaluation processes. They suggest effective evaluation comes from a clear definition of the problems to be addressed and a critical evaluation of both existing solutions and the new system at the initiation of the blockchain project [58]. Ongoing analysis of project performance provides evidence that can be assessed by current stakeholders as well as by independent evaluators.

3.3 Outcomes

Participation in blockchain consortia provides a broad range of outcomes for both individual participants and the broader ecosystem. We separate these outcomes into three categories. The first is partner operations, which refers to direct effects of the blockchain on day-to-day activities. The second is partner impacts, which are the longer-term financial and other impacts enabled by participation in the consortium. Third is ecosystem value. The ecosystem itself, with its growing database of blockchain transactions and network participation, generates value in a number of ways.

3.3.1 Partner Operations

Exploring the whole range of direct and indirect benefits and costs is essential for understanding the potential or realised value of an enterprise blockchain for its participants. Commonly discussed benefits include increased efficiency, reduced costs and risks, and enhanced customer experience [74].

Process improvements are often the driver for blockchain implementation and participation. The ability to track each action in a workflow renders processes visible and creates opportunities for improvement. Evaluation of potential blockchain benefits often begins with the identification of pain points and frictions. The potential for an accurate, agreed-upon transaction record to reduce paperwork-processing dispute resolution is a common source of improvement, as is the disintermediation resulting from reduced need for external verification. Similar to the implementation of ERP systems, participation in blockchain consortia encourages companies to reengineer their business processes for the blockchain environment [75].

A focus on *business integration* encourages participants in an enterprise blockchain to re-think and reengineer both external and internal company processes [56]. In some cases, consortium participation enables processes to be shared or outsourced. For example, when one blockchain partner performs a "Know Your Customer" analysis to comply with anti-money laundering regulations, other partners can rely on that analysis and avoid incurring additional costs to trade with the customer. The adoption of industry best practices through process standardisation provides another opportunity for performance improvement [75].

Security enhancements available in blockchain environments further affect operations for many partners. Data, digital assets, and intellectual property can be secured and authenticated using cryptography, and consensus models reduce the potential for destruction or alteration of information [29, 30]. Decentralised identity functionality enables enhanced privacy for customers, employees, and transacting partners. It also enhances opportunities to minimise sensitive data collected and stored and reduces the need to secure such data. The level of cybersecurity maturity among participants increases through the validated provenance of all intercompany transactions recorded on the blockchain. In some cases, such agreements can be executed automatically [18].

3.3.2 Partner Outcomes

Blockchain use cases vary in their objectives and significance for blockchain partners. In some cases, blockchain solutions are integral to firm strategy. In other cases, they lead to economic outcomes, new or reformed relationships with consortium partners, and environmental and social impacts.

Strategic benefits can be gained in a number of ways. Adoption of blockchain technologies may contribute to reputational effects, as firms may be seen as forward-thinking or they may affect the firm's strategic goals directly. Yuthas et al. [6] provide examples of companies that have strengthened strategic capabilities in several ways. Some partners have built upon existing capabilities, for example, by using provenance-based systems to validate product claims. Others have built blockchain-specific capabilities such as developing expertise or consortium governance that can extend to future projects. Consortium platforms have also been used to share data and strategic resources, leading to the development of new projects and strengthened partner relationships.

Economic benefits arise through a variety of avenues. Operational improvement derives from reduced costs through the elimination of processes and intermediaries, or enhanced efficiency through process performance and reduced risk. Improvements in transparency and visibility improve planning and increase predictability in ways that enhance asset utilisation and delay the need for new capital investments [26, 44]. Improvements in service responsiveness and quality that result from redesigned processes can increase revenue by attracting new customers and reducing turnover. New products and business models can help partners to serve new markets or enhance services to existing markets. All of these changes allow firms to create and capture new sources of value.

Relational outcomes realised through ties between partners are established or strengthened through strategic collaborations [76]. Consortium participants may collaborate in a variety of ways. Smart contract-based business arrangements reduce the cost associated with establishing and maintaining trust with trade partners and improve relationships at the firm level [75]. The blockchain-driven redesign of business processes can also facilitate new relationships at the firm level. Participation in consortium-level initiatives can build relationships as members work together to resolve governance and technological issues. Strategic alliance experience suggests that relationships formed through one project can carry over to other collaborative efforts.

Environmental and social outcomes also result from blockchain efficiencies. Reduced use of paper resulting from increased digitalisation is a small but not trivial example of creating more sustainable business operations. Outcomes will vary by firm and industry, but can be significant. For example, the Digital Shipping Container Association (DCSA) is developing standards for a system that will help carriers move away from "hurry up and wait" itineraries towards reaching ports just in time to unload. This change has the potential to significantly reduce excessive use of fuel and, in turn, greenhouse gas emissions [77]. Digitalisation and blockchain-enabled connectivity in the maritime sector can be pivotal in reducing the industry's collective carbon footprint [78].

3.3.3 Ecosystem Value

Blockchain systems also create outcomes at the ecosystem level, providing potential benefits for all consortium members. Blockchain partnerships can take many forms, including relational agreements among participants and for-profit entities. Regardless of the specific form, a consortium will incur costs of operations and generate value at the ecosystem level, some of which can be distributed to partners.

Forrester's Total Economic Impact model identifies basic elements of direct economic benefits from blockchain systems in a study commissioned by IBM [79]. Costs of delivering a blockchain solution include costs of the pilot phase, costs of bringing the solution to commercial scale, and the ongoing costs of maintaining the system. Benefits to the blockchain provider or ecosystem include fees for joining the network, ongoing membership fees, and transaction and contract execution fees paid by partners for using the system.

Participation in blockchain consortia requires companies to shift focus away from capturing value through competition and towards the systemic benefits provided by collaboration. The collaboration supported by an enterprise blockchain can provide value to all partners by providing access to new, authenticated, and vetted trading partners on the network. Although these benefits are realised by individual companies, they are created by the consortium. Blockchain systems provide access to technological capabilities that may otherwise be unavailable to individual firms, particularly small producers that can pay membership and transaction fees but do not possess advanced skills or technology. Ecosystems enable sharing and reduction of regulatory, compliance, and lobbying costs as well as the costs of developing and implementing standards.

Improvements in performance for ecosystem partners provide additional benefits for partner stakeholders. Customers, for example, will ultimately benefit from increased efficiency and quality. Ecosystem success may likewise be associated with improved utilisation of assets and reduced waste across the network. This can provide both economic and environmental benefits as the footprint for the production and delivery of goods is decreased [80].

4. Conclusion

Companies are investing heavily in exploring blockchain technologies, and industry projections suggest a rapid growth of these technologies in numerous verticals. For this vision to be realised, business capabilities must catch up to technological capabilities. Business processes must be redesigned to take advantage of the many benefits the technology can provide. Organisations and their leaders must learn to effectively form and govern consortia and associated relationships.

The consortium capabilities framework presented in this chapter provides an overview of core business elements that can promote blockchain success. By developing and employing these capabilities at the firm and network levels, consortia can better realise the promise of this still-new technology. This framework fills a current void in the literature by providing a practical set of guidelines for companies and consortia to consider when building and maintaining their networks.

References

[1] Fabrice Lumineau, Wenqian Wang, and Oliver Schilke, "Blockchain Governance—A new way of organizing collaborations?" Organization Science, 2020.

[2] S. Davidson, P. De Filippi, and J. Potts, "Blockchains and the economic institutions of capitalism," The Journal of Institutional Economics, vol. 14, (4), pp. 639–658, 2018.

[3] A. Dutra, A. Tumasjan, and I. M. Welpe, "Blockchain is changing how media and entertainment companies compete," MIT Sloan Management Review, vol. 60, (1), pp. 39–45, 2018.

[4] M. A. Engelhardt, "Hitching healthcare to the chain: An introduction to blockchain technology in the healthcare sector," Technology Innovation Management Review, 7, (10), 2017.

[5] M. Janssen, V. Weerakkody, E. Ismagilova, U. Sivarajah, and Z. Irani, "A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors," International Journal of Information Management, vol. 50, pp. 302–309, 2020.

[6] Kristi Yuthas, Yolanda Sarason, and Asad Aziz, "Strategic value creation through enterprise blockchain," The Journal of The British Blockchain Association, 4, (1), pp. 3–10, 2021.

[7] K. W. Prewett, G. L. Prescott, and K. Phillips, "Blockchain adoption is inevitable—Barriers and risks remain," Journal of Corporate accounting & finance, vol. 31, (2), pp. 21–28, 2020.

[8] F. Werner, M. Basalla, J. Schneider, D. Hays, and J. Vom Brocke, "Blockchain adoption from an interorganizational systems perspective–a mixed-methods approach," Information Systems Management, vol. 38, (2), pp. 135–150, 2021.

[9] M. Ozturan, I. Atasu, and H. Soydan, "Assessment of blockchain technology readiness level of banking industry: Case of Turkey," International Journal of Business Marketing and Management (IJBMM), vol. 4, (12), pp. 01–13, 2019.

[10] D. Ghode, V. Yadav, R. Jain, and G. Soni, "Adoption of blockchain in supply chain: An analysis of influencing factors," Journal of Enterprise Information Management, 2020.

[11] Elissar Toufaily, Tatiana Zalan, and Soumaya Ben Dhaou, "A framework of blockchain technology adoption: An investigation of challenges and expected value," Information & Management, vol. 58, (3), pp. 103444–103461, 2021.

[12] Yogesh K. Dwivedi Hughes, Santosh K. Misra, Nripendra P. Rana, Vishnupriya Raghavan, and Viswanadh Akella, "Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda," International Journal of Information Management, vol. 49, pp. 114–129, 2019.

[13] R. Ziolkowski, G. Miscione, and G. Schwabe, "Decision problems in blockchain governance: Old wine in new bottles or walking in someone else's shoes?," Journal of Management Information Systems, vol. 37, (2), pp. 316–348, 2020.

[14] H. M. Kim, and M. Laskowski, "Toward an ontology□ driven blockchain design for supply□ chain provenance," Intelligent Systems in Accounting, Finance and Management, vol. 25, (1), pp. 18–27, 2018.

[15] D. E. O'Leary, "Configuring blockchain architectures for transaction information in blockchain consortiums: The case of accounting and supply chain systems," Intelligent Systems in Accounting, Finance and Management, vol. 24, (4), pp. 138–147, 2017.

[16] A. Kumar, R. Liu, and Z. Shan, "Is blockchain a silver bullet for supply chain management? Technical challenges and research opportunities," Decision Sciences, vol. 51, (1), pp. 8–37, 2020.

[17] S. Rao, A. Gulley, M. Russell, and J. Patton, "On the quest for supply chain transparency through Blockchain: Lessons learned from two serialized data projects," Journal of Business Logistics, vol. 42, (1), pp. 88–100, 2021.

[18] J. Dai, and M. A. Vasarhelyi, "Toward blockchain-based accounting and assurance," Journal of Information Systems, vol. 31, (3), pp. 5–21, 2017.

[19] S. Yoo, "Blockchain based financial case analysis and its implications," Asia Pacific Journal of Innovation and Entrepreneurship, 2017.

[20] M. O'Dair, and R. Owen, "Financing new creative enterprise through blockchain technology: Opportunities and policy implications," Strategic Change, vol. 28, (1), pp. 9–17, 2019.

[21] T. Hardin, and D. Kotz, "Amanuensis: Information provenance for health-data systems," Information Processing & Management, vol. 58, (2), p. 102460, 2021.

[22] J. Mattke, A. Hund, C. Maier, and T. Weitzel, "How an enterprise blockchain application in the US pharmaceuticals supply chain is saving lives," MIS Quarterly Executive, vol. 18, (4), 2019.

[23] S. Biswas, K. Sharif, F. Li, Z. Latif, S. S. Kanhere, and S. P. Mohanty, "Interoperability and synchronization management of blockchain-based decentralized e-health systems," IEEE Transactions on Engineering Management, vol. 67, (4), pp. 1363–1376, 2020.

[24] K. Miyachi, and T. K. Mackey, "hOCBS: A privacy-preserving blockchain framework for healthcare data leveraging an on-chain and off-chain system design," Information Processing & Management, vol. 58, (3), p. 102535, 2021.

[25] S. Höhne, and V. Tiberius, "Powered by blockchain: Forecasting blockchain use in the electricity market," International Journal of Energy Sector Management, 2020.

[26] L. D. Xu, E. L. Xu, and L. Li, "Industry 4.0: state of the art and future trends," International Journal of Production Research, vol. 56, (8), pp. 2941–2962, 2018.

[27] K. W. Prewett, G. L. Prescott, and K. Phillips, "Blockchain adoption is inevitable—Barriers and risks remain," Journal of Corporate accounting & finance, vol. 31, (2), pp. 21–28, 2020.

[28] Y. Wang, and A. Kogan, "Designing confidentiality-preserving Blockchain-based transaction processing systems," International Journal of Accounting Information Systems, vol. 30, pp. 1–18, 2018.

[29] A. Vatankhah Barenji, Z. Li, W. M. Wang, G. Q. Huang, and D. A. Guerra-Zubiaga, "Blockchain-based ubiquitous manufacturing: a secure and reliable cyber-physical system," International Journal of Production Research, vol. 58, (7), pp. 2200–2221, 2020.
[30] M. Kuperberg, "Blockchain-based identity management: A survey from the enterprise and ecosystem perspective," IEEE Transactions on Engineering Management, vol. 67, (4), pp. 1008–1027, 2019.
[31] X. Xu, G. Sun, L. Luo, H. Cao, H. Yu, and A. V. Vasilakos, "Latency performance modeling and analysis for hyperledger fabric blockchain network," Information Processing & Management, vol. 58, (1), p. 102436, 2021.
[32] A. Carvalho, J. W. Merhout, Y. Kadiyala, and J. Bentley II, "When good blocks go bad: Managing unwanted blockchain data," International Journal of Information Management, 57, p. 102263, 2021.
[33] H. Song, N. Zhu, R. Xue, J. He, K. Zhang, and J. Wang, "Proof-of-Contribution consensus mechanism for blockchain and its application in intellectual property protection," Information Processing & Management, vol. 58, (3), p. 102507, 2021.
[34] Y. Zhang, L. Zhang, Y. Liu, and X. Luo, "Proof of service power: A blockchain consensus for cloud manufacturing," Journal of Manufacturing Systems, vol. 59, pp. 1–11, 2021.
[35] L. W. Wong, L. Y. Leong, J. J. Hew, G. W. H. Tan, and K. B. Ooi, "Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs," International Journal of Information Management, vol. 52, p. 101997, 2020.
[36] X. Pan, X. Pan, M. Song, B. Ai, and Y. Ming, "Blockchain technology and enterprise operational capabilities: An empirical test," International Journal of Information Management, vol. 52, p. 101946, 2020.
[37] J. L. Hartley, and W. J. Sawaya, "Tortoise, not the hare: Digital transformation of supply chain business processes," Business Horizons, vol. 62, (6), pp. 707–715, 2019.
[38] K. Werbach, and N. Cornell, "Contracts ex machine," Duke Law Journal, vol. 67, p. 313, 2017.
[39] L. Y. Yeh, P. J. Lu, S. H. Huang, and J. L. Huang, "SOChain: A privacy-preserving DDoS data exchange service over soc consortium blockchain," IEEE Transactions on Engineering Management, vol. 67, (4), pp. 1487–1500, 2020.
[40] C. Reyes, C., "(Un) Corporate Crypto-Governance," Fordham Law Review, vol. 88, (5), p. 1875, 2020.
[41] N. E. Vincent, and R. Barkhi, "Evaluating blockchain using COSO," Current Issues in Auditing, vol. 15, (1), pp. A57–A71, 2021.
[42] P. Tasca, A. Hayes, and S. Liu, "The evolution of the bitcoin economy: Extracting and analyzing the network of payment relationships," The Journal of Risk Finance, 2018.
[43] R. Olsen, S. Battiston, G. Caldarelli, A. Golub, M. Nikulin, and S. Ivliev, "Case study of Lykke exchange: Architecture and outlook," The Journal of Risk Finance, 2018.
[44] T. Zheng, M. Ardolino, A. Bacchetti, and M. Perona, "The applications of Industry 4.0 technologies in manufacturing context: A systematic literature review," International Journal of Production Research, vol. 59, (6), pp. 1922–1954, 2021.
[45] S. Guerreiro, "Conceptualizing on dynamically stable business processes operation: A literature review on existing concepts," Business Process Management Journal, 2020.
[46] M. C. Lacity, "Addressing key challenges to making enterprise blockchain applications a reality," MIS Quarterly Executive, vol. 17, (3), pp. 201–222, 2018.
[47] L. Zavolokina, R. Ziolkowski, I. Bauer, and G. Schwabe, "Management, governance and value creation in a blockchain consortium," MIS Quarterly Executive, Epub-ahead, 2020.
[48] J. Nathan, and B. Jacobs, "Blockchain consortium networks: Adding security and trust in financial services," Journal of Corporate Accounting & Finance, vol. 31, (2), pp. 29–33, 2020.
[49] G. Schwabe, "The role of public agencies in blockchain consortia: Learning from the Cardossier," Information Polity, vol. 24, (4), pp. 437–451, 2019.
[50] A. Pólvora, S. Nascimento, J. S. Lourenço, and F. Scapolo, "Blockchain for industrial transformations: A forward-looking approach with multi-stakeholder engagement for policy advice," Technological Forecasting and Social Change, vol. 157, p. 120091, 2020.
[51] Naseem Naqvi, "Editorial," Journal of the British Blockchain Association, vol. 4, (1), p. 15, 2021.
[52] M. Swan, Blockchain: Blueprint for a new economy. O'Reilly Media, Sebastopol, CA, USA, 2015.
[53] A. Tapscott, Blockchain revolution: How the technology behind Bitcoin is changing money, business, and the world. Penguin, New York, NY, 2016.
[54] M. Iansiti, and K. R. Lakhani, "The truth about Blockchain," Harvard Business Review, vol. 95, (1), pp. 118–127, 2017.
[55] Staphanie Hurder, Why Enterprise Blockchains Fail: No Economic Incentives. 02 March 2020. Available: https://www.coindesk.com/why-enterprise-blockchains-fail-no-economic-incentives
[56] L. Pietrewicz, "Coordination in the age of industry 4.0," Economic and Social Development: Book of Proceedings, pp. 264–274, 2019.
[57] Dante Disparte, "Why enterprise blockchain projects fail," Forbes 20 May 2019. Available: https://www.forbes.com/sites/dantedisparte/2019/05/20/why-enterprise-blockchain-projects-fail/?sh=2d271c7a4b96.
[58] N. Naqvi, and M. Hussain, "Evidence-based blockchain: Findings from a global study of blockchain projects and start-up companies," Journal of the British Blockchain Association, vol. 3, (1), 2020.
[59] K. Wüst, and A. Gervais, "Do you need a blockchain?" 2018 Crypto Valley Conference on Blockchain Technology (CVCBT). Zug, pp. 45–54, 2018.
[60] PwC. Blockchain. 6 May 2015. Available: https://www.pwc.co.uk/blockchain.html
[61] N. Gaur, "Blockchain challenges in adoption," Managerial Finance, 2020.
[62] T. Jensen, J. Hedman, and S. Henningsson, "How TradeLens Delivers Business Value With Blockchain Technology," MIS Quarterly Executive, vol. 18, (4), 2019.
[63] L. Hsu, and M. Chen, "Impacts of ERP systems on the integrated interaction performance of manufacturing and marketing," Industrial Management & Data Systems, vol. 104, (1), pp. 42–55, 2004.
[64] O. Andersen, and L. Vogdrup-Schmidt, "Rivals reject blockchain solution from Maersk and IBM," 15 May 2018. Available: https://shippingwatch.com/carriers/Container/article10602520.ece
[65] Amin Vafadarnikjoo, and Hadi Badri Ahmadi, and James J. H. Liou, Tiago Botelho, and Konstantinos Chalvatzis, "Analyzing blockchain adoption barriers in manufacturing supply chains by the neutrosophic analytic hierarchy process," Annals of Operations Research, 2021.
[66] World Economic Forum. Inclusive deployment of blockchain for supply chains: A framework for blockchain interoperability. Geneva: World Ecomomic Forum, 2020. Available: http://www3.weforum.org/docs/WEF_A_Framework_for_Blockchain_Interoperability_2020.pdf
[67] IDC. A New IDC MarketScape Assesses Eleven Providers of Blockchain Services. 16 June 2020. Available: https://www.idc.com/getdoc.jsp?containerId=prUS46572520
[68] C. Barrera, and S. Hurder, Cryptoeconomics: Designing effective incentives and governance models for blockchain networks using insights from economics. Toronto: Blockchain Research Institute, 2020.
[69] L. Laidin, K. Papadopoulou, and N. Dane, "Parameters for building sustainable blockchain application initiatives," The Journal of the British Blockchain Association, vol. 2, (1), 2019.
[70] Global Blockchain Business Council. Global Standard Mapping Initiative (GSMI) 2020. Geneva: Global Blockchain Business Council, 2020.
[71] Darcy W. E. Allen, and Chris Berg, "Blockchain governance: What we can learn from the economics of corporate governance," Journal of the British Blockchain Association, vol. 3, (1), 2020.
[72] Paolo Tasca, and Claudio J. Tessone, "Taxonomy of blockchain technologies: Principles of Identification and Classification," Ledger, vol. 4, 2019.
[73] Rowan van Pelt, Slinger Jansen, Djuri Baars, and Sietse Overbeek, "Defining blockchain governance: A framework for analysis and comparison," Information Systems Management, 2020.
[74] A. Banda, et al., IBM Blockchain: The founders handbook. Armonk: IBM, 2020.
[75] Shuchih Ernest Chang, Yi-Chian Chen, and Ming-Fang Lu. "Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process," Technological Forecasting & Social Change, vol. 144, pp. 1–11, 2019.
[76] R. Gulati, N. Nohira, and A. Zaheer, "Strategic networks," Strategic Management Journal, vol. 21, (3), pp. 203–215, March 2000, doi: 10.1002/(SICI)1097-0266(200003)21:3<203::AID-SMJ102>3.0.CO;2-K.
[77] DCSA. "Standards for a just-in-time port call." 2020.
[78] UNCTAD. Digitalizing the port call process. Geneva: United Nations, 2020.
[79] Forrester Consulting. Emerging Technology Projection: The Total Economic

Impact™ Of IBM Blockchain. Cambridge: Forrester, 2018.
[80] Mahtab Kouhizadeh, and Joseph Sarkis. "Blockchain practices, potentials, and perspectives in greening supply chains," Sustainability, vol. 10, (10), p. 3652, 2018.

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AN EXCELLENCE STANDARDS FRAMEWORK

FOR

UK'S NATIONAL BLOCKCHAIN ROADMAP (NBR)

(VISION 2030)

The British Blockchain Association

Advocating Evidence Based Blockchain

RECOMMENDATIONS BY

THE CENTRE FOR EVIDENCE-BASED BLOCKCHAIN

CEBB | Centre for Evidence-Based Blockchain

JULY 2021

www.britishblockchainassociation.org

FOREWARD

This framework sets out a blueprint to devise the UK's National Blockchain Roadmap. It is a concise summary of the key recommendations that aim to inspire and reform Britain's DLT landscape. It builds on the excellent foundational principles set by blockchain academics, industry leaders, policymakers and communities over the past decade.

At this critical juncture, the timely recommendations provide clarity, inspiration and guidance to build a world-class blockchain ecosystem. It is an informative tool that can be used to construct the key components of the UK's Blockchain economy. There is real momentum and enthusiasm among the DLT stakeholders and the UK is ready to capitalise on opportunities offered by emerging technologies.

There is a pressing need to devise policies that are evidence-based. In the midst of the challenge lies some of the greatest opportunities. The principles and recommendations put forward in this excellent framework will position the UK at the forefront of DLT leadership, advance best standards, and provide signposts for future development.

Martin Docherty-Hughes MP
Chair, UK All-Party Parliamentary Group on Blockchain

FOREWARD

This is a landmark report – an evidence-based summary of excellence standards that lays the foundations of a holistic and interdisciplinary approach towards the UK's National Blockchain Roadmap. The UK has emerged as a world leader in the field of Blockchain. However, there is further work to be done. In times of uncertainty, there was an emergent need to establish a scientific blueprint that provides objectivity and precision to deliver the next 10-15 year DLT roadmap for the UK. Blockchains have been in existence for more than a decade and it is about time we measure the societal impact of their applications. We have the tools and frameworks of evidence-based blockchain to evaluate projects against rigorous standards and deploy those that show demonstrable evidence of effectiveness.

These recommendations will provide the foundation of targeted action steps, policies and benchmarks to advance best practices. The credit goes to the Centre for Evidence-Based Blockchain for their insightful contributions and to the British Blockchain Association for their convening and production of this report, expert navigation and synthesis of the many complex issues that it covers. Peer review is a critical part of the process of becoming a trusted source of information. It is traditionally considered as a benchmark in most sciences to examine the accuracy, integrity, validity and reliability of the information. This quality control filter builds authority and leads to increased collaboration and creativity. I truly believe that this report will become a milestone in setting the agenda and scientific policy framework for the UK's National Blockchain Roadmap. Our collective aspiration is to build a progressive and resilient DLT ecosystem in which UK's DLT sector and communities can then thrive.

I hope that these recommendations will stand as the blueprint for the UK's DLT roadmap and that it will provide a firm basis for a DLT -based digital UK. I welcome the arrival of this report and look forward to building a more trusted UK DLT economy with the BBA and other stakeholders in the quadruple helix innovation ecosystem.

Lord Holmes of Richmond MBE
Vice-Chair, UK All-Party Parliamentary Group on Blockchain

PREFACE

It is an understatement to say that blockchain is transforming the societal fabric of our lives. Policymakers and regulators face increasing pressure to support blockchain innovation while ensuring that policies are safe, cost-effective, consumer-centred, business-friendly, and based on trustworthy, reliable, and reproducible evidence.

Blockchain exists at the junction of technical, social, legal, and political paradigms; thus, there is a strong need for interdisciplinary harmony within the branches of distributed ledger technology (DLT). Blockchain ecosystems must provide freedom for innovation while at the same time, the stakeholders should be held accountable for the communities they intend to serve.

This framework outlines the essential components of the UK's National Blockchain Roadmap (NBR). Though primarily applicable to the UK DLT landscape, the framework may be equally relevant for other nations with similar economies that are experimenting with blockchain deployment. The benchmarks built upon these frameworks are intended to create a world-class, dynamic, and responsive DLT ecosystem.

The recommendations contained in this report are constructed on academic and industry research outputs built on peer-reviewed scientific data. This document is intended to provide a blueprint for the UK's National Blockchain Roadmap and to inform other evidence-based implementations of DLT in the United Kingdom and beyond.

Dr Naseem Naqvi FBBA
Chair, Centre for Evidence-Based Blockchain
President, The British Blockchain Association

RECOMMENDATIONS

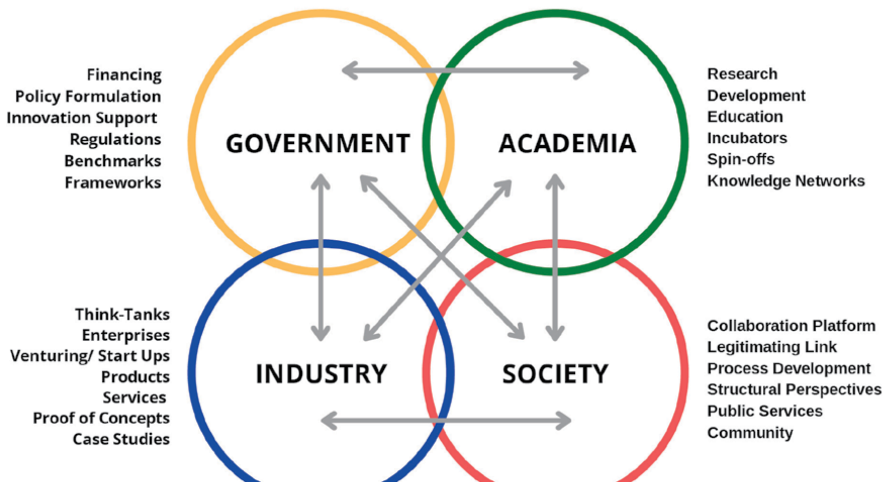
01

FOSTER "QUADRUPLE HELIX" BLOCKCHAIN INNOVATION ECOSYSTEMS

Evidence ecosystems are greater than the sum of their parts. Interventions, including those related to distributed ledger ecosystems, are most effective when deployed as a collective effort to benefit society and drive structural changes beyond the scope of any one organisation. The government must support blockchain clusters of quadruple-helix innovation systems by collaborating with policymakers, academia, industry, and public services. Best-practice standards should be established to nurture and advocate 'extended knowledge networks' (such as the Centre for Evidence-Based Blockchain) that will advance holistic, multi-disciplinary benchmarks in blockchain.

References:
The quadruple helix model of innovation for Industry 4.0:
http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1684-19992019000100025

Micro- and Macro-Dynamics of Open Innovation with a Quadruple-Helix Model:
https://www.researchgate.net/figure/The-roles-of-the-quadruple-helix-model-for-open-innovation-micro-and-macro-dynamics_fig4_333795559



Modified from: Developed notion of a Quadruple Helix innovation system DOI:10.1007/s13132-012-0098-3

Bridging the Blockchain Research and Practice Gap

Knowledge Society Policy Handbook (2016)

02

BUILD A PUBLIC REPOSITORY OF SUCCESSFULLY IMPLEMENTED BLOCKCHAIN USE CASES

In a 2016 blockchain report, Sir Mark Walport recommends:

"Government should establish trials of distributed ledgers in order to assess the technology's usability within the public sector. We suggest that the trials should be coordinated in a similar fashion to the way that clinical trials are implemented, reported and assessed, in order to ensure uniformity and maximize the rigour of the process."

We propose that the UK should not only establish the trials proposed by Walport but also build a public repository of successfully implemented use cases based on high-quality, peer-reviewed evidence from the UK and elsewhere. This repository would take the form of public permissioned data and would be managed by a federated consensus network of key stakeholders of the NBR's Sub-Speciality Steering Groups (SSGs, page 15), all of whom would have "write" access.

References:

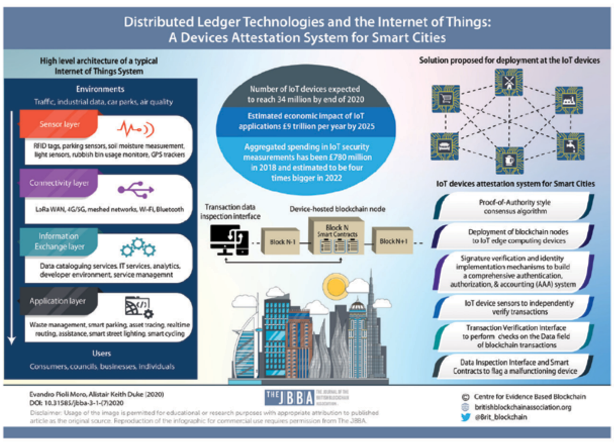
E-Voting on the Blockchain:
https://jbba.scholasticahq.com/article/4451-e-voting-on-the-blockchain

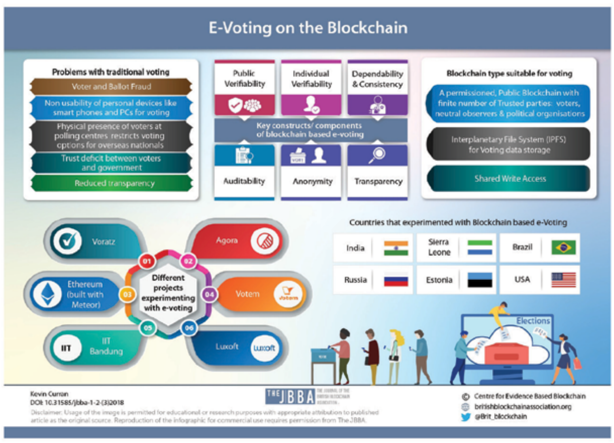
Distributed Ledger Technologies and the Internet of Things: A Devices Attestation System for Smart Cities:
https://jbba.scholasticahq.com/article/12500-distributed-ledger-technologies-and-the-internet-of-things-a-devices-attestation-system-for-smart-cities

Parameters for Building Sustainable Blockchain Application Initiatives:
https://jbba.scholasticahq.com/article/7758

Academic Certification using Blockchain: Permissioned versus Permissionless Solutions
https://jbba.scholasticahq.com/article/13618-academic-certification-using-blockchain-permissioned-versus-permissionless-solutions

Blockchain for real-time attribution, provenance and recognition of scientific research:
https://core.artifacts.ai/journal/jbba





03

ESTABLISH MEASURES TO AUDIT THE SOCIETAL IMPACT OF BLOCKCHAIN APPLICATIONS

We propose UK government work in collaboration with DLT Think-Tanks such as the British Blockchain Association to undertake regular audits of DLT projects using EBB's PCIO framework for evaluation of blockchain applications.

How do we know that the interventions worked? How do we know that a blockchain-based system works more efficiently than a legacy system? Blockchain think-Tanks should take an action-oriented approach to guide the use of blockchain. The pragmatic impact of all DLT based interventions should be reviewed and reflected over time to ensure they remain credible and relevant for the communities they intended to serve.

The 7 major domains of societal impact are:
Enterprise Economy / Industry and Private Sector
Society, Behavior and Culture
Public Policy and Legal
Environmental
Health, Life Sciences and Quality of Life (QOL)
Political and Governance
International / Trans-National

References:
Evidence Based Blockchain:
https://jbba.scholasticahq.com/article/16795-evidence-based-blockchain-findings-from-a-global-study-of-blockchain-projects-and-start-up-companies

EVIDENCE-BASED BLOCKCHAIN:

BLOCKCHAIN EXCELLENCE FRAMEWORK
(HIGH-IMPACT CASE STUDY)

ACADEMIC IMPACT

(PUBLICATIONS, CITATIONS, RESEARCH ENVIRONMENT)

↓

SOCIETAL IMPACT (THE "**BIG 7**")

> ENTERPRISE ECONOMY/ INDUSTRY
> SOCIETY AND CULTURE
> PUBLIC POLICY
> ENVIRONMENTAL
> HEALTH AND QUALITY OF LIFE (QOL)
> POLITICAL AND GOVERNMENT
> INTERNATIONAL / TRANS-NATIONAL

KEY INDICATORS	RANKING METRICS
IDEA/ CONCEPT	**EXCEPTIONALLY NOVEL** in developing Solutions, Concepts or Paradigms
PROJECT DESIGN	**EXCEPTIONALLY RIGOROUS** FOR METHODOLOGY (**EBB PCIO FRAMEWORK)**
OUTPUTS	Generate **EXCEPTIONALLY SIGNIFICANT** Data Set, Outcomes or proposals
IMPACT	A **FORMATIVE** influence on Intellectual Agenda, Policies, National Guidelines, Benchmarks and Standards
POINT OF REFERENCE (POR)	A **PRIMARY** or **ESSENTIAL** Point of Reference (POR)

Source: Modified from UK REF and EBB PCIO Framework


GOVERNMENT & POLITICAL
ACADEMIC
SOCIETY & CULTURE
PUBLIC POLICY
Blockchain: Societal Impact
HEALTH & QOL
ENTERPRISE/ INDUSTRY
INTERNATIONAL/ TRANS-NATIONAL
ENVIRONMENTAL

04

AVOID DUPLICATION OF EXISTING WORK

The UK government has produced important reports related to blockchain since 2015, including the Walport Report (2015–16), Lord Holmes Report (2017), and 'Unlocking Blockchain' by Rt Hon Eddie Hughes MP., et al (2018).

In drafting a national blockchain roadmap for the UK, it is important to avoid duplication of existing work by revisiting and extracting key recommendations and proposals made in other reports.

Well-constructed plans must be established for the dissemination of consistent and reliable information and to ensure consistency among stakeholders regarding the language and taxonomy of DLT applications. When possible, DLT solutions should be integrated into existing systems instead of building de novo solutions from scratch. In a 2018 report, Eddie Hughes et al. proposed the establishment of a UK "Chief Blockchain Officer" and a long-term blockchain department target of 1% efficiency savings by embracing blockchain and other associated innovative technologies.

References:
Distributed ledger technology: beyond blockchain:
https://www.gov.uk/government/news/distributed-ledger-technology-beyond-block-chain

Distributed Ledger Technologies for Public Good:
https://chrisholmes.co.uk/wp-content/uploads/2020/12/Distributed-Ledger-Technologies-for-Public-Good_leadership-collaboration-and-innovation.pdf

Unlocking Blockchain: Embracing New Technologies to drive Efficiency and Empower the Citizen:
https://jbba.scholasticahq.com/article/3741-unlocking-blockchain-embracing-new-technologies-to-drive-efficiency-and-empower-the-citizen


THE JBBA

ANALYSIS

OPEN ACCESS
ISSN Print: 2516-3949
https://doi.org/10.31585/jbba-1-2-(6)2018

Unlocking Blockchain: Embracing New Technologies to drive Efficiency and Empower the Citizen

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[4] Director, FREER, UK
Correspondence: rebecca@freeruk.com
Received: 25 June 2018 **Accepted:** 4 July 2018 **Published:** 5 July 2018

Abstract
With their innovative and fundamentally liberalising approach to data storage, distributive ledger technologies

05

AGREE UPON THE TERMS AND TAXONOMY USED TO DESCRIBE EVIDENCE AND STANDARDS

The UK must be consistent and coherent in its use of the term 'evidence' in the context of blockchain policymaking. A transparent framework should be established to develop and present summaries of evidence. This framework will support a systematic approach to making practice recommendations for NBR.

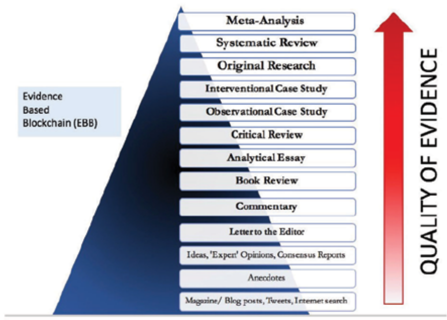
We recommend the establishment of **levels** of evidence and **grades** of recommendations, as in other established scientific disciplines, to facilitate the assessment, development, and evaluation of distributed ledger technology projects (Hussain, 2021).

References:

Evidence-Based Blockchain: Findings from a Global Study of Blockchain Projects and Start-up Companies:
https://jbba.scholasticahq.com/article/16795

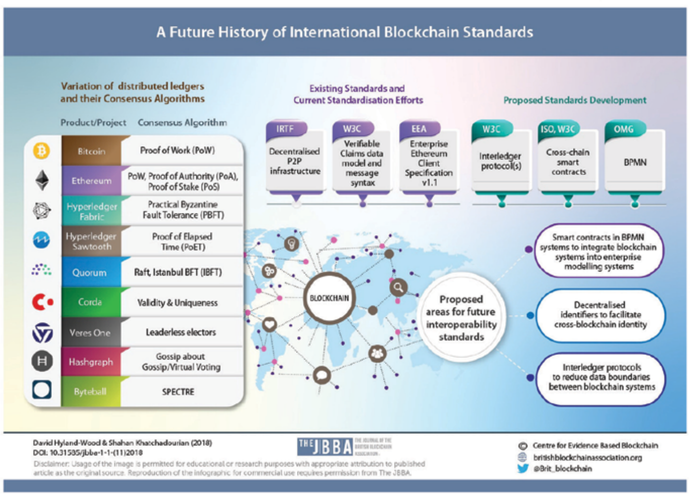
A Future History of International Blockchain Standards:
https://jbba.scholasticahq.com/article/3724-a-future-history-of-international-blockchain-standards

Level of Evidence and Grade of Recommendation:
M. Hussain, The JBBA, https://jbba.scholasticahq.com/post/1041-level-of-evidence-and-grade-of-recommendation



Blockchain Hierarchy of Evidence

(Copyright © N Naqvi, 2018, The Journal of the British Blockchain Association)



Level of Evidence	Grade of Recommendation
Level 1 Multiple peer-reviewed research studies from at least two independent institutions Evidence synthesis of critically appraised papers Meta-Analysis and Systematic Reviews High-quality Randomised comparative studies National evidence guidelines	**Grade A** Established proof of effectiveness or efficiency Clear evidence of benefits Strong evidence to recommend the action
Level 2 Single peer-reviewed research article Single peer-reviewed interventional case study Single high power comparative industry research Critical review Analytical essay	**Grade B** Scientific presumption * Benefits > risks Fair/ moderate evidence to recommend the action
Level 3 Non peer-reviewed case study Low power comparative industry research Book review White paper Consensus reports, Letter to the editor Commentary, Committee reports	**Grade C** Benefits = Risks Low or conflicting level of evidence Risk of bias Insufficient evidence to make a recommendation
Level 4 No scientific publication or case study Untested hypothesis Expert opinion without explicit critical appraisal Anecdotes / historical data Blog posts Narrative	**Grade D** Consider alternatives Risk of harm > proposed benefit Risk of serious bias Fair evidence to recommend against the action

Evidence Based Blockchain: Levels of Evidence & Grades of Recommendation

Source: M. Hussain, The JBBA, https://jbba.scholasticahq.com/post/1041-level-of-evidence-and-grade-of-recommendation

Factors that can reduce the quality of evidence:
Limitations in study design or execution (risk of bias)
Inconsistency of results
Indirectness of evidence
Imprecision
Selection bias
Insufficient data
Lack of peer-review / critical appraisal

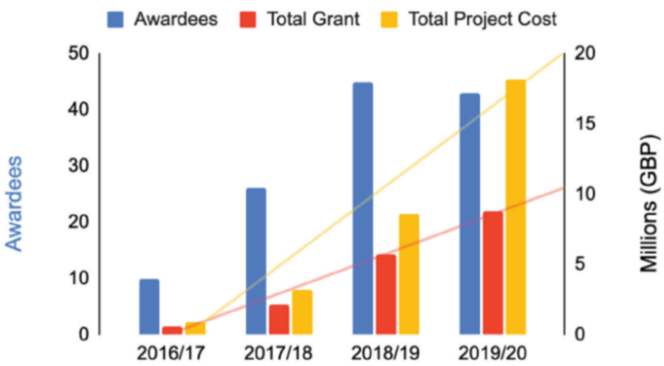
06

EMBED QUALITATIVE AND QUANTITATIVE EVIDENCE INTO NATIONAL BUDGETING PROCESSES AND DECISIONS

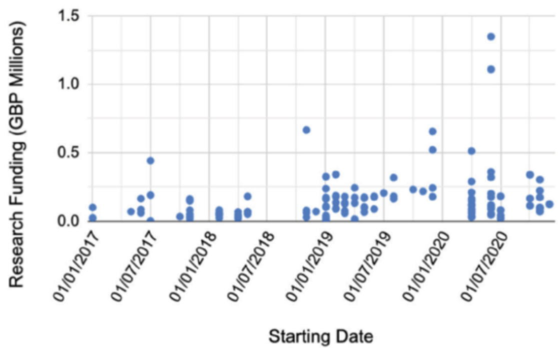
It is a challenging task to make evidence-based policy decisions in rapidly evolving innovative technology systems. Some blockchain systems are not linear (i.e., problem – intervention – impact) but follow complex system logic that is non-linear, emergent, and adaptive. A flexible and dynamic approach is needed to adapt policies to a rapidly progressive ecosystem. Barriers to translating evidence from research to practice must be identified. When possible, evidence drawn from high-quality research (i.e critically appraised peer-reviewed studies) must be embedded into national budgeting processes and policies (Ellul., 2021).

References:

Blockchain is dead! Long live Blockchain!:
https://jbba.scholasticahq.com/article/21948-blockchain-is-dead-long-live-blockchain



Innovate UK total blockchain-related project funding, costs and awardees



Innovate UK-funded blockchain-related research and development projects

Global research examining metrics including budgets and investment; company registries and data; community engagement, projects and source code repositories; academic research and programmes; social media posts; and public interest in Blockchain and Distributed Ledger Technologies
Ellul., 2021: https://doi.org/10.31585/jbba-4-1-(8)2021

(Innovate UK's public transparency dataset on their funded projects was used and projects were filtered out so that only the ones whose description or title contained the following terms were included: *Blockchain, Cryptocurrency, Cryptocurrencies, DLT, DLTs, Distributed Ledger Technology, Distributed Ledger Technologies, Bitcoin, Ethereum, Hyperledger, Smart contract, Smart contracts, Cryptocurrency exchange, Crypto exchange.* The dataset also contains projects that were withdrawn, which were excluded from this analysis. The version uploaded on 8 January 2021 was used).

07

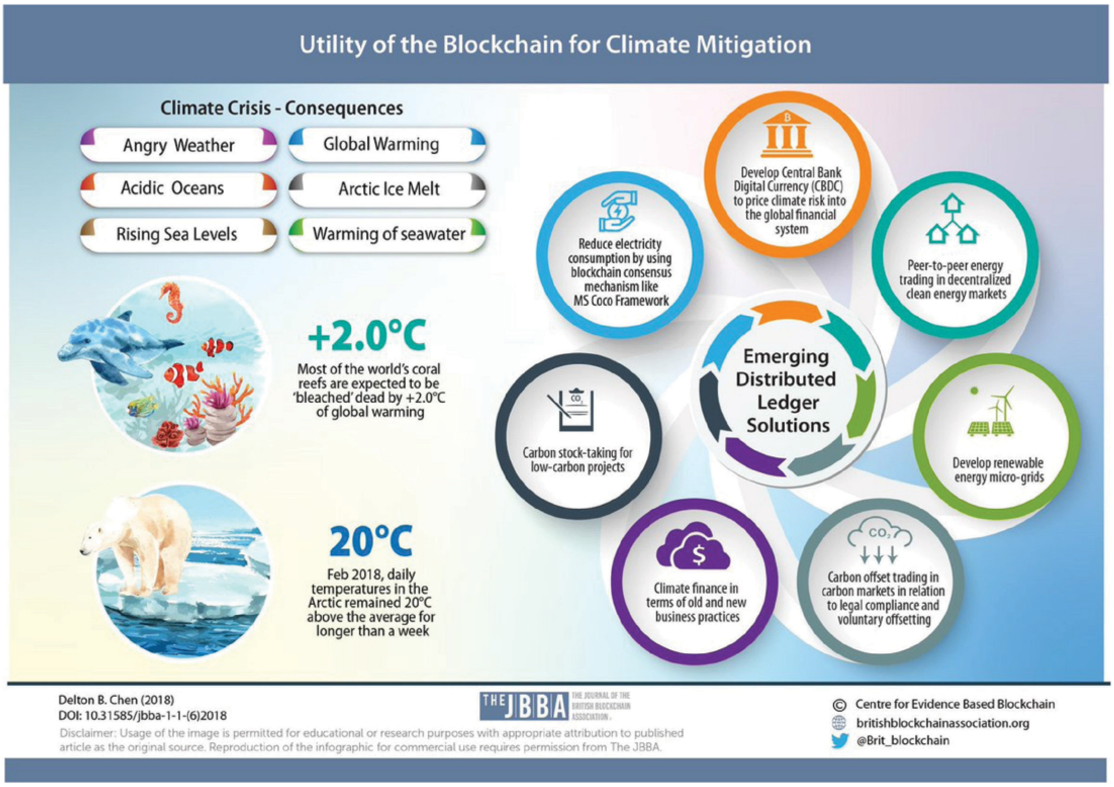
ESTABLISH BLOCKCHAIN SUB-SPECIALITY STEERING GROUPS (SSG)

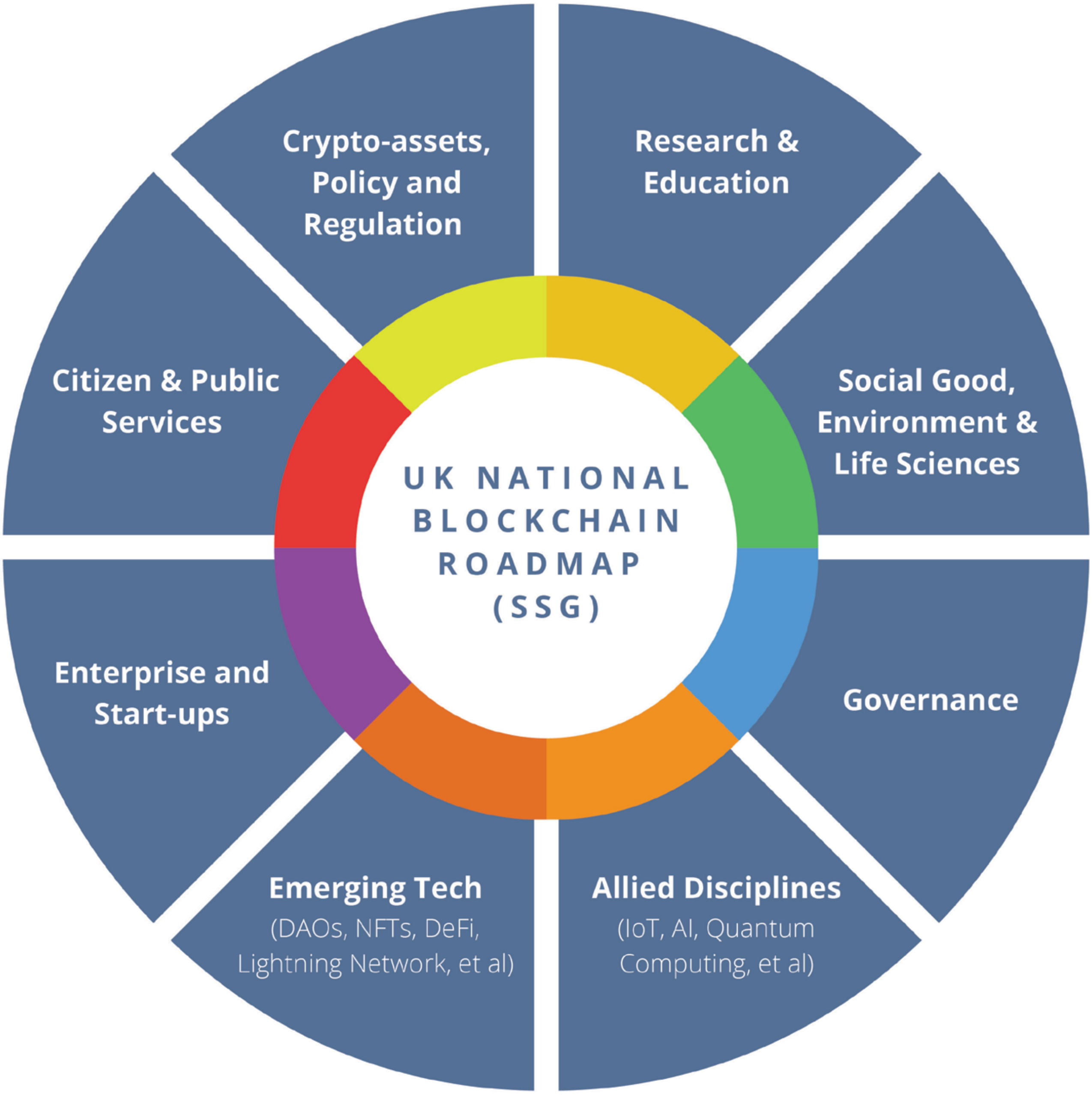
We propose the formation of sub-speciality steering groups (SSGs) to review the progress of the NBR and oversee its strategic implementation.

New and emerging markets (e.g., decentralised finance, nonfungible tokens, self-sovereign identity, crypto assets, supply chain, and central bank digital currency) are highly specialised areas that must be supervised by subject matter experts. These experts should be drawn from a broad range of organisations and should be tasked with overseeing the strategic direction of SSGs aligned with the broad vision of the NBR.

SSGs must leverage the capabilities and intellectual resources of neutral think tanks, such as the British Blockchain Association. Mechanisms must be established to translate innovative ideas into practice to create value for end-users. SSGs must also build dynamic capabilities to discuss, debate, and propose best practices in blockchain technology. All SSG output should feed into the dynamic NBR frameworks, and SSGs should collaborate with multidisciplinary industry consortia to share intellectual resources and information about best practices. We propose eight SSGs during the phase1 of the NBR (page 14).

References:
Utility of the Blockchain for Climate Mitigation:
https://jbba.scholasticahq.com/article/3577





SUB-SPECIALITY STEERING GROUPS (SSG)

08

FOSTER EVIDENCE-INFORMED POLICY MAKING

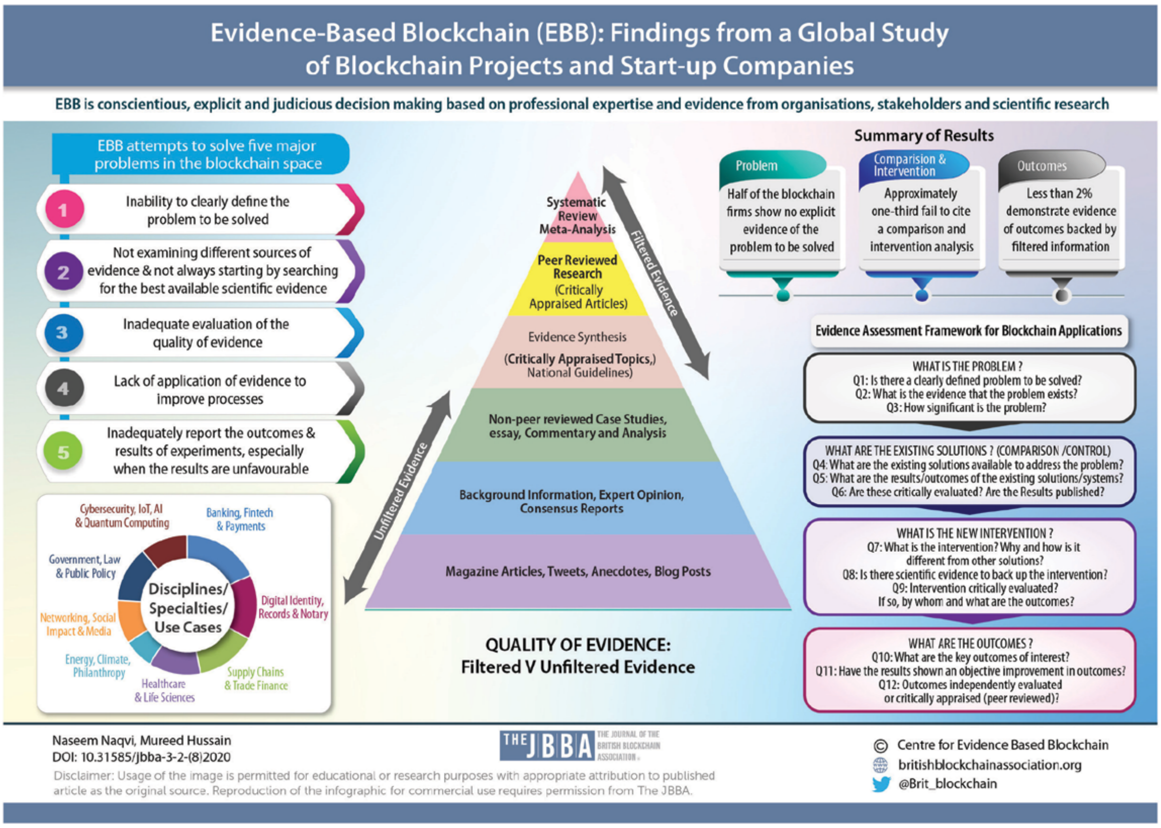
European Commission report (2020) states that 'it is now relevant for decision-makers to have an evidence-based perspective on which benefits DLT can generate through projects targeting social and public good'. There is an urgent need for evidence-based practice in the field of blockchain. Fewer than 2% of blockchain projects demonstrate evidence of impactful outcomes supported by critically appraised peer-reviewed data, according to research conducted by the Centre for Evidence Based Blockchain (Naqvi et al., 2020) The NBR must compile all evidence-based resources in distributed ledger technologies to strengthen policy-making efforts.

The think tank should focus on the impact narrative and metrics to establish robust underlying frameworks. The potential impact of blockchain on future policies, society, economy, law, culture, and environment must be taken into consideration. All DLT enterprises should consider appointing a 'Chief Evidence Officer' to provide scientific rigour to workflows and business processes.

References:

Evidence-Based Blockchain: Findings from a Global Study of Blockchain Projects and Start-up Companies
https://jbba.scholasticahq.com/article/16795-evidence-based-blockchain-findings-from-a-global-study-of-blockchain-projects-and-start-up-companies

Unlocking Blockchain: Embracing New Technologies to drive Efficiency and Empower the Citizen:
https://jbba.scholasticahq.com/article/3741



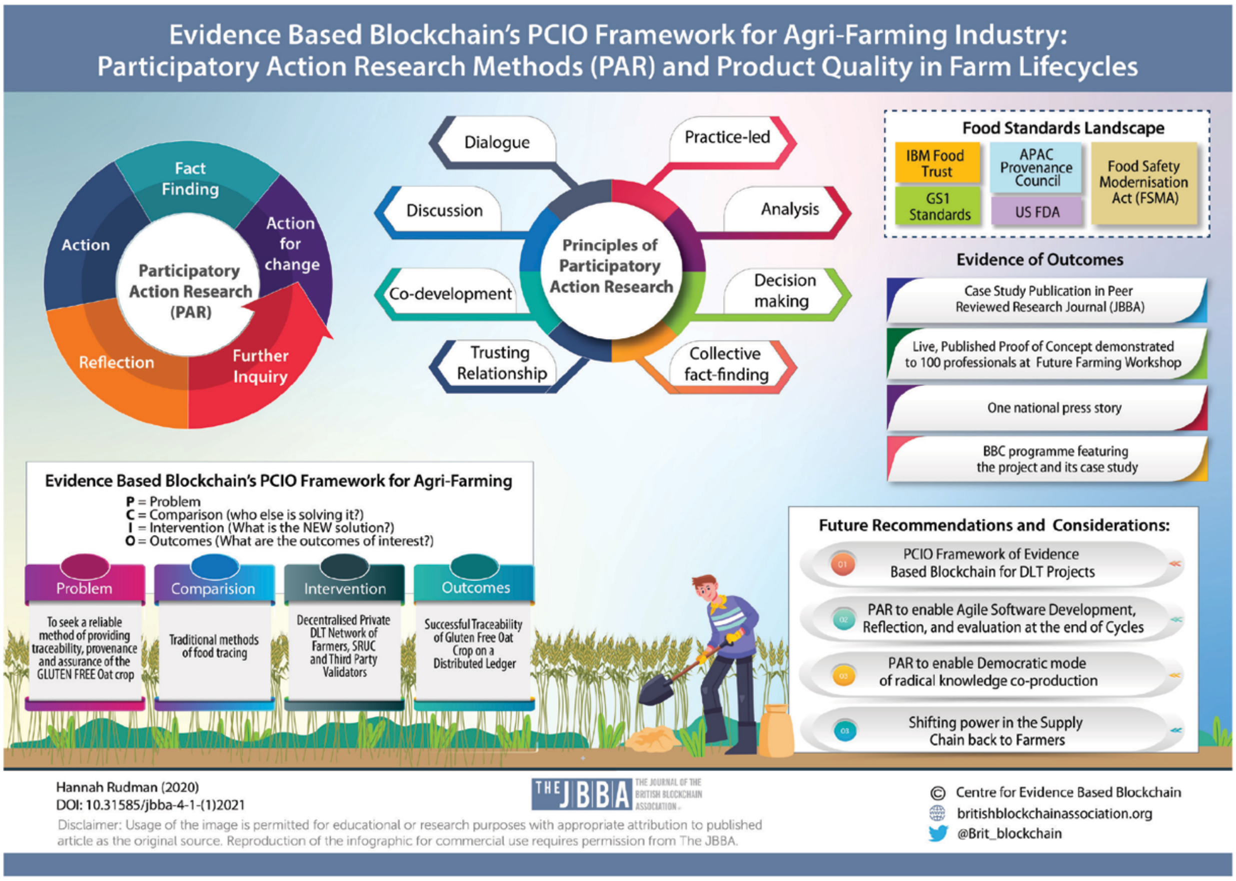
09

COMMIT RESOURCES AND CAPACITY TO GENERATE AND DEPLOY HIGH-QUALITY EVIDENCE

There is a need for strategic intent and senior-level buy-in for NBR to identify sources of evidence, develop and test blockchain pilots, and deploy interventions based on high-quality evidence. The use of resources must be constantly and dynamically optimised and aligned with emerging data (Rudman, 2021).

This approach should apply to all stages of quality management in blockchain interventions, namely:
Quality Assurance
Quality Control
Quality Management

References:
Evidence based Blockchain or Agri-Farming:
https://jbba.scholasticahq.com/article/17845-piece-of-cake-assuring-specific-qualities-of-product-in-farm-lifecycles-with-dlt-can-evidenced-based-practice-be-supported-by-participatory-action-research-methods



10

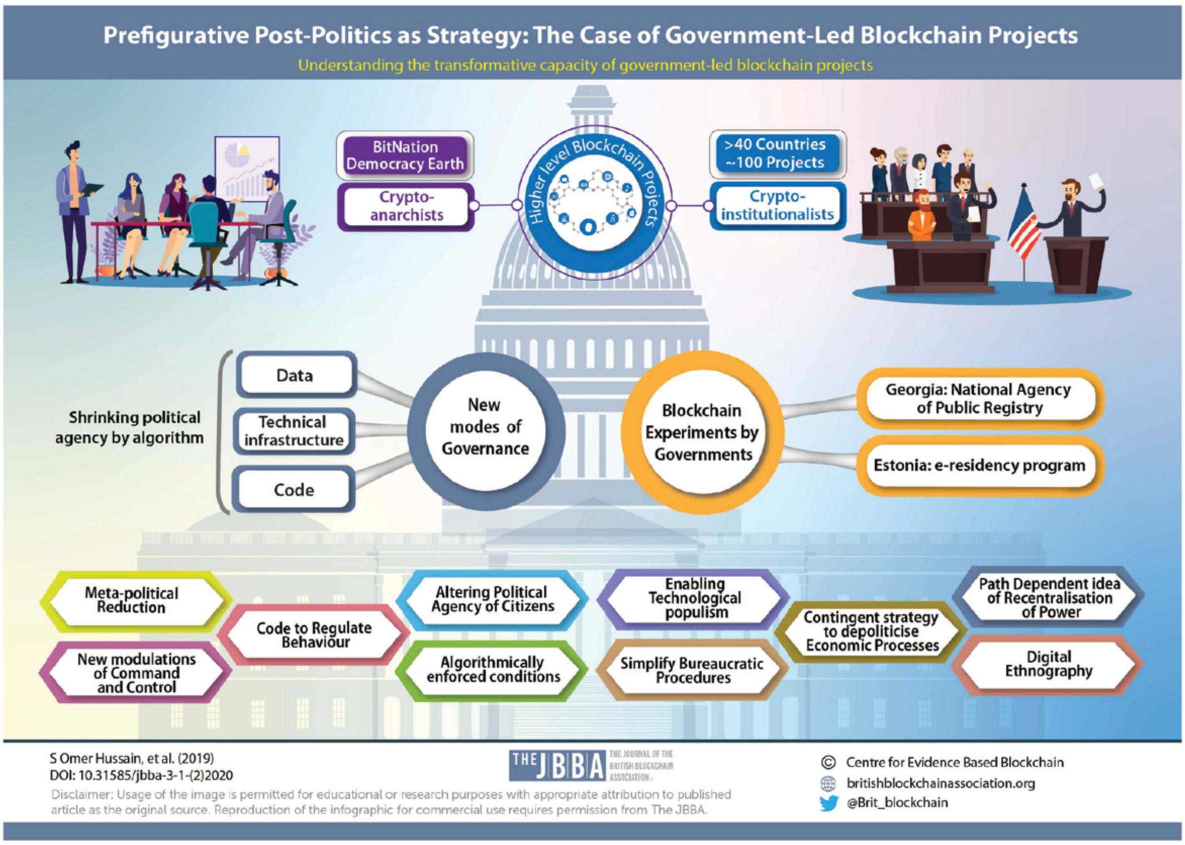
DIRECT RESOURCES TO PROGRAMMES AND POLICIES BACKED BY RESEARCH AND ENCOURAGE PROMISING PROGRAMMES TO BUILD THEIR OWN RESEARCH BASE

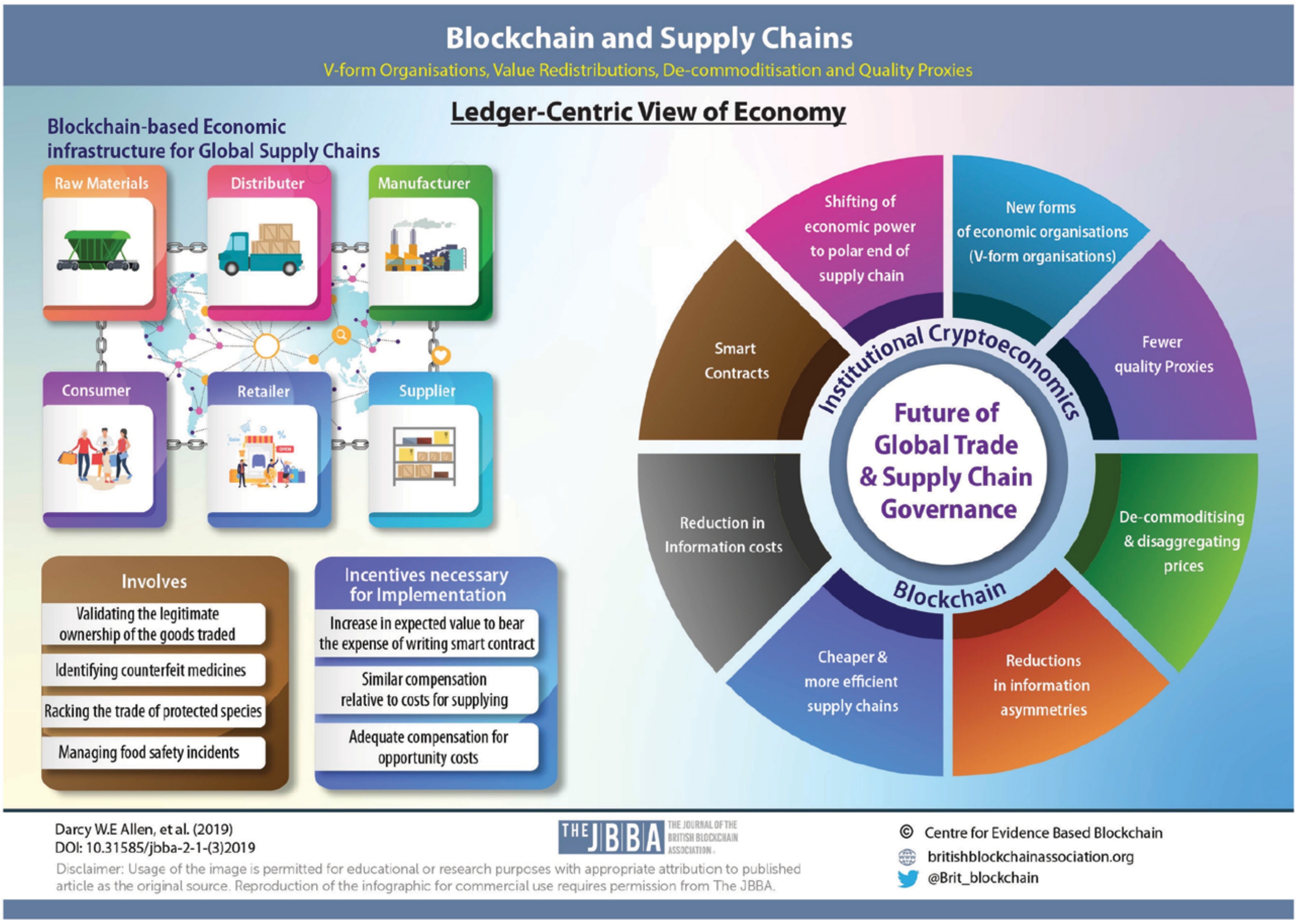
All resources must be directed to promote the development and testing of specific and targeted DLT pilots, keeping in view both proximal and distal outcomes. (Hussain, et al 2019). The resources must be directed to projects, programmes and policies that are backed by high-quality research. The interventions that have successfully demonstrated evidence of impact should be encouraged to build their own research base, nexus and consortiums.

A National blockchain roadmap must provide a robust infrastructure to design new and innovative DLT systems based on testable hypotheses and empirical data. The outcome of these pilots and the lessons learnt should feed into the further refinement of NBR.

References:

Prefigurative Post-Politics as Strategy: The Case of Government-Led Blockchain Projects:
https://jbba.scholasticahq.com/article/11203-prefigurative-post-politics-as-strategy-the-case-of-government-led-blockchain-projects





Blockchain and Supply Chains: V-form Organisations, Value Redistributions, De-commoditisation and Quality Proxies:
https://jbba.scholasticahq.com/article/7556-blockchain-and-supply-chains-v-form-organisations-value-redistributions-de-commoditisation-and-quality-proxies

11

UTILISE THE POTENTIAL OF BLOCKCHAIN FOR GOVERNMENT AND PUBLIC SERVICES

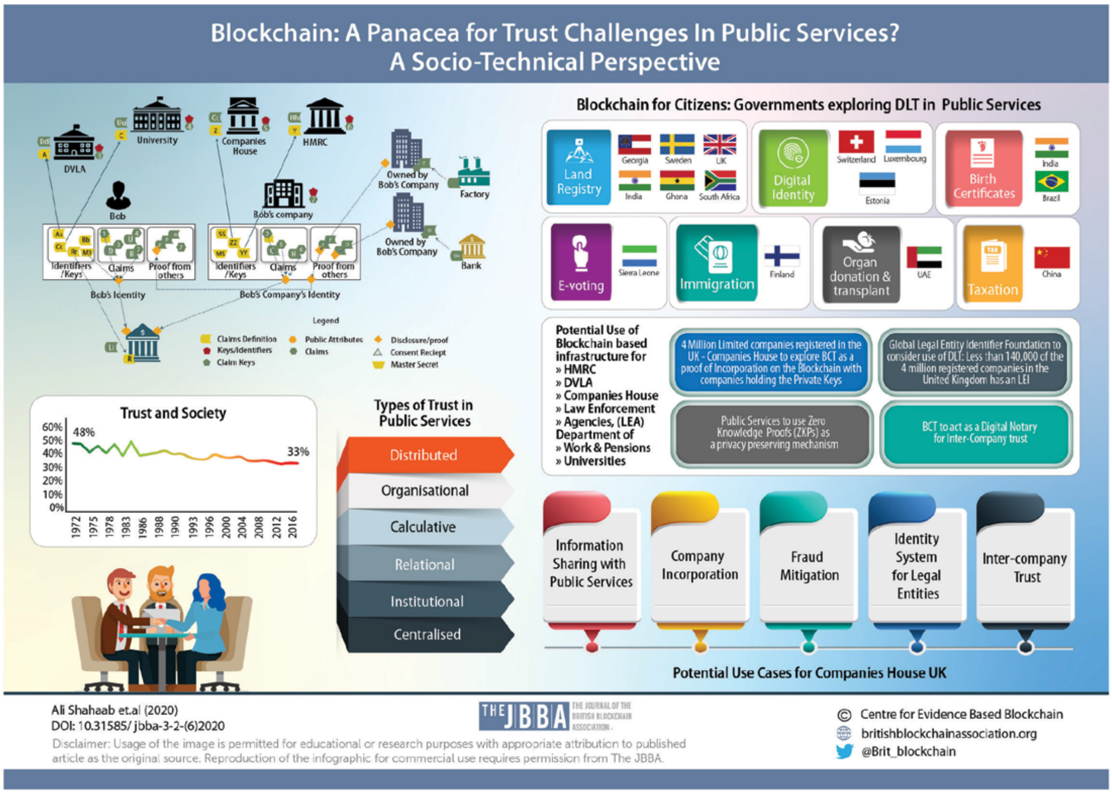
Blockchain is already transforming the infrastructure of a host of government and public sector applications. The governments around the world have successfully explored the potential of blockchain to benefit operations in the context of the broader society, including land registration (Georgia, UK, Sweden, India, South Africa), digital identity management (Switzerland, Estonia, Luxembourg), birth certificates (Brazil), immigration (Finland), organ donation and transplant (UAE), taxation (China), and many others. One example of such adoption is the potential for Companies House to explore the use of DLT to manage UK companies' registration records, according to research published in the JBBA (Shahaab., et al 2020). We recommend that the NBR explore the multidisciplinary application and far-ranging impact of blockchain for public services through stakeholder engagement.

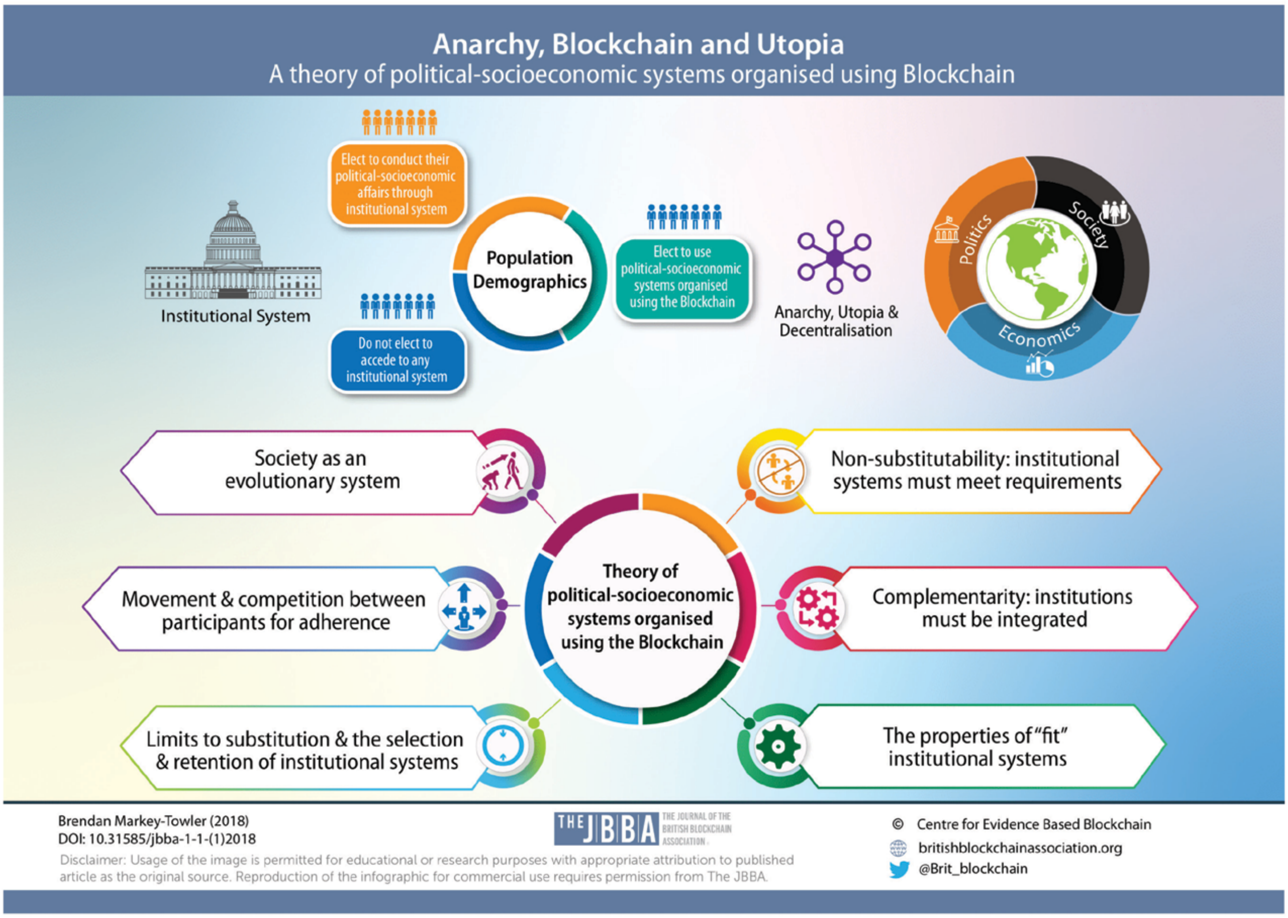
References:

Blockchain - A Panacea For Trust Challenges In Public Services? A Socio-technical Perspective:
https://jbba.scholasticahq.com/article/14128-blockchain-a-panacea-for-trust-challenges-in-public-services-a-socio-technical-perspective

Blockchains for Government: Use Cases and Challenges:
https://dl.acm.org/doi/fullHtml/10.1145/3427097

GOV.UK - Use of distributed ledger technologies to verify the provenance of goods:
https://www.gov.uk/government/publications/use-of-distributed-ledger-technologies-to-verify-the-provenance-of-goods





A Theory of Political-Socioeconomic Systems organised using Blockchain:
https://jbba.scholasticahq.com/article/3400-anarchy-blockchain-and-utopia-a-theory-of-political-socioeconomic-systems-organised-using-blockchain

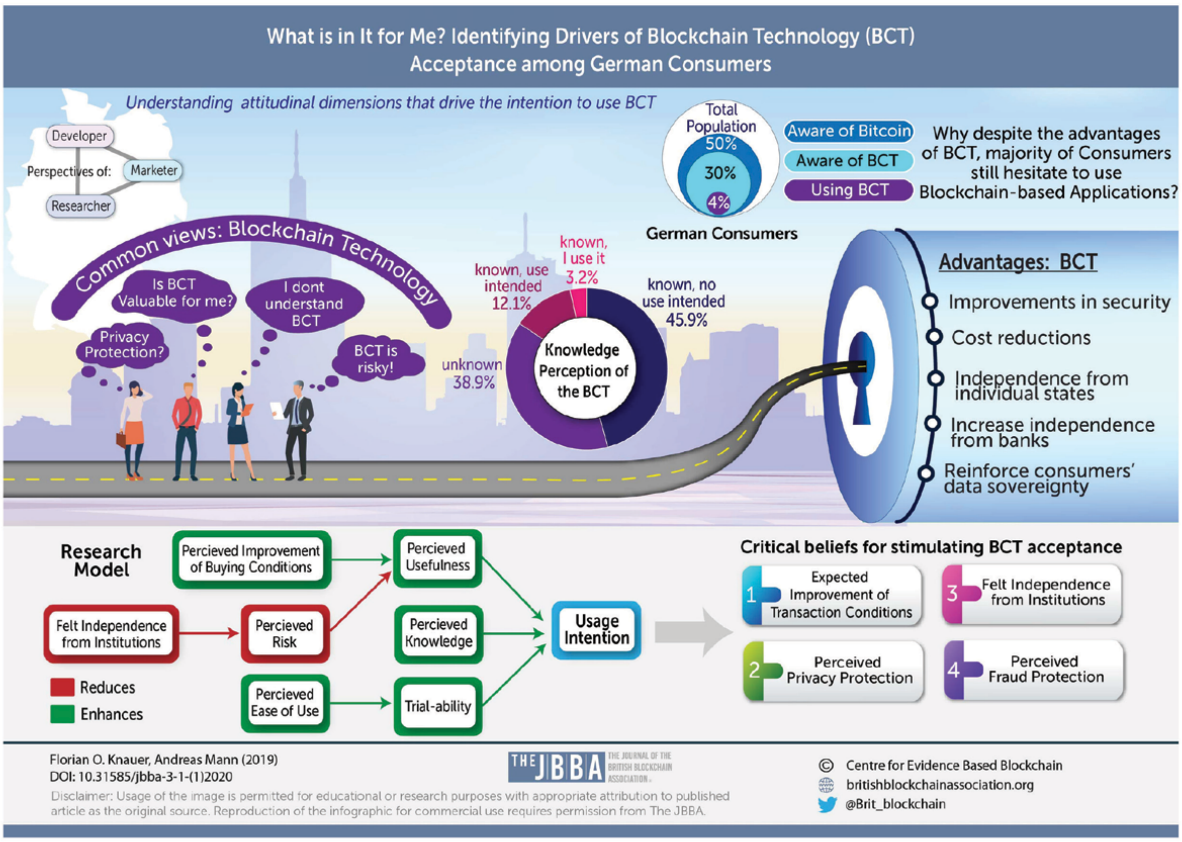
12

BUILD CONSENSUS AMONG STAKEHOLDERS AND IDENTIFY BARRIERS TO BLOCKCHAIN ADOPTION

The key drivers of blockchain technology acceptance among consumers must be identified, and the layers of 'abstraction' between consumers and technology interfaces must be minimised. The first task is to identify stakeholders and engage with them in a bi-directional manner by addressing their concerns and expectations, as well as offering support and resources to build sustainable applications (Mann., et al 2019).

A dialogue must be encouraged between public services, policymakers, and vendors. Any consensus must focus not just on outcomes but also on building processes and ongoing relationships with stakeholders. The government must ensure that all initiatives—including academic outputs, policy developments, and broader economic impacts—are aligned with the proposed national blockchain roadmap. Strategies must be developed to establish blockchain execution frameworks in existing stakeholder networks to ensure all components work together coherently. A recognition of commonality must be proactively established and agreed upon among the various stakeholders. This includes shared mission, vision, goals, roadmap and key deliverables to enhance synergy.

References:
What is in It for Me? Identifying Drivers of Blockchain Acceptance among German Consumers:
https://jbba.scholasticahq.com/article/10484-what-is-in-it-for-me-identifying-drivers-of-blockchain-acceptance-among-german-consumers



13

DRAW ON NATIONS' 'COLLECTIVE WISDOM': GARNER SUPPORT THROUGH COLLABORATION WITH OTHER COUNTRIES

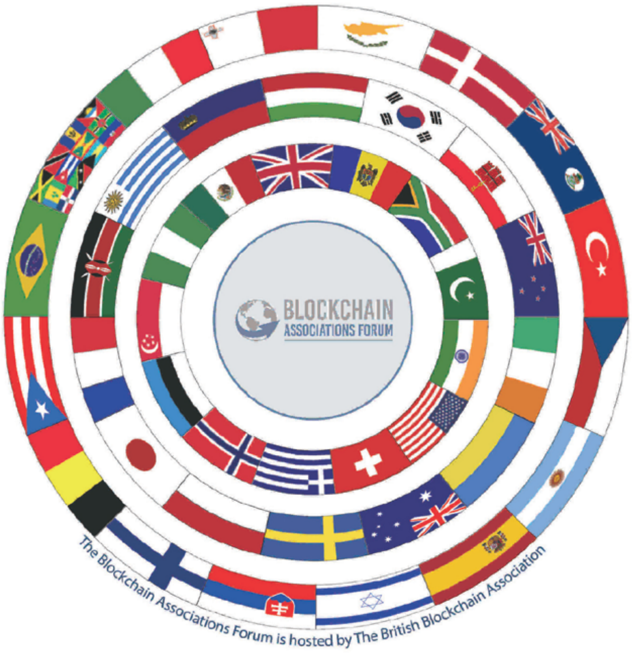
The NBR should embrace a collaborative approach with international players, build new links and connections with market leaders, and share best practices to learn from other countries that have successfully implemented blockchain in their socio-economic infrastructures. A global platform such as the Blockchain Associations Forum provides a platform for an exchange of ideas, resources and shared objectives, as well as an interconnected bridge to support harmonisation efforts in the spirit of inclusion, diversity, and collaboration.

The UK must adopt a culture of learning to identify the DLT interventions and strategies that are most likely to be effective over an extended period of time. All interconnected links must be managed over time to ensure continued alignment with the overarching vision proposed in the roadmap.

References:
The Blockchain Associations Forum:
The Blockchain Associations Forum (BAF)

Centre for Evidence Based Blockchain (CEBB) Africa Summit

Singapore's OpenToken offerings: Context and Consequences



BLOCKCHAIN
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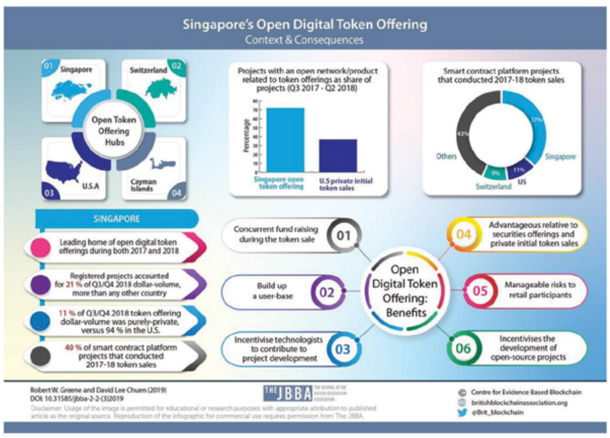


14

STRIVE TO BECOME A "CENTRE OF EXCELLENCE" IN DISTRIBUTED LEDGER TECHNOLOGIES

The UK has established itself as a leader in the field of blockchain with a world-class portfolio of initiatives, including the Journal of the British Blockchain Association (JBBA), Financial Conduct Authority's regulatory sandbox, the Centre for Evidence-Based Blockchain (CEBB), Blockchain International Scientific Conferences (ISCs), Blockchain Fellowships (FBBA), Blockchain All-Party Parliamentary Group APPG, et al. We have the potential to become an international centre of excellence for blockchain. An NBR must build on our national capacity to advance blockchain knowledge and research, and policymakers must engage with a broad range of relevant stakeholders. National think tanks such as the BBA could take an active leadership role by promoting and supporting the synthesis, transfer, and utilisation of evidence to identify best practices for blockchain.

The NBR must ensure that systems are established to ensure a steady pace of incremental improvement. A proactive approach must be taken to address the ethical, societal, environmental, technical, and operational challenges posed by the deployment of distributed ledgers.

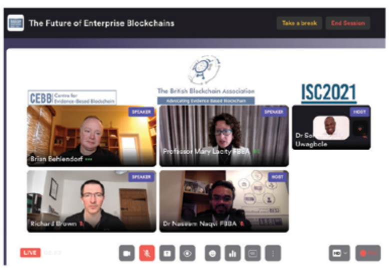
The British Blockchain Association

Advocating Evidence Based Blockchain

THE JBBA THE JOURNAL OF THE BRITISH BLOCKCHAIN ASSOCIATION

2nd Blockchain International Scientific Conference ISC2020, UK (11 March 2020)

CEBB Centre for Evidence-Based Blockchain



15

CONDUCT REGULAR EVALUATIONS OF BLOCKCHAIN BASED PROGRAMMES

Public services and blockchain vendors should be held accountable to taxpayers and must ensure that their blockchain solutions consistently deliver on their promises. Randomised controlled trials (RCTs) and systematic reviews should be used to evaluate DLT interventions to ensure that they remain cost-effective, up-to-date, and suited to their intended purpose. Based on the philosophical foundations and consumer-centred interventions of blockchain technology, it is important that accountability and support mechanisms are established (Naqvi., et al 2020) to facilitate blockchain pilots and start-ups as they move from basic sciences to distribution. The initial evaluation should include Evidence Based Blockchain's **PCIO Framework (Problem - Comparison - Intervention - Outcome)** and ask the following three questions:

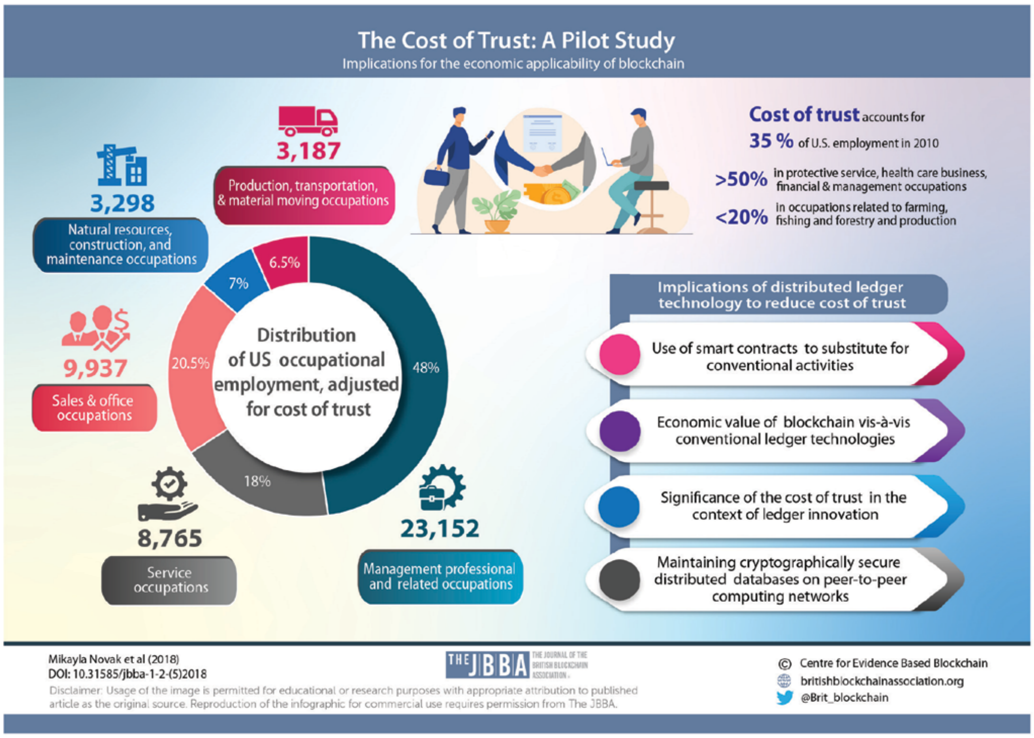
CAN it work? (Efficacy)
DOES it work? (Effectiveness)
Is it WORTH It ? (Efficiency)

References:

Parameters for Building Sustainable Blockchain Application Initiatives
https://jbba.scholasticahq.com/article/7758-parameters-for-building-sustainable-blockchain-application-initiatives

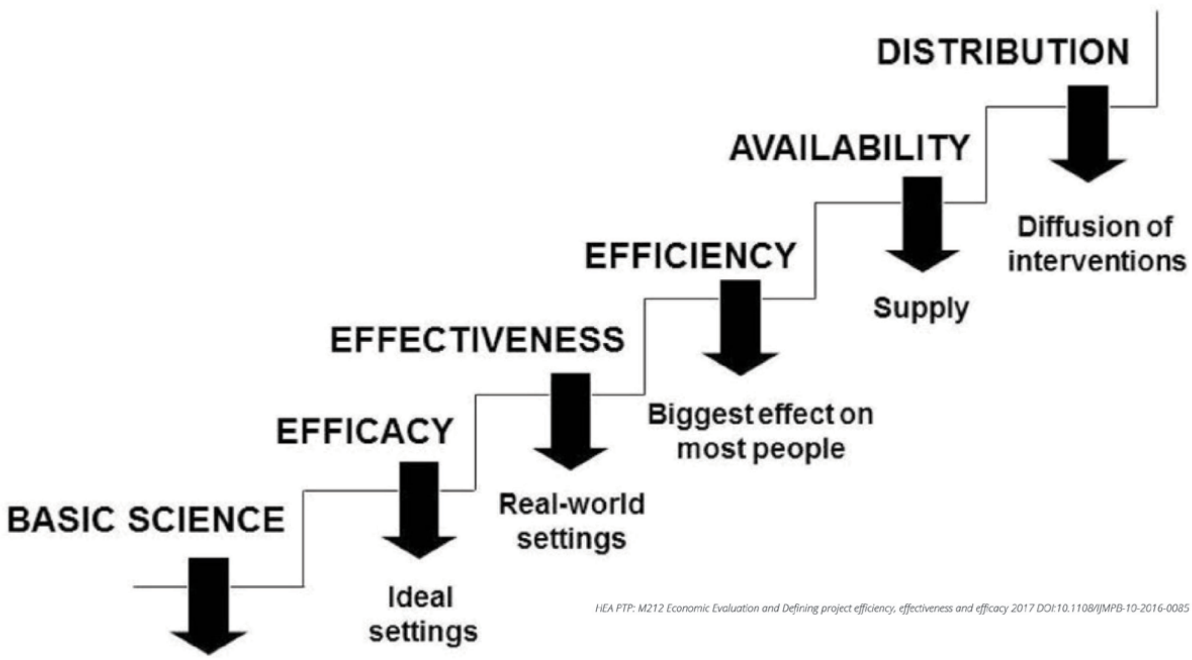
Evidence-Based Blockchain: Findings from a Global Study of Blockchain Projects and Start-up Companies
https://jbba.scholasticahq.com/article/16795-evidence-based-blockchain-findings-from-a-global-study-of-blockchain-projects-and-start-up-companies

The cost of Trust: A Pilot Study:
https://jbba.scholasticahq.com/article/5037-the-cost-of-trust-a-pilot-study



PCIO Framework of Evidence Based Blockchain

Evidence Based Blockchain:
https://jbba.scholasticahq.com/article/16795-evidence-based-blockchain-findings-from-a-global-study-of-blockchain-projects-and-start-up-companies



16

ESTABLISH A LONG-TERM ROAD MAP FOR INDUSTRY GROWTH AND WORKFORCE PLANNING

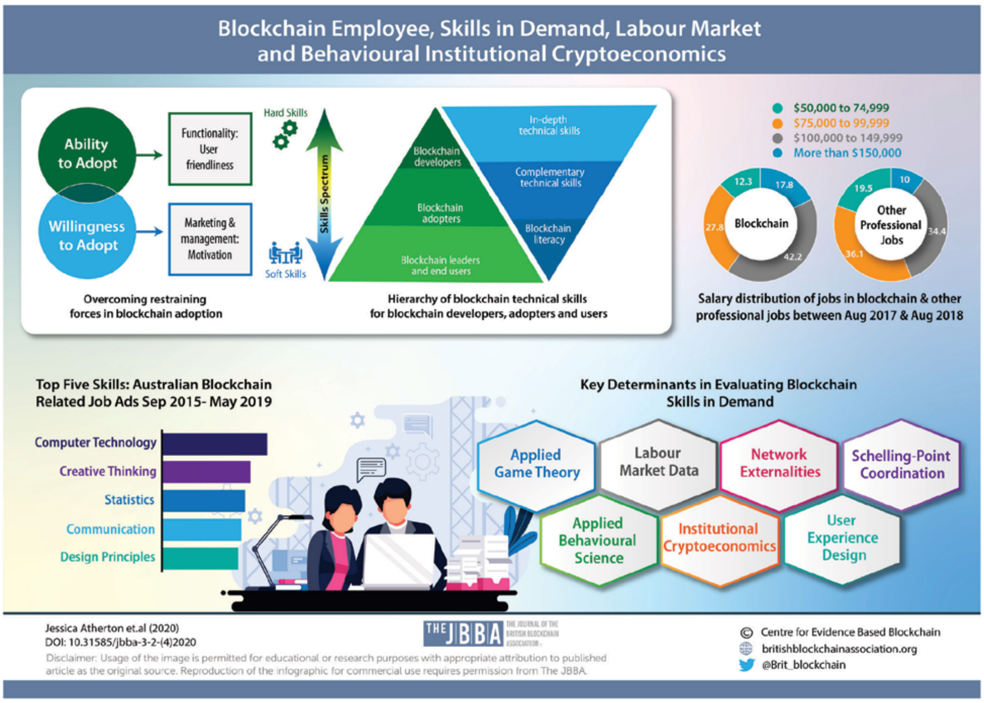
Blockchain technology has created new market employment opportunities. According to the latest research on the blockchain labour market data, blockchain expertise was the most in-demand skill set in 2020 (Atherton., et al 2020) and there has been a 300–500% annual increase in the global demand for blockchain developers. In Great Britain, start-up companies pay new blockchain developers and junior developers up to $60,000 per year and large enterprises pay up to $140,000 per year (The Global Blockchain Employment Report, 2021).

The UK must position itself as an attractive hub for the blockchain and crypto assets employment market. It is critical to focus on the training, recruitment, and retention of the best and the brightest minds in blockchain technology to boost the economy and create jobs. Support and training for soft skills such as creativity, communication, and leadership must also be emphasised. The government must ensure that measures are established to nurture an environment that is supportive of blockchain and crypto-asset enterprises. Such measures could include regulatory certainty, employment permits/visas, tax relief, funding and grants, and business support.

References:

Who is the Blockchain Employee? Exploring Skills in Demand using Observations from the Australian Labour Market and Behavioural Institutional Cryptoeconomics:
https://jbba.scholasticahq.com/article/13390-who-is-the-blockchain-employee-exploring-skills-in-demand-using-observations-from-the-australian-labour-market-and-behavioural-institutional-cryptoeconomics

The Global Blockchain Employment Report:
https://theblockchainacademy.com/wp-content/uploads/sites/6/2021/04/2021-Global-Blockchain-Employment-Report.pdf



17

BUILD SECURE CYBER INFRASTRUCTURES FOR BLOCKCHAIN APPLICATIONS

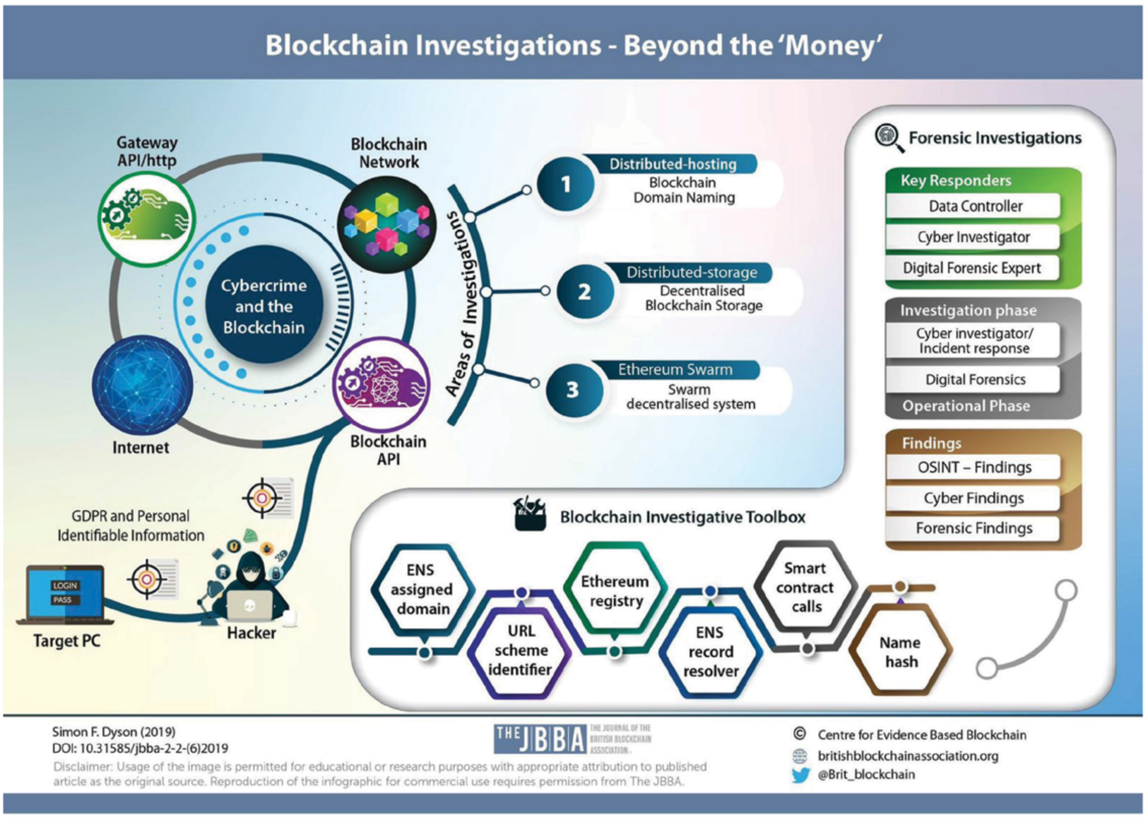
Cybercriminal activity costs $6 trillion globally, which makes it the third largest economy in the world (behind the USA and China). Blockchain technology relies on cryptographic security; however, it is a common misconception that all facets of blockchain technology applications are inherently secure by design. Some blockchains are immutable, but their application programming interfaces (APIs) and external access points may be vulnerable to sensitive data hacks and leaks that could result in substantive financial damage to blockchain firms (Dyson 2019).

Therefore, it is vital to ensure the security of blockchain cyber infrastructures and APIs and to provide blockchain technology vendors with resources, training, and a forensic 'toolbox' in case of a security breach.

References:

The Challenges of Investigating Cryptocurrencies and Blockchain Related Crime:
https://jbba.scholasticahq.com/article/5779-the-challenges-of-investigating-cryptocurrencies-and-blockchain-related-crime

Blockchain Investigations - Beyond the 'Money':
https://jbba.scholasticahq.com/article/10027-blockchain-investigations-beyond-the-money



18

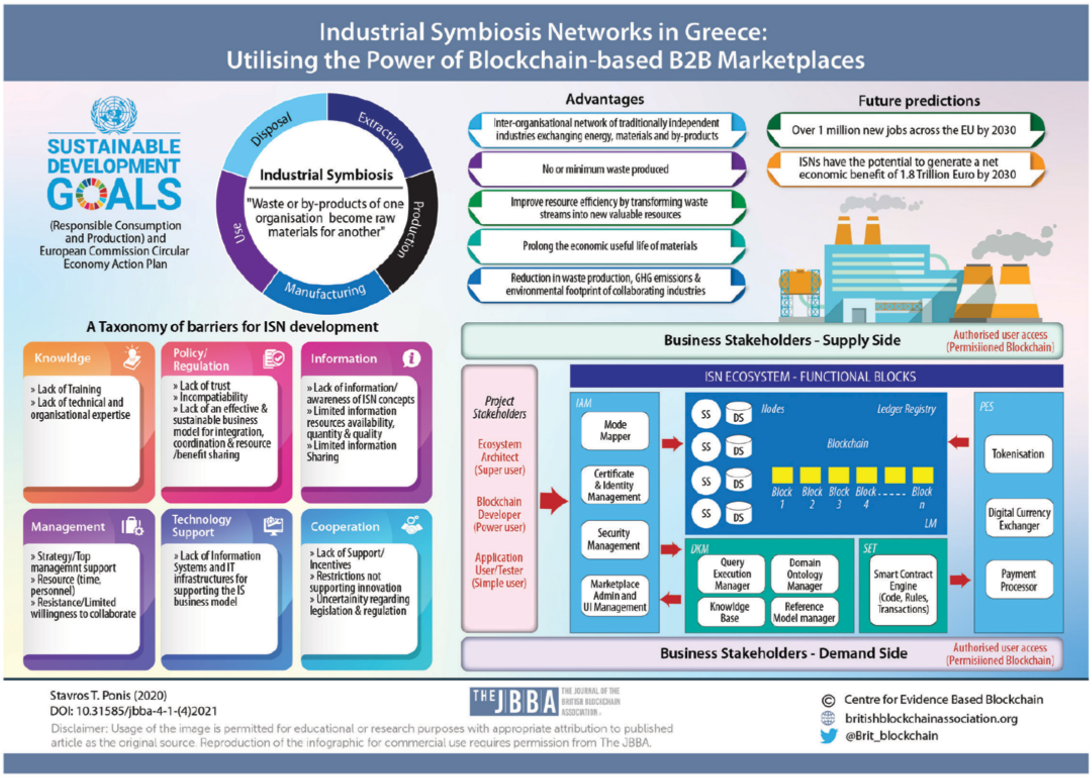
WORK TOWARD THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS(SDG)

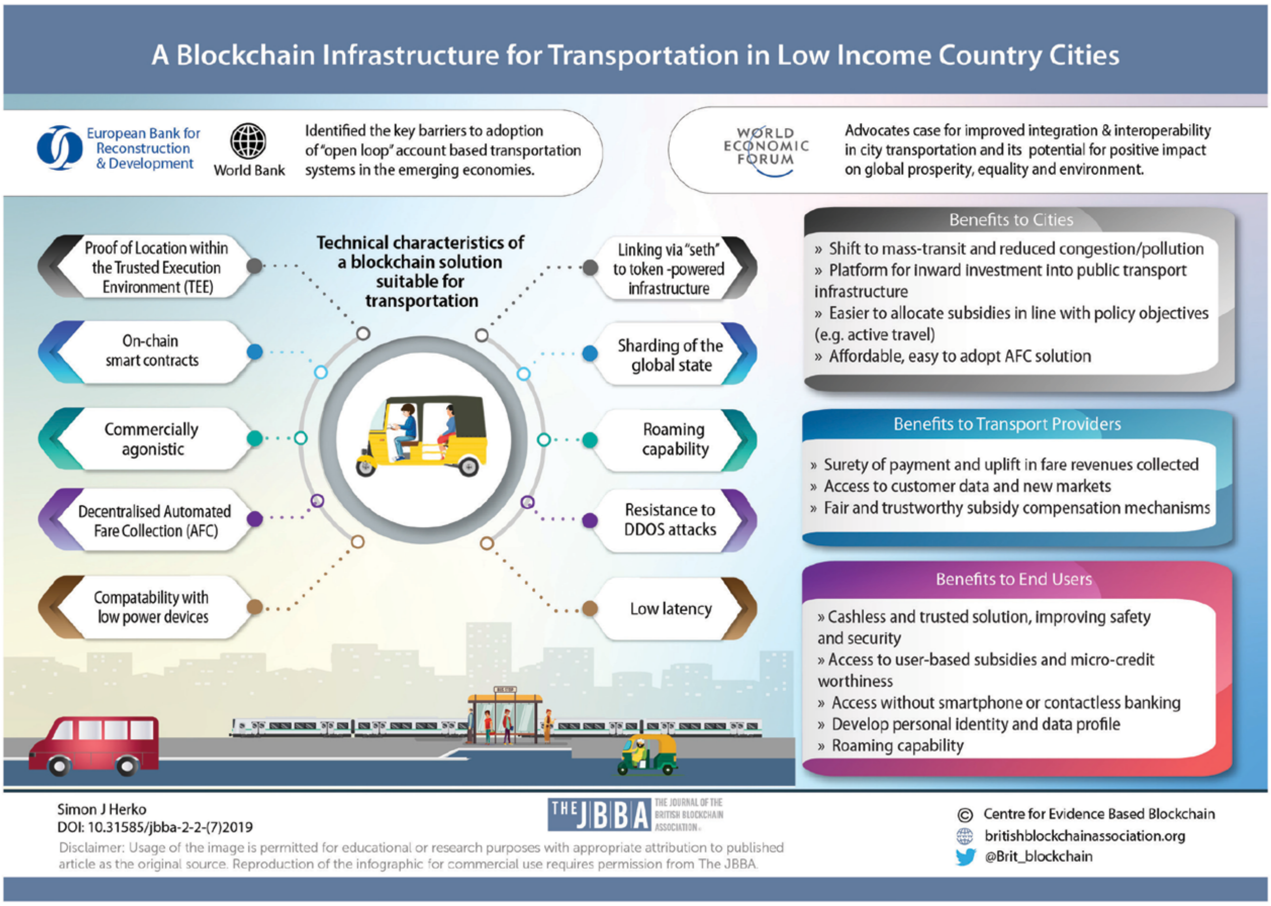
Blockchain technology has the potential to accelerate the achievement of the United Nations Sustainable Development Goals (UN SDGs) by creating US$ 12 trillion in market opportunities and 380 million new jobs. Taking action on climate change alone would result in savings of US$26 trillion by 2030 (Business and Sustainable Development Commission, 2017; Better Business Better World: Report of the Global Commission on the Economy and Climate, 2018). The Sustainable Development Goals were adopted by all United Nations Member States in 2015. Sustainable Development Goal 12—'Responsible Consumption and Production'—calls for a substantial reduction in waste generation through prevention, reduction, reuse, and recycling. Under this initiative, companies are encouraged to adopt sustainable practices and integrate sustainability information into their reporting cycles, and the aim is to achieve sustainable global management and resource efficiency by 2030. The research cited below refers to some of the practical applications of blockchain toward UN SDGs (Ponis 2020), (Chen 2018).

References:

Industrial Symbiosis Networks in Greece: Utilising the Power of Blockchain-based B2B Marketplaces:
https://jbba.scholasticahq.com/article/18206-industrial-symbiosis-networks-in-greece-utilising-the-power-of-blockchain-based-b2b-marketplaces

UN Secretary-General's Strategy for Financing the 2030 Agenda:
https://www.un.org/sustainabledevelopment/sg-finance-strategy/





An example of Blockchain for UN SDGs (9 - 13):

Industry, Innovation & Infrastructure, Reduced Inequalities, Sustainable Cities and Communities, Responsible Consumption and Production, Climate Action

https://jbba.scholasticahq.com/article/10235-a-blockchain-infrastructure-for-transportation-in-low-income-country-cities-and-beyond

19

DEVISE EVIDENCE BASED POLICIES ON DIGITAL CURRENCIES

With Decentralised Finance and Central Bank Digital Currencies (CBDCs) set to impact the way we manage our finances, it is prudent that UK NBR should guide an evidence-informed approach to digital assets. *"Evidence-Based rulemaking is not yet the norm in Crypto regulation"*, said SEC Commissioner, Hester Pierce, in her keynote speech at the British Blockchain Association's Annual International Conference on March 15, 2021.

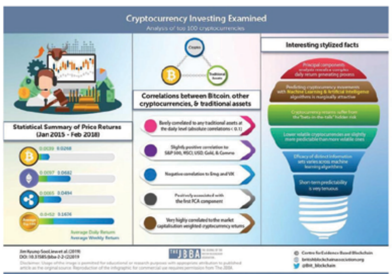
It is pertinent to explore and address the pain points around the national-level adoption of digital assets. For example, how do we ensure self-sovereignty and financial privacy around Central Bank Digital Currencies (CBDCs)? How do we integrate CBDCs with the existing systems to achieve a more efficient payment and settlement system for international trades and securities? How do we design a stable currency system that serves the underserved segment of the payments and cross-border remittances ecosystem? Given the UK's expertise and available resources, a CBDC or expressly, a Central Bank Authorised Digital Currency (CBADC), with privacy protection cryptography would offer certain advantages, such as a reduction in corporate inclusion costs with lower counter-party risks, reduction in counterparty risk, thus lowering operations' cost, stimulating innovation and creating jobs, new business models and financial products and lower the cost of entry barriers.

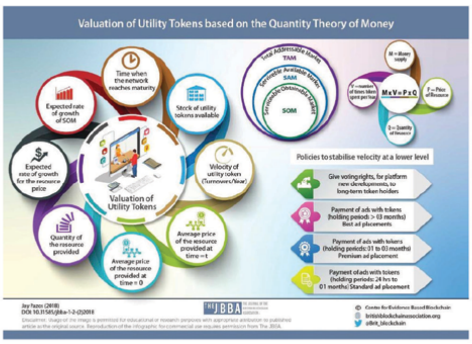
The Cryptoassest SSG (*page 32*) would work closely with all market stakeholders of the ecosystem, namely: Financial Conduct Authority (FCA), Bank of England, HM Treasury, crypto-asset developers and issuers, liquidity providers and trading platforms, financial intermediaries, payments and merchant service providers, custodial wallet providers, et al.

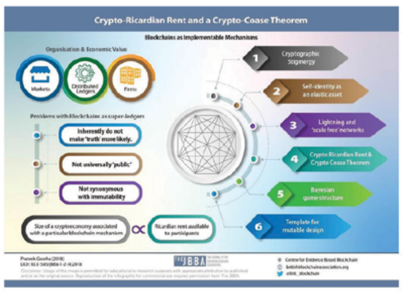
References:

Paper, Plastic, Peer-to-Peer: Remarks at the British Blockchain Association's Conference "Success Through Synergy - Next generation Leadership for Extraordinary Times":
https://www.sec.gov/news/speech/peirce-paper-plastic-peer-to-peer-031521

Central bank digital currencies: foundational principles and core features:
https://www.bis.org/publ/othp33.htm







CRYPTO ASSET SUB-SPECIALITY STEERING GROUP (SSG)

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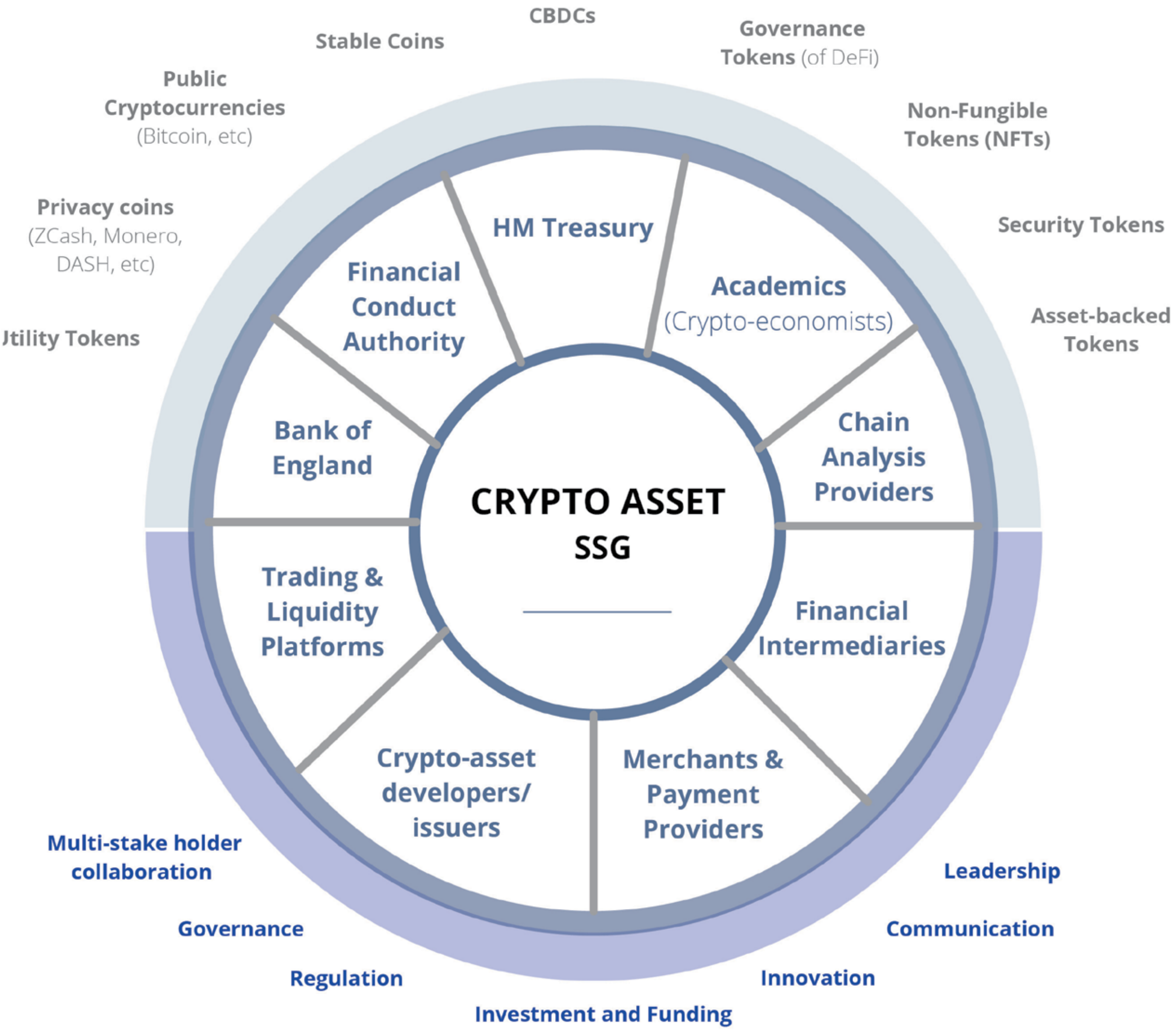


20

DEVELOP A FUTURISTIC VISION OF BLOCKCHAIN AND DISTRIBUTED LEDGERS

The UK NBR should develop a futuristic vision of distributed ledgers. Blockchain technology is moving at a breath-taking pace. Future threats loom, such as the impact of quantum computing on distributed ledgers (Campbell 2020). However, an exciting new plethora of market opportunities and trends exist, including non-fungible tokens (NFTs) (Uribe 2020), decentralised finance (DeFi), Blockchain-as-a-Service (BaaS), Decentralised Autonomous Organisations (DAOs), enterprise blockchains (K. Yuthas 2021), et al. DeFi currently accounts for more than $100 billion in assets, and the NFTs market surged to more than $2.2 billion in the first quarter of 2021.

The NBR must be responsive, flexible, and dynamic to the innovative blockchain industry developments. The Emerging Tech SSG should provide evidence-based expertise and guidance to capitalise on the emerging DLT trends.

References:

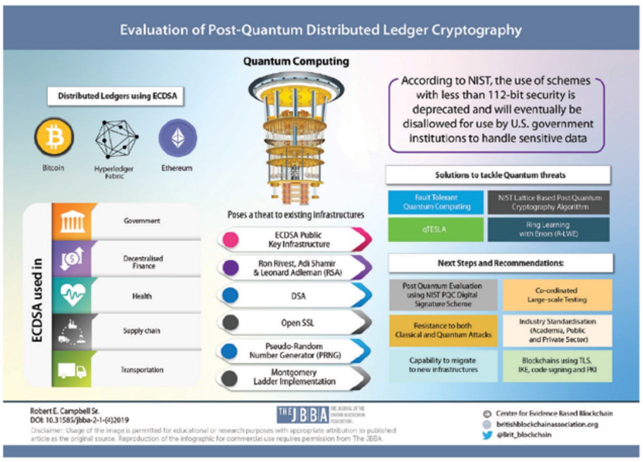
Evaluation of Post-Quantum Distributed Ledger Cryptography:
https://jbba.scholasticahq.com/article/7679-evaluation-of-post-quantum-distributed-ledger-cryptography

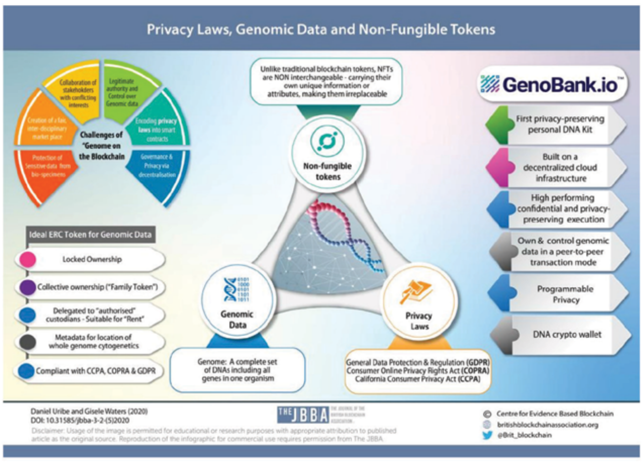
Transitioning to a Hyperledger Fabric Quantum-Resistant Classical Hybrid Public Key Infrastructure:
https://jbba.scholasticahq.com/article/9902-transitioning-to-a-hyperledger-fabric-quantum-resistant-classical-hybrid-public-key-infrastructure

The Need for Cyber Resilient Enterprise Distributed Ledger Risk Management Framework:
https://jbba.scholasticahq.com/article/12257

Privacy Laws, Genomic Data and Non-Fungible Tokens:
https://jbba.scholasticahq.com/article/13164-privacy-laws-genomic-data-and-non-fungible-tokens

Strategic Value Creation through Enterprise Blockchain:
https://jbba.scholasticahq.com/article/21638-strategic-value-creation-through-enterprise-blockchain





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The British Blockchain Association (The BBA) was established in 2017. It is a non-profit, neutral industry think-tank advancing evidence-based adoption of Distributed Ledger Technologies. The Centre for Evidence Based Blockchain operates under the auspices of the BBA. The JBBA is the world's first scientific peer-reviewed blockchain research journal available both in print and online. The BBA works in collaboration with the UK's Department for International Trade, The BBC, British embassies, UK Blockchain APPG, UNDP, Commonwealth Africa Anti-Corruption Centre CAACC, and other international ecosystem stakeholders.

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cebb@britishblockchainassociation.org.

The British Blockchain Association
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A BBA student chapter helps reinforce classroom and experiential learning. In addition to the learning that occurs during chapter meetings, the submission of research articles to the JBBA journal helps develop industry-specific skills, along with skills in project management, technical writing and interpersonal communications.

Chapter activities culminate at the annual scholars in Blockchain conference, where students interact with students from other chapters, BBA members and advisors and network with industry leaders, scientists, and researchers.

The BBA recognises that students are the future leaders of the industry, and treats them as such. Chapters instil future professionals with an understanding of the role that collaboration, research, development and networking plays in blockchain developments and industry progress.

REASONS TO START THE BBA STUDENT CHAPTER

Encourage student collaboration

Foster dialogue about trends, issues, movements, opportunities impacting the blockchain industry

Connect to industry professionals and career opportunities

Obtain leadership experience driving BBA student chapter activities

Form student and professional relationships across the BBA including those with students from other chapters

Compete in hacking events

Publish papers in the JBBA

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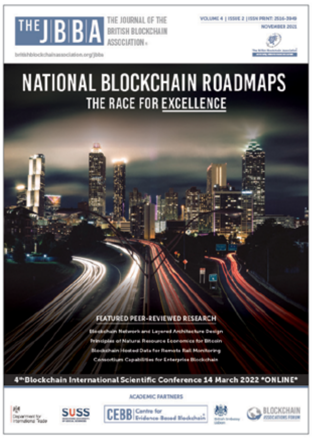

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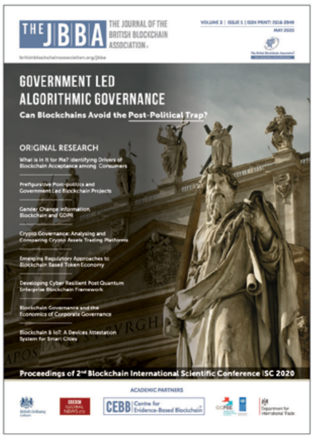

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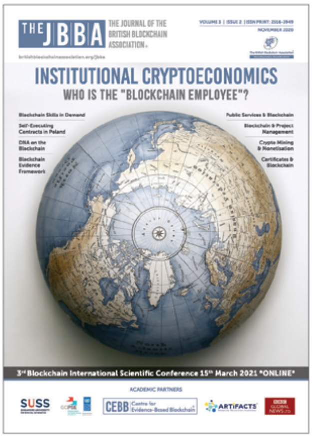

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