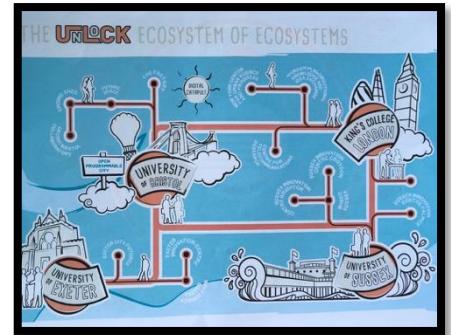# DISRUPTIVE OPPORTUNITIES

CAPTURING & EXCHANGING KNOWLEDGE ABOUT
BLOCKCHAIN, DLTs & SMART CITIES

*Compiled by University of Bristol on behalf of the
UnLoCK consortium*

April 2018

1. SUMMARY

Smart Cities hold huge potential, and pose particular challenges, due to their complex ecosystems of technology and people. This report explores the disruptive opportunities of Blockchain and Distributed Ledger Technologies (DLTs) to the development of Smart Cities. The ideas captured are varied and challenging: how do we deal with the explosion of datasets? What happens when machines rather than people are the primary users of data? What if citizens owned their own data? And can Blockchain and DLTs engender "Trustless Trust"?

Stakeholders from across the Smart City value chain, representing Higher Education Institutions (HEIs), industry, and community organisations, were initially drawn together on a Higher Education Funding Council for England (HEFCE) Connecting Capabilities Fund (CCF) grant application. Their aim is to explore and capture knowledge about disruptive technologies, so that innovation can be used effectively to deliver multiple benefits and create shared value. This report is an initial output of the Universities Learning to Co-Create Knowledge (UnLoCK) collaboration, highlighting both key areas where Blockchain and DLTs might make an impact, and the importance of cross sector collaboration to move beyond the 'hype' often associated with technological innovation and enabling tangible progress to be made.

2. BACKGROUND

Smart City Ecosystems

Defining a 'Smart City' is complex, but in general terms, Smart Cities concern the application of digital technologies, data and analytics to the challenges and opportunities of increased global urbanization. They are places where "there is effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" [i]. Smart Cities may bring environmental, social or organisational efficiency benefits. Above all, Smart Cities are a significant economic opportunity, with an estimated value of $408 Billion by 2020, or an annual $40.8 billion to the UK economy in traditional areas of industrial strength, such as product design, and infrastructure design engineering[ii].

Blockchain, Distributed Ledger Technologies

Blockchain and Distributed Ledger Technologies (DLTs) are familiar as the enablers of Bitcoin and other cryptocurrencies. But their potential application is far wider, by allowing many different forms of data to be linked, shared and traded securely between peers, using rules that are agreed collectively, and widely-dispersed keys that ensure security and privacy. They could be extremely disruptive to existing business and operational models:

> *"Blockchain will affect the way that individuals and organisations interact, the way that businesses collaborate with one another, the transparency of processes and data, and, ultimately, the productivity and sustainability of our economy"* [iii]

3. UnLoCK

Universities Learning to Co-Create Knowledge (UnLoCK) is a cross-sector consortium that stems from University of Bristol's application to the HEFCE Connecting Capabilities Fund (CCF)[iv]. UnLoCK mirrored the CCF's aims – to enable step-change improvements in the capture and exchange of knowledge between HEIs and Industrial partners. The goal being to significantly accelerate economic growth in support of UK Government Industrial Strategy by achieving the following long-term transformations, from:

- o the engaged university → a dynamic knowledge exchange system
- o institutional knowledge → ecosystem benefits
- o small scale pilots → a porous, open, connected innovation platform
- o university 'spin outs' → industry and university 'spin-ins'
- o knowledge exchange → continuous, dynamic and iterative learning
- o restrictive IP → agreements that facilitate use and uptake of data
- o top-down institutional 'push' → creating citizen-led demand or 'pull'

The HEI partners in UnLoCK, Bristol, Kings' College London, Sussex and Exeter, work as part of well-established, place-based Smart City (or 'Digital') eco-systems. By capturing and connecting knowledge, developing shared practices, and by extending engagement to innovative industry and community partners, UnLoCK seeks to create an 'ecosystem of ecosystems'. This is why UnLoCK consortium partners are drawn from all points along the Smart City value chain. Some are steeped in the workings of the technologies; others are expert in the social or ethical issues raised. The presence of all partners is necessary, as collaboration and co-creation of knowledge is essential to realising value.

The aim of UnLoCK is to shift away from static knowledge exchange frameworks to dynamic knowledge exchange systems. These should better reflect the variable, evolving and flourishing nature of local eco-systems and the contexts in which innovation thrives. The focus is on co-designing the new knowledge exchange value model with partners both on the supply and demand sides; and through using Blockchain, to explore innovative ways to automate the exchange of data and capture the whole value that this creates.

UnLoCK identifies the need for an innovative, agile and flexible approach to knowledge exchange across the complex, multi-agency ecosystems of Smart Cities. Conceptualised as a "Circular Model" this dynamically captures, shares and integrates knowledge. HEFCE itself recommends investment in collaborative ecosystems noting, "If we are to provide assurance to Government that university leaders are leading effective technology transfer, then we need to raise awareness and understanding in university management, but also policy-makers and funders, of the critical importance of, and dimensions to, ecosystem development."[v]

4. IDENTIFYING DISRUPTIVE OPPORTUNITIES

The University of Bristol surveyed UnLoCK stakeholders to identify areas where Blockchain and DLTs may enable Smart Cities. The responses point to a wide range of disruptive opportunities, of different types and at different scales, such as dealing with an explosion of datasets, sharing data with "robots", and empowering citizens to manage their own data and digital identities. Although diverse, these issues are linked by the common thread of the use of Blockchain technologies to build trust, allowing a greater number of organisations and individuals to transact safely and efficiently. Many of these opportunities raise new questions and require new thinking about how to capture and exchange knowledge.

A summary of the challenges and opportunities identified by stakeholders is set out below.

THEME: Efficiency and compliance with rapid growth in data
STAKEHOLDER: Ghassan Karame, NEC corporation; David Core, Bacs; Peter McBurney
and Mischa Dohler, King's College London

OPPORTUNITY Smart Cities are based on the digitisation of cities, and creation of 'The Information Society'. Whilst this change has been rapid, the knowledge systems that underpin this transformation are immature. Digitisation has ported the existing problems of lack of transparency and bureaucratic inefficiency to the digital world, while speeding up processes. These problems are exaggerated as cities, organisations and enterprises are currently in a hybrid phase where data is split between paper form and digital form, sometimes overlapping, sometimes inconsistent.

At the same time Smart Cities generate copious amounts of new data, exacerbating the difficulties of effective data sharing across business, community and higher education ecosystems the traditional approach to data management is to develop a 'single version of the truth', leading to increasingly large and complex data structures, which is unsustainable in an increasingly digital world. Large organisations have struggled to maintain control of data across proliferating contact channels, leading to a lack of agility to changing customer needs. Simultaneously, the complexity and sheer volume of data sets has exploded.

Issues of compliance and preserving integrity and resilience across complex structures that may lack direct contractual relationships, is of great interest to Bacs and the wider finance sector. The Financial Conduct Authority (FCA) note[1]:

> *"DLT solutions could deliver regulatory requirements more efficiently than current systems, substantially reducing costs for firms and regulators alike."*

New data privacy and control requirements, including the General Data Protection Regulations (GDPR), are a response to the growing recognition of the value that data can unlock, and concerns that there is a lack of transparency in the value exchange between consumers and corporate entities.

Blockchain and DLTs have the potential to increase transparency, and trust between institutions and between institutions and citizens. A prominent feature of DLTs is a secure database deployed in environments where there is no existing trust amongst participants. Blockchain can mitigate against corruption and enforce transparency by making data easily accessible, but not easily alterable. The result is many possible Smart City applications, including digital healthcare to provide patients and healthcare providers with secure and fast access to medical data; securely sharing sensitive information between governmental agencies to increase public safety; and the tracking of goods from their raw materials to the point of sale.

Blockchain and DLTs may increase productivity, efficiency, and reduce costs in complex systems and supply chains, with significant commercial value arising from DLTs digitizing and automating workflows that span multiple organizations. Many Smart City applications involve optimizing workflows, and these benefits could lead to a wave of Business Process Re-engineering (BPR) as companies move their data from multiple, different internal databases to single, shared databases held on Blockchain.

OPPORTUNITY UnLoCK can provide an important opportunity to engage differently with HEIs and Industry, and for these partners to also engage differently with communities. Blockchain and DLTs are disruptive technologies that might enable more inclusive and diverse civic participation and seek to push boundaries of how we collectively understand the potential of technology to transform society.

It is not yet clear how Blockchain might enable new systems of knowledge exchange, and capture of interactions between academic researchers and city users, where no formal contract is in place. But blockchains and distributed ledgers allow for interactions between parties without a prior history together and without any reason to trust each other, and smart contracts can enable automated charging and payment for access rights to expertise, or to the use of devices. These services or rights may be unbundled in terms of time, extent of services and location, so that (for example) a car driver could purchase insurance at the start of each journey instead of an entire year.

Blockchain and DLTs might enable new value to be created from very large, complex and dynamic datasets, as they allow for a much more atomised charging of assets in a very trusted and decentralised manner. For instance, one could monitor exactly how specific information propagates through the network including when mash-ups and top-up intelligence is created. This in turn allows for reverse-engineering the value chain and therefore, have the original owners of datasets receive financial rewards and/or recognition. Similar systems could be developed to record the use of university research by companies and residents of cities.

Disruptive opportunities include transparent transactions between people, councils, businesses and universities; transformative new societal interactions based on the idea of "trustless trust", i.e. confidence in a relationship with no pre-existing contact; and new ways of sharing and redistributing knowledge, decision making, economic wealth, intellectual property and provenance. For example, the use of Blockchain to verify the provenance of materials across complex supply chains, using environmentally sound materials in the construction of housing, and calculating carbon reduction. Or, how Blockchain might be used to support circular economy approaches to manufacturing and construction, supporting local labour, thus keeping money and resources within communities most in need of economic growth.

Smart Cities could use Blockchain and DLTs to improve sustainability, by tracking the provenance of building materials as changes of ownership and/or custody of assets are registered on the chain. This means that provenance can be recorded and analysed. Commercial applications already exist that use Blockchain technologies for this purpose, including financial assets such as shares, and physical assets such as diamonds. Building materials and other movable or semi-fixed assets (such as sensor devices) are obvious applications that would be of great relevance to partners in UnLoCK as well as to those engaged in delivering Smart Cities more generally.

THEME: Benefits for citizens: what if every individual held their own data?
STAKEHOLDER: Glenn Parry, University of the West of England (UWE); Peter McBurney
and Mischa Dohler, Kings' College London

OPPORTUNITY Blockchain and DLTs could play a valuable role in relation to citizens and identity. What if every individual held their own data, rather than multiple, overlapping databases held by organisations, containing millions of records?

A key challenge for Smart Cities is to establish the identity of individuals, and link these to service requirements and entitlements. Sharing data could provide significant time and cost savings, but integration, legal and security challenges make this nearly impossible. Instead, data could be held by the individual, with the use of personal data stores (PDS) that are more than dumb storage lockers. Validating someone's data usually requires a third party with multiple validations requiring the same information many times over. But with Blockchain, a document could have an associated cryptographic hash validated by a trusted party. The hash is stored in the Blockchain, creating the public immutable record. To prove the validity of the document the individual's document is linked to the hash; if it matches it is valid. To 'forget' the association, the document can be deleted or changed, rendering the hash meaningless.

Enabling citizens to engage with smart technology and share their data to improve services without relinquishing control – combining DLTs with adequate privacy and confidentiality provisions - poses many challenges. UnLoCK is an important and timely intervention as the technology is still very immature, but we expect to see progress in these areas in the next five years.

GDPR regulations will require individual permission for any data processing done by an organisation. Organisations may benefit from reduced risk and cost of holding personal data, as algorithms could run queries on encrypted PDS and send out results, protecting the individual's identity. Processing is done on the individual's device, reducing central processing power, potentially speeding up queries on city wide data and providing network effects and cost reduction. The challenge is in building the network and agreeing who pays. Such infrastructure would benefit everyone, and so it could be argued that it should be a Government provided asset.

THEME: Managing organisational risks and allowing citizens control of their own data

STAKEHOLDER: Sarah Green, University of Bristol; Peter McBurney and Mischa Dohler, King's College London

OPPORTUNITY A key aspect of Blockchain is the ability to record severable datasets. This allows users to only upload data that they want to share, without inputting any identifying details (such as address, email, contact information), meaning they can harness the sharing potential of the software without being made vulnerable by it. This characteristic of Blockchain, historically the reason why cryptocurrencies are so appealing to criminals, is now one of its principal attractions. As well as the appeal of reduced risk to users, this characteristic is of considerable interest to organisations wishing to reduce data liability. If organisations can sever information that has operational relevance from that which does not, they limit access to relevant data sets, and remove the risk of liability for disseminating other data without authority.

Blockchain can help SMEs to transfer technologies and approaches within and across cities. DLTs allow trusting relationships between parties with no prior contact, and for the cataloguing and maintenance of a standardised database of assets. This supports a trusted supply chain of technology across cities with very different demand-side profiles, allowing SMEs to develop Smart City scaleable and replicable applications.

For Smart Cities, Blockchain aligns the incentives of all stakeholders. It is a platform that gives users an incentive to co-operate and to make the system work, as this then enhances the reputation and trust of all participants. This could encourage people to store socially useful information, such as registers of property titles, authenticity and provenance.

OPPORTUNITY Looking at physical assets through the filter of location gives new insight to their effective operation, their exposure to external risk or their influence on or by third parties. In the data world, place is the glue that holds disparate pieces of information together in a single logical model. This is a fundamental principle that enables not just smart cities, but more connected and intelligent places of all kinds.

Traditionally this information has been shared in the form of a (digital) map, but the world moves on and Ordnance Survey (OS) is preparing for a new 'data-driven' future where machines rather than people will be the primary consumers of our data. This requires a restructuring of our data around explicit references to objects. The graphic map will remain, but simply as a derivative representation of the data. Data will be king, the fuel for the Digital Economy. And for this to work it requires a new, safe and secure way to deliver and authenticate the data.

Based on its ability to allow transactions between unfamiliar entities (for example IoT devices) in a trusted, traceable manner without incurring significant costs, blockchain holds potential to address a significant number of areas for OS.

Those transactions could be large (properties), complex (legal contracts for services) or small and simple (such as high-volume, micro-payment services). Blockchain has the potential to effectively remove barriers of access to data associated with securing that data (commonly represented in the form of a licence and/or a fee) by making the transaction seamless or machine-readable. The reduced friction in accessing data, while enabling a vast volume of transactions, enables cost reductions to the end-user (who is frequently making micro-payments) that for all intents and purposes removes all transaction friction.

In addition, it is apparent to OS that a distributed ledger would benefit from access to a register of features, be it a land parcel or an asset, that provides a common understanding of location, extent and spatial relationship to other features. For example, a security check could be performed for a credit card transaction in the form of a location check, requiring the originator, recipient or the transacted item to all be in the same location for the transaction to be valid. Everything happens somewhere; being able to identify the 'where' is an excellent way to filter anomalies in patterns of feature interactions.

In the case of large transactions such as property the use of this technology (crypto-cadastre) for land registration is already being explored in countries such as Honduras and Ghana with the promise of simplifying a complex process to increase confidence in protection of land rights. This is a basic requirement for many to be able to raise capital, which offers the basis of fundamental economic change in many parts of the globe. OS, through its programme of institutional support to foreign governments and national mapping agencies, is keen to foster understanding of the benefits and pitfalls of adopting such an approach.

THEME: "Grid-edge" innovation for smart cities: blockchain and the national grid
STAKEHOLDER: Colin Nolden, University of Bristol

OPPORTUNITY Grid-edge innovations - the smart, connected hardware and software close to end-users of the national power grid - are disrupting traditional energy sector business models. Combining blockchain with renewable energy generation (usually solar PV), batteries and smart meter systems enables Peer-to-Peer (P2P) electricity trading.

Blockchain can track energy and financial transactions, with data on electricity generation and consumption supporting consumer purchase, sale and swapping of electricity. P2P electricity trading enables those with renewable energy technology to sell electricity locally, and can lower costs by cutting out traditional intermediaries and allowing consumer-producers to sell electricity directly to other consumers.

Several UK cities are repeating US trials that connect households with renewable energy technologies with households entirely powered by conventional grid electricity.

Smart City innovation and experimentation should include Blockchain-enabled smart power grids (in line with Ofgem's regulatory sandbox), whilst protecting users dependent on traditional infrastructure from rising maintenance costs.

5. Conclusion

Smart Cities are characterised by technologies such as Blockchain and DLTs that invite us to look again at established city systems, imagining how technology might transform them in the future. From driverless cars that may rarely need to park; to the Internet of Things (IOT) that harvests real-time data on all aspects of city life, predicting, pre-empting and managing behaviors; to Artificial Intelligence, Machine Learning and Robotics that herald a 'fourth Industrial revolution' – the disruptive opportunities are vast.

It is also commonly understood that in the short term, innovative technology over promises. A cycle of hype followed by a period of despair is seen as an almost inevitable pre-cursor to determining the true value of technological innovation. But does this have to be the case? Should we be seeking a new knowledge model that better meets the needs of those involved in determining and delivering Smart Cities?

Of course, Blockchain, DLTs and other disruptive technologies are not simple, off-the-shelf solutions. They often raise significant questions, which cannot be easily answered now. Blockchain, for example, is known to require a considerable amount of energy to process its dispersed transactions. There is concern about a lack of robustness in the underlying code, which may leave vulnerability to attack. There is also a general sense of unease at the absence of transparency and compliance with regulation. The stakeholders in UnLoCK can imagine numerous areas where the technological innovation of Blockchain promises tangible benefits, whilst recognising such concerns.

UnLoCK stakeholders are seeking systems that better account for global carbon emissions and underpin shared action to minimise climate change impacts. They are seeking to more effectively monitor and manage supply chains and to enable citizens to own and manage personal data. They also recognise the need to plan for a world where interconnected autonomous systems are a primary user of data and where algorithms and Machine Learning are a significant generator of new knowledge. Responding to these disruptive opportunities requires both technological innovation and a new approach.

UnLoCK points to the value of cross agency collaborative research where stakeholders come together at an early stage to generate shared understanding of the disruptive opportunities associated with technology innovation. They use multiple lenses to identify shared questions for research and learning before co-producing creative solutions that can be applied, tested and refined in real-world environments. This is the real "Disruptive Opportunity" that UnLoCK seeks to champion, as the basis for making progress both with Smart Cities, and for the effective sharing of knowledge more widely.

6. APPENDIX: ACKNOWLEDGEMENTS

The participants in the research are,

- BACS
  - UnLoCK partner Bacs is responsible for processing over 70% of household bill payments and 90% of salary payments. Bacs seeks to identify and assess emerging technologies that may change the payment needs and behaviours of all end users including, consumers, corporates and Governments. Specifically, Bacs recognises Blockchain and DLTs as being significant because they offer opportunities to radically change the support and management processes that sit around payments, helping to maintain integrity and resilience across the wider payments ecosystem.

- KINGS' COLLEGE LONDON
  - Professor Peter McBurney is based at King's Department of Informatics which hosts world-class Centres in Telecommunications, Robotics and AI. Professor McBurney is a recognised expert in Blockchain and distributed ledgers.
  - Professor Mischa Dohler is Professor in Wireless Communications at King's College London, driving cross-disciplinary research and innovation in technology, sciences and arts. He is Head of the King's Centre for Telecommunications Research.

- KNOWLE WEST MEDIA CENTRE
  - UnLoCK partner Knowle West Media Centre (KWMC) works in communities across Bristol, particularly those less advantaged and least likely to be early adopters of technology. KMWC finds creative ways to engage with groups of people to co-design technology that is relevant and addresses issues affecting their everyday lives. KWMC believes the co-design of technology, to support development of the kind of communities and environments that people want to live in, offers opportunities to reimagine and redesign services, and positively reconfigure the relationships between city council, voluntary and private sectors, universities and citizens

- NEC
  - UnLoCK supporter NEC Corporation has 100 years of expertise in technological innovation to empower people, businesses and society. NEC is promoting the transformative benefits of Blockchain technology and helping advance its adoption but is also very aware of the practical challenges.

- ORDNANCE SURVEY
  - UnLoCK partner Ordnance Survey (OS) is a world leading Authority on the creation and use of maps and geospatial data.

- UNIVERSITY OF BRISTOL
    - The University of Bristol is the lead institution for the UnLoCK project.
    - Sarah Green is Professor of Private Law at the University of Bristol and is currently working on virtual currencies, Blockchain issues surrounding intermediated securities, smart contracts, sale of goods law as applicable to digitised assets, and wage theft.
    - Dr Colin Nolden is a Vice Chancellor's Fellow, Colin's research interests span energy and climate service business models, energy and climate policy, and sustainability.

- UNIVERSITY OF THE WEST OF ENGLAND
    - UnLoCK Advisor Professor Glenn Parry is interested in value and what 'Good' means for an organisation. Recent work has examined value and business models - how organisations function, can adapt, create positive experiences for customers and make money, and provide benefit for society. Glenn likes to apply academic theory in practice, testing ideas and learning from outcomes.

The report has been prepared by Stephen Hilton, Anthea Terry and Lisa Kehoe, University of Bristol, with thanks to the UnLoCK stakeholders.

7. ENDNOTES

[i] Making Cities Smarter (BRITISH Standards Institute, 2014)
[ii] The Smart City Market Opportunities for the UK (ARUP, 2013)
[iii] https://www2.deloitte.com/uk/en/pages/innovation/articles/blockchain.html
[iv] http://www.hefce.ac.uk/ke/ccf/