Centre for Blockchain Technologies

UCL

Distributed Ledger Technology in the Supply Chain

Supported by the Retail Blockchain Consortium

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UCL CBT

Disclaimer: Data for this report have been gathered from a substantial number of sources, including in-person interviews and desktop research. While every reasonable effort has been made to verify the source and accuracy of the data collected, the research team cannot exclude potential errors and omissions. Opinions expressed in this report reflect those of the authors and not necessarily those of their respective institutions.

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Special thanks go to Patrick Timmis (UCL CBT) for the data collection, initial analysis and initial drafting of this report. Wing Lee (Hashreader) for the report design and feedback on data collection. Finally, to Tomaso Aste (UCL CBT), Lars Gladhaug (UCL CBT) and Alexander Kirby (UCL CBT) for reviewing the drafts.

EXECUTIVE SUMMARY

Distributed Ledger Technology (DLT) is expected to become a vital part of the infrastructure that will help to digitise and improve efficiency in global supply chains. But where is DLT being adopted and what is the current adoption in industry? This report aims to shed light on these questions, focussing on the functional usage areas of DLT in Product Tracing, Logistics, Financial Transactions, Retail Operations and Circular Economy. Within these usage areas, the focus has been in the Grocery, Healthcare and Fashion sectors.

In total 105 projects were analysed over a period of three months between November 2018 to January 2019.

The analysis of these DLT projects have revealed the following main findings:

- Progress of projects is well developed with nearly 15% of projects analysed having moved into production.
- Projects are nearly equally split between the Americas, Europe and Asia. On a country level, the USA dominates. Chinese projects are underreported due to the lack of English language information available. This conclusion can be made by comparing the number of patents being filed by Chinese companies, which are comparable to those filed by American companies.
- Over half of all projects analysed are utilising private blockchains.
- The Grocery sector has the greatest number of active projects.
- The greatest number of projects is within the Product Tracing usage area, followed by Logistics and Financial Transactions. The Circular Economy and Retail Operations areas are not well developed but are beginning to attract attention.
- There are overlaps between projects when analysing by application areas (i.e. projects that operate in one usage area also operate in other usage areas). This is not the case when looking at sectors; for instance, Grocery projects overlap with Healthcare and Fashion, but Fashion and Healthcare do not.
- Funding levels and the operational scale of projects are approximately equivalent across Product Tracing, Logistics and Financial Transactions. Progress and partners are most developed in the Product Tracing area and Logistics, with Financial Transactions not yet as developed.

SECTION A: INTRODUCTION

1. ABOUT THIS REPORT

1.1. Overview of this Report

Distributed Ledger Technology (DLT) is on a path to disrupt many aspects of business and society that deal with the coordination of information and trust. DLT has the potential to become the new layer for economic value transfer within the modern technology stack (also referred to as the internet of value). It also has, through the usage of programmatically executable contracts (also known as smart contracts), the capability to automate many processes.

A little over ten years since its emergence, DLT has predominantly developed within the Financial Services sector and it is within this sector that the greatest level of investment and experimentation has occurred. Outside of this sector, one of the biggest areas where DLT is making an impact is within the supply chain sector. Well-functioning global supply chains ensure the smooth and timely movement of goods all over the world and underpin the globalised economy. It is astonishing that this industry, with all its operational complexity, is still run on predominantly manual procedures and processes. For example, global import / export approvals processes can incorporate as many as 30 indifferent individual approvals, which are made using paper-based documents.[1]

Despite the increasing opportunity for digitisation and looming disruption, currently, application areas and progress of DLT adoption in this area are not well understood. This report seeks to shed light on where DLT is being applied functionally in global physical supply chains and within certain sectors.

As part of the research for this report, over 100 relevant blockchain projects (see Appendix 2) were analysed (including projects that are start-ups, company projects and consortia) in the retail physical supply chain domain. Analysis of the data gathered through this research supports the narrative of both the general trends observed in the blockchain physical supply chain domain and at the use case level, where some specific projects are explored in more detail to unpack some of what has been done so far – from proofs of concept, to pilots and commercial scale deployments.

This report assumes no prior knowledge of blockchain, and the introductory section is designed to illustrate the fundamentals of what DLT is and how it can be applied in a retail value chain context. In the use case specific sections, the report draws on insights from the research data and dives deeper into how use cases work in practice, including the potential value added as well as implementation challenges. There is also a glossary of important terms for reference.

1.2. Hype and Disillusionment in Blockchain

Many would argue that DLT is at a critical point in its development, having moved past the “peak of inflated expectations” (a period of tremendous interest focussed around Initial Coin Offerings (ICO)) and moving toward (or through) the “trough of disillusionment” (some have

[1] CBInsights (2018) *Major Links In The Global Trade Supply Chain That Blockchain Could Transform.* Available at https://www.cbinsights.com/research/maritime-logistics-shipping-blockchain-global-trade/ [Accessed June 2019].

labelled this as the “Crypto Winter” – a period of disappointment in DLT not having lived up to the hype) according to the Gartner Hype Cycle.[2]

Interest has shifted from public permissionless blockchains towards private permissioned ones (better known as enterprise blockchains) and it is within this enterprise segment that we are currently seeing the bulk of development work and corporate interest. Many projects are now moving past the proof of concept and pilot stage to real world deployment. Whilst the technology is still in its early days, one can expect to see significant deployments at scale throughout 2019 and into 2020 as pilot projects move into production phase.

For DLT to reach its full potential, it must cross the chasm from early adoption to mainstream adoption.[3] For this to happen, DLT needs to build further momentum in terms of its utilisation, progress and potential incremental value within industry, with decision makers at leading firms understanding where it should be adopted and implementing it.

Therefore, this report comes at the right moment. Whilst the blockchain story is still only just beginning, we are at a point today where many use cases are well developed and ready for closer evaluation and adoption and indeed it appears that progress and utilisation are very much developing.

There are challenges ahead, particularly since distributed ledgers require new ways of working which should involve all stakeholders in an industry (including in many cases direct competitors).[4] So, as the technology and specific use cases are increasingly proven through the more than 100 projects included in the research for this report, the real challenge for the future is bringing about industry-level collaboration and adoption.

[2] For further information on the Gartner Hype Cycle see *Gartner Hype Cycle.* Available at: https://www.gartner.com/en/research/methodologies/gartner-hype-cycle [Accessed July 2019].
[3] One could say moving from early adopters to the early majority. Crossing the Chasm is a term introduced by Geoffrey Moore in his book “Crossing the Chasm”. Moore, G. (2014) Crossing the Chasm 3rd Edition. *HarperCollins.* Available at: http://www.geoffreyamoore.com/books-by-geoffrey-moore/ [Accessed July 2019].
[4] Tasca, P. and Widmann S. (2017) The Challenges Faced by Blockchain Technologies – Part 1. *Journal of Digital Banking, Volume 2 / Number 2.* Available at: https://www.ingentaconnect.com/content/hsp/jdb001/2017/00000002/00000002/art00005 [Accessed June 2019].

1.3. Scope of What's Included

This report initially focuses on the Grocery, Fashion and Healthcare sectors, but includes research from many other sectors as well.[5] Underpinning the report is an extensive dataset covering more than 100 relevant projects across the defined usage areas. The usage areas reflect those applications which are most relevant to the retail supply chain today. They are not necessarily mutually exclusive for a given project – for example, some projects offer a solution which addresses both logistics tracking and facilitates financial transactions. A description of the usage areas is given in Table 1.

Table 1: Description of usage areas.

Usage area	What's included
Product (Tracing)	Product provenance, track and trace, anti-counterfeit
Logistics	Supply chain management and inventory optimisation, digital paper, cold chain / environment history recording
Financial Transactions	Smart contract payments, direct selling, token-based payments, reconciliation
Retail Operations	Loyalty management, refunds management, customer identification
Circular Economy	Reduce, reuse, recycle – supporting secondary uses and reselling

[5] These sectors reflect the initial focus of the RBC.

2. INTRODUCTING BLOCKCHAIN IN THE RETAIL VALUE CHAIN

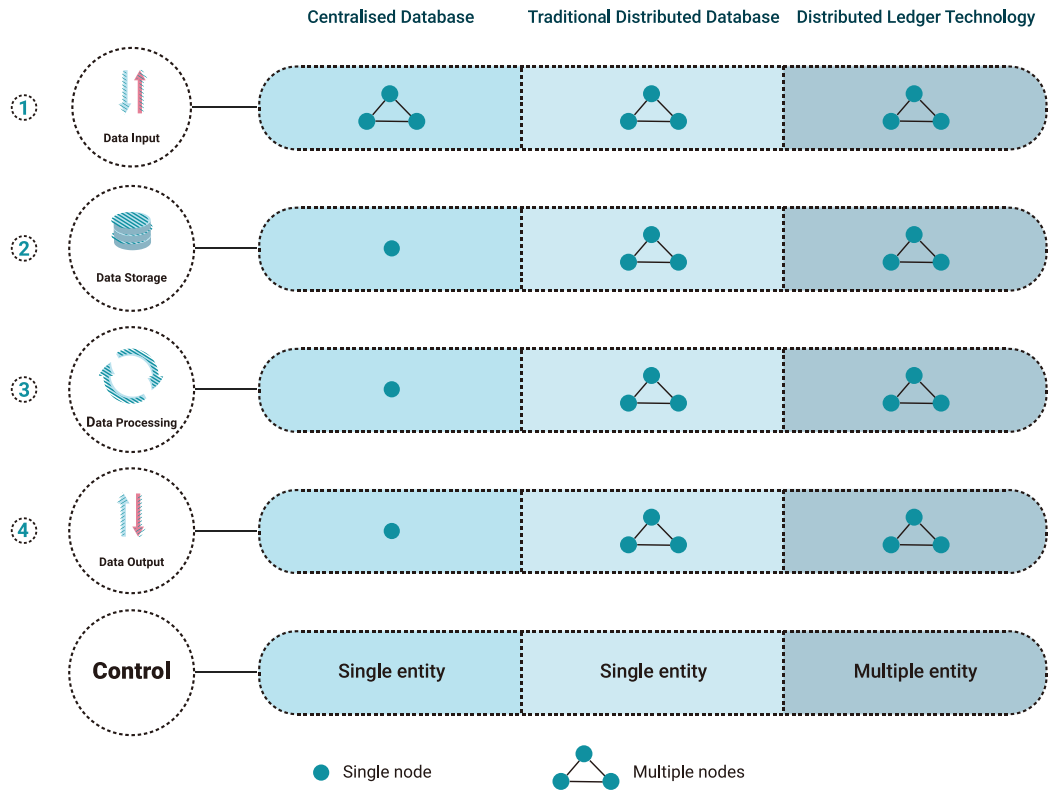
2.1. What is Blockchain

In our definition of blockchain, we explore three key concepts: distributed data, blockchain and consensus.[6]

Distributed Data

The concept of distributed, decentralised data is fundamental to understanding blockchain technology and its implications for the supply chain. Whilst traditionally data is housed in central servers (typically controlled by a single organisation), in a distributed ledger this data is replicated across the network of users. Figure 1 shows the differences between centralised databases, traditional distributed databases and DLTs.

Figure 1: From databases to distributed ledgers.[7]



This data structure effectively means that all participants in a network have the same data and also the ability to read and write to the ledger. Hence in a supply chain context, all actors from the source to the point of sale (and indeed after the point of sale) work from the same data and are able to participate in the reading and writing of this data.

[6] For a broader introduction to DLT see CCAF (2018) *Distributed Ledger Technology Systems.* Available at: https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/publications/distributed-ledger-technology-systems/#.XTDWZ-hKjD4 [Accessed July 2019]. For a more technical introduction see Antonopoulos, A. (2017) Mastering Bitcoin (2nd Edition). *O'Reilly.* Available at: https://bitcoinbook.info/ [Accessed July 2019].
[7] Figure adapted from CCAF (2018) *Distributed Ledger Technology Systems*. Available at: https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/publications/distributed-ledger-technology-systems/#.XTDWZ-hKjD4 [Accessed July 2019].

Blockchain

Blockchain is a type of DLT, which securely records information in cryptographically sealed blocks replicated across a peer-to-peer network.[8] Although it was originally created as a means of facilitating payment without any trusted central authority (Bitcoin), blockchain's potential reaches far beyond cryptocurrencies. Blockchain ledgers can include product history, identities, logistics tracking, land titles – almost anything of value. Figure 2 describes some of the main features and properties of blockchains.

Figure 2: Overview of blockchain.

DLT comprises a ledger of transactions which is distributed on different nodes or computer devices, each of which individually participate in the network by replicating, validating and saving a copy of the ledger. There is no central authority at the command, no arbitrator, and each node that proceeds to the registration and storage works independently.

Within DLT, blockchain's distinguishing feature is that it is the only form of DLT that employs a connected and encrypted chain of transaction "blocks" to reach consensus on the distributed ledger. Blocks are continuously added to the chain and data within the blocks can no longer be modified or deleted. These blocks are closed by the cryptographic hash, which will reconcile with the hash of the next block. Therefore, whilst all blockchains are DLTs, all DLTs are not blockchain.

[8] Throughout this report, the terms blockchain and DLT will be used interchangeably and unless specified in the text, blockchain refers to the wider family of DLTs.

Consensus

The validity of the data logged in DLT and thus its security is based on participant voting – this can take many forms and is known as the “consensus mechanism”. At each update, each participant (or node) votes and the valid update is agreed through majority votes. This is where the “distributed trust” concept of DLT comes from – it is critical that the network is set up appropriately to ensure that the consensus is reliable.

There is a trade-off to be made: in a private distributed ledger network where participants already trust one another, simple majority voting is possible, but in a public distributed ledger network a robust consensus mechanism is needed.

Blockchain Uses

Blockchain uses can be categorised into three main buckets:

1. Storage of digital records (identities, assets, voting rights, etc).
2. Exchange of digital assets (via direct peer-to-peer transactions which remove the need for middlemen).
3. Recording and executing smart contracts (using code to embed contract rules into processes, thereby automating selected functions within the contract (to become self-triggering as per agreed contract terms)).

There are many misconceptions regarding blockchain technologies and this is understandable given the early stage of the technology and its perceived complexity. Table 2 elaborates on some of the common misunderstandings related to DLT.

Table 2: Three key blockchain mythbusters.

Myth	Reality
 **Blockchain is the same as Bitcoin**	• Bitcoin is one of the applications of blockchain. • Blockchain technology can be used for many other applications.
 **Blockchain data represents the truth and an improvement on traditional databases**	• Blockchain can verify all transactions and data contained on a blockchain (e.g. Bitcoin). However, it cannot assess whether an external data input is accurate. • Blockchain's advantages come with significant technical trade-offs (such as efficiency). Traditional databases often provide the better solution for common business problems. • Blockchain's key strength is in low-trust environments where participants have no way to trade directly or through an intermediary.
 **Blockchain is immutable or tamper-proof and is 100% secured**	• Blockchain data structure is append only and therefore data cannot be removed. • Some blockchains can be tampered with if greater than a certain percentage of the network-computing power is controlled and all previous transactions are rewritten. However, this is largely impractical.[9] • Blockchain uses immutable data structures and the overall security will also depend on associated applications.

[9] This is dependent on the type of blockchain and consensus mechanism used and can vary significantly.

2.2. Blockchain's Distinguishing Characteristics

Blockchain brings several key advantages versus a traditional database.

First, it is transparent and auditable, since all transactions are visible to authorised participants and are traceable within the ledger. Auditing becomes relatively straightforward, since identical copies of the ledger are made on each instance or node of the ledger. The ledger is also immutable, meaning transactions cannot be erased or modified without approval and traceability on the distributed ledger. Furthermore, all accounts are identifiable on a pseudo-anonymous basis – ranging from fully anonymised accounts (in certain public blockchains) to known actors within a private distributed ledger (e.g. within an enterprise distributed ledger).

Secondly, blockchain is reliable. The technology is resilient since it doesn't have a single point of failure and operates with extremely high redundancy (since the ledger is duplicated across each participating node). This also means that it is significantly more difficult to attack or corrupt: for example, an attacker targeting a public blockchain would need to manipulate or assume control of some percentage of the distributed ledger nodes in order to tamper with the shared ledger.[10]

Thirdly, blockchain enables efficient settlement processing, since transactions are processed directly from peer to peer without the need for multiple intermediaries. Where transactions occur, both sides are executed simultaneously, and the ledgers are automatically updated as an integral part of the value transfer process.

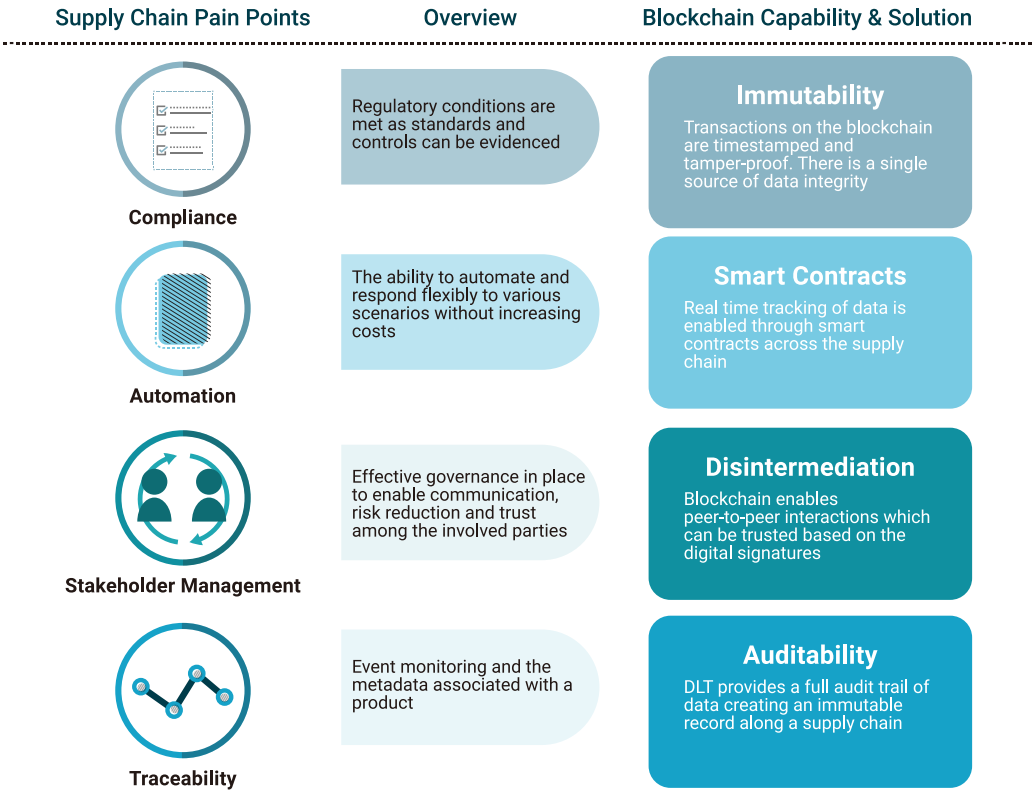
Finally, blockchain offers potentially low-cost solutions since it uses computing power rather than traditional manpower to complete back office processes which normally require significant involvement of accountants and bookkeepers (to ensure correct, timely and transparent transaction reporting), auditors (as periodic validators of transaction records) and trusted third parties (as external and impartial purveyors of trust).

[10] The percentage of control required varies by the type of blockchain and consensus mechanism. For the Bitcoin blockchain this manipulation can occur if more than 50% of the nodes are controlled.

2.3. What Blockchain Means for the Retail Value Chain

In a retail context, the most significant domain in which blockchain can create transformational change is the physical product supply chain. By putting assets first, blockchain can enable an efficient flow of data and funds from each stakeholder at each step of the chain. This can deliver fundamentally new ways of working and brings a visibility and control on each supply chain which is simply not achievable in centralised configurations where data has to pass from one environment to the next. However, transformation is never straightforward – particularly so in the context of increasingly complex supply chains with multiple manufacturers, processors and distributors along the way. It requires a collective engagement and industry-level initiatives to drive adoption and deliver benefits to the supply chain participants and end consumers. Figure 3 describes how DLT addresses some of the major pain points in supply chains.

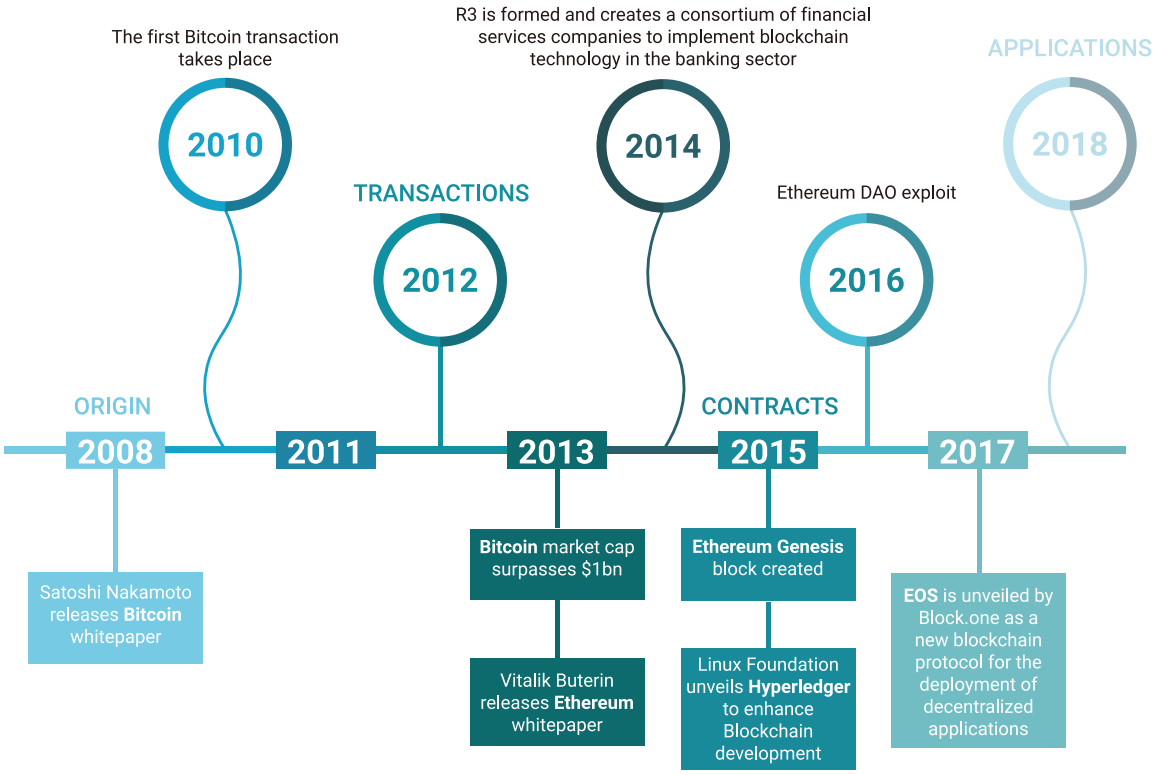
Figure 3: Blockchain capabilities as a solution to supply-chain issues.



2.4. Brief History of Blockchain for the Retail Supply Chain

Blockchain technology is still very new. Whilst the first Bitcoins were mined in 2009, it is only since around 2014 that there were blockchain protocols which could be used to develop applications. Figure 4 shows a timeline of major events in the evolution of DLT over the last 10 years.

Figure 4: The history of blockchain technology.



Today, blockchain is about a lot more than Bitcoin and cryptocurrency. The real interest for enterprise applications is in leveraging the technology to create better information systems which create business value. For example, in the supply chain the technology unlocks new ways of working which aren't possible in the traditional, centralised world.

In the supply chain the technology unlocks new ways of working which aren't possible in the traditional, centralised world

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Awareness of blockchain is high within the retail industry, with nearly nine out of ten people in the industry convinced that blockchain will be important to the future of retail with the potential for material savings by streamlining operations and eliminating manual tasks.[11]

[11] 87% of respondents were convinced blockchain would be important to the future of retail according to the survey. See Cognizant (2017) *Retail: Opening the Doors to Blockchain.* Available at: https://www.cognizant.com/whitepapers/retail-opening-the-doors-to-blockchain-codex2879.pdf [Accessed July 2019].

However, the challenges to implementation are real and early deployments are typically confined to single usage areas as a proof of concept. Let's consider the history of where we are today – what has been achieved so far and what is still unproven or requiring further work.

Global retail leaders have been quick to explore the potential of distributed ledgers. Walmart[12], the world's largest grocery chain, was among the first to explore the technology's potential and announced in September 2018 that it would require some of its U.S. leafy greens suppliers to adopt blockchain technology within a year.[13] However, Walmart is not a typical retailer and few companies are able to require their suppliers to adopt any required technology. Other retailers will likely want to engage with suppliers, regulators and customers before deciding how to capitalise on DLT's many potential benefits.

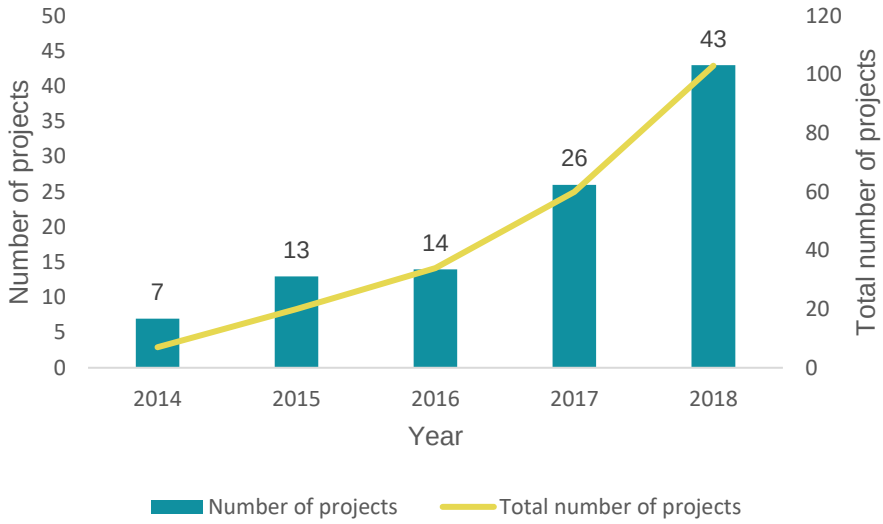
In pharmaceuticals, leading industry players such as Pfizer[14] are working on use cases to improve the traceability of medications and facilitate compliance with new industry regulations. In October 2018, following testing by participants, Mediledger[15] launched its first project to verify and process saleable returns.[16] Using a permissioned blockchain, the project seeks to facilitate compliance with increasingly stringent supply chain management regulations such as the U.S. Drug Supply Chain Security Act (DSCSA)[17].

Financial services are at the forefront of blockchain innovation, with some well-developed solutions in trade finance and supply chain financing which show promising benefits for the retail industry. For example, Voltron[18], We.Trade[19] and Marco Polo[20] all offer trade financing solutions which can unlock trade financing barriers which are currently a highly bureaucratic paper-based process requiring multiple intermediaries and often prohibitively high costs – especially for SMEs with a limited track record of cross-border trade. The same blockchain properties provide significant potential to improve efficiencies in supply chain financing by allowing direct peer to peer trading which is intrinsically linked to products and is part of an auditable chain of transactions which could be referred back to in case of any breach of contract (e.g. defective products or payment defaults). Some examples in the financial transaction's usage area will be considered.

[12] Walmart - https://www.walmart.com/
[13] Walmart (2018) *In Wake of Romaine E. coli Scare, Walmart Deploys Blockchain to Track Leafy Greens.* Available at: https://corporate.walmart.com/newsroom/2018/09/24/in-wake-of-romaine-e-coli-scare-walmart-deploys-blockchain-to-track-leafy-greens [Accessed June 2019].
[14] Pfizer - https://www.pfizer.com/
[15] Mediledger - https://www.mediledger.com/
[16] Morris, N. (2018) MediLedger: Pharmaceutical industry's blockchain network. *Ledger Insights.* Available at: https://www.ledgerinsights.com/mediledger-pharmaceutical-blockchain/ [Accessed June 2019].
[17] DSCSA - https://www.fda.gov/drugs/drug-supply-chain-integrity/drug-supply-chain-security-act-dscsa
[18] Voltron - https://www.voltron.trade/
[19] We.Trade - https://we-trade.com/
[20] Marco Polo - https://www.marcopolo.finance/

This research includes analysis of 105 projects. The earliest started in 2014 and most projects started in 2018 (43 projects founded). Figure 5 shows the number of projects founded by year and cumulatively.

Figure 5: Blockchain projects by year of founding.[21]



[21] Two projects founded in 2019 not included on chart.

SECTION B: ANALYSIS

3. HIGH LEVEL OBSERVATIONS

3.1. General Analysis

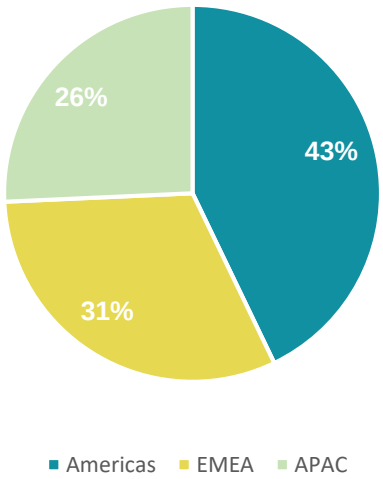
Geography

Before looking more closely at the sectors and usage areas of the analysed projects, general trends and statistics at a macro level are initially explored.

Figure 6 shows where projects are located regionally. From a regional perspective, there is a relatively even split globally, with the Americas narrowly leading the way.

Projects are relatively evenly split globally on a regional basis

Figure 6: Project locations by region (% of projects).

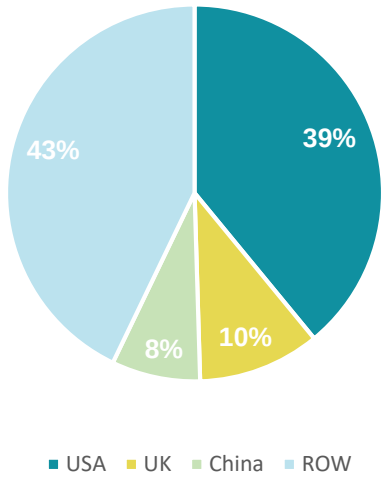


However, drill down to a country perspective and we can see that the concentration is lumpy, with the USA, China and UK accounting for more than half of all projects.

Chinese firms are most likely underrepresented in this research, probably due to a lack of international project publicity

Figure 7 shows the breakdown of projects on a country level.

Figure 7: Project locations by country (% of projects).



It is interesting to note that Chinese projects are most likely underrepresented in this research. Most of the desktop research was conducted on English language sources. In this regard, Chinese projects have not internationalised their progress and publicised internationally. This contradicts international patent filing statistics where Chinese firms are as active (if not even more active) as firms from the USA, suggesting that Chinese firms should most probably have further representation.[22]

[22] Hard Fork (2019) *Data: China has the most blockchain patents, despite banning cryptocurrency.* Available at: https://thenextweb.com/hardfork/2019/03/13/data-china-is-patenting-all-the-blockchain-tech-despite-banning-cryptocurrency/amp/ [Accessed July 2019].

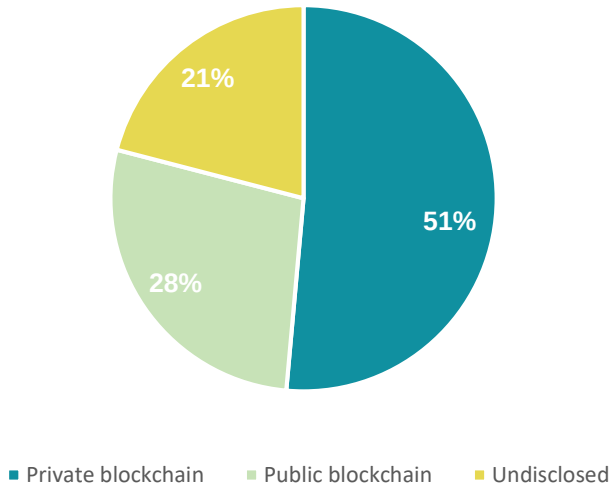
Permissioning

With regards to protocol type, private blockchains account for slightly more than half of all projects. This reflects the fact that many of the projects covered are intended for enterprise use, with an inherently permissioned structure for supply chain participants.

Private blockchains account for slightly more than half of all projects

Figure 8 shows the breakdown of projects by their use of what type of blockchain (public, private or undisclosed/not applicable).

Figure 8: Public vs private blockchain projects (% of projects).

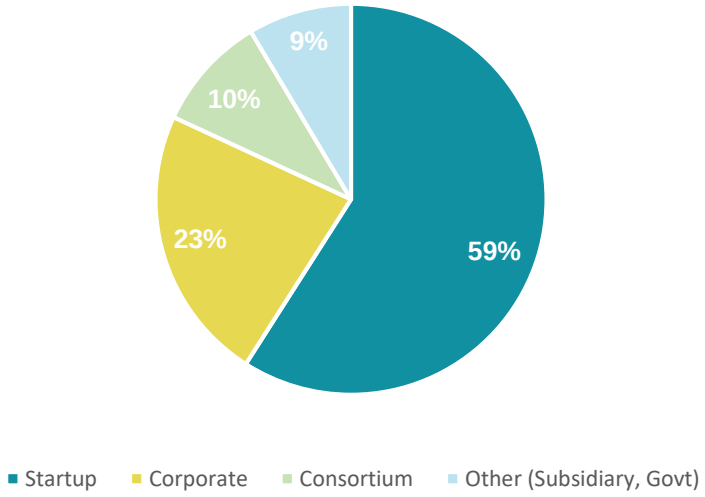


Project Structuring

Out of the 105 projects that this research has analysed, the most commonly observed operational structure is Start-ups (62 projects)[23], followed by Corporates, Consortia and finally other structures which include Government entities and Subsidiaries. This is in line with what one would expect given that the impetus for experimentation and development in this space has come from newly established companies. Figure 9 shows the breakdown of projects by their operational structure.

Start-ups form the bulk of projects analysed in this research

Figure 9: Projects by operational structure (% of projects).



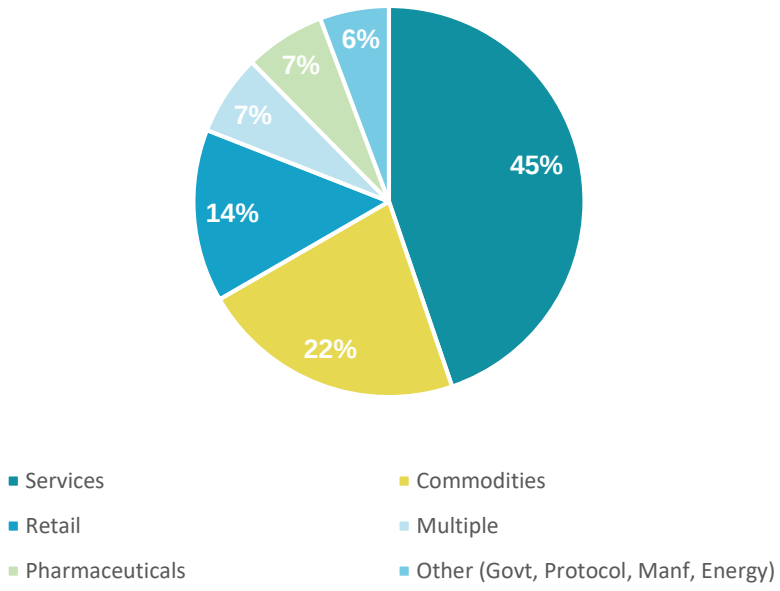
[23] Start-up is defined as an early stage company that has not established a dominant position in their market

Projects by Sector

Projects researched come from many different sectors, with the largest being from the services sector[24]. This is followed by the commodities and the retail sector. Figure 10 shows the breakdown of projects by the sector they operate in.

The services sector dominates project focus

Figure 10: Projects by sector (% of projects).

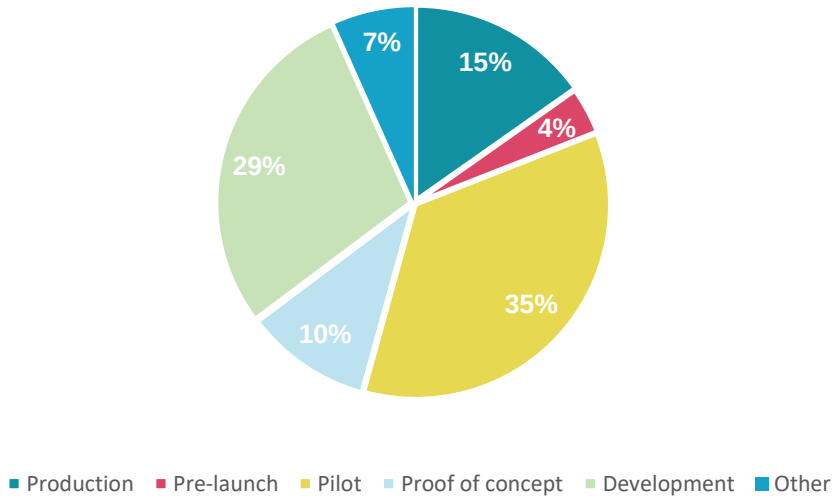


[24] Services sector is defined as consultancy and management services.

Projects by Stage of Development

Out of those projects that were investigated, it is important to note that a not insignificant number of projects are in production with nearly 15% of projects at this stage. Most projects remain at either the development or proof of concept stages indicating experimentation is still the focus of most projects. Figure 11 shows the breakdown of projects by their stage of development.

Figure 11: Projects by stage of development (% of projects).



3.2. Project Evaluation Methodology

The database which underpins this report was collected in two main steps. First, a wide-ranging data gathering exercise was carried out in order to pull together all potentially relevant projects, including start-ups as well as in-house company initiatives. As a second step, each project was rated according to four evaluation metrics which would then be used to sort and filter the projects which merit deeper analysis.

Each start-up project was evaluated according to assessment criteria relating to four areas: operations, funding, progress and partners.[25] A total of 62 start-ups were evaluated on this basis. The four metrics were each evaluated on a scale of 0-5 points and summed to give a total score:

a. Progress (project development status).
b. Funding (project funding status).[26]
c. Operations (size of project based on employee count).[27]
d. Partners (evaluation of scale and credibility of project partners).

[25] Projects that were analysed are presented in Appendix 2. 43 non-start-up projects (e.g. company initiatives and consortia) were not included due to lack of data for the funding and operations criteria.
[26] Start-ups only (not applicable for assessment of company projects).
[27] Start-ups only (not applicable for assessment of company projects).

The assessment criteria are presented in Table 3.

Table 3: Project evaluation criteria.

Score	Progress	Funding	Operations	Partners
Unit of measure	**Project development**	**$m raised**	**Employees**	**Grade of partners**
5	Production	>20	>50	Blue chip with DLT credentials
4	Pre-launch	10-20	30-49	Other blue chips
3	Pilot	5-10	20-29	Multiple other MNCs* / govt
2	Proof of Concept	1.5-5	10-19	Single MNC / govt
1	Development	$0.5-1.5m	5-9	Other partners
0	Ideation	<$0.5m	<5	No partners

*Multinational Corporation

These scoring criteria were applied to every project covered by the research which enables an approximative comparative ranking of projects across different industries and application areas.

Some projects which might at first glance appear to merit a high ranking, on closer scrutiny are not in reality as credible as they would seem

In the first instance, this research is based on published data, however there are clearly some projects which might at first glance appear to merit a high ranking but which on closer scrutiny – combined with DLT industry knowledge – are not in reality as credible as they would seem. This is one of the challenges of researching at the project level in the DLT space which requires a mix of industry understanding and science - however the data still can provide significant insights into where development is happening and what the most advanced projects are.

3.3. Applications Areas & Industry Sectors Analysis

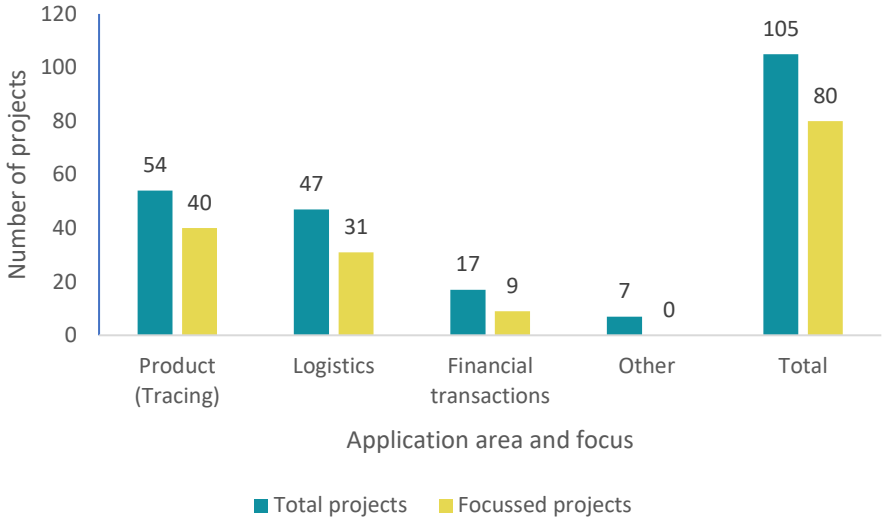
The research undertaken has been broken down by usage/application areas and industry sector. In the following sections we discuss some higher-level insights gained from the research before examining in more detail each of the usage areas.

Usage / Application Areas

Product tracing is the largest area in which projects are operating, followed closely by the logistics application area. With less than half as many projects as the other two areas, financial transactions is the third largest area. Both retail operations and circular economy projects come under other as there are too few projects for analysis. Figure 12 shows the number of projects by application areas and focus.

Most projects are focussed on product tracing and logistics

Figure 12: Projects by application area and focus (number of projects).

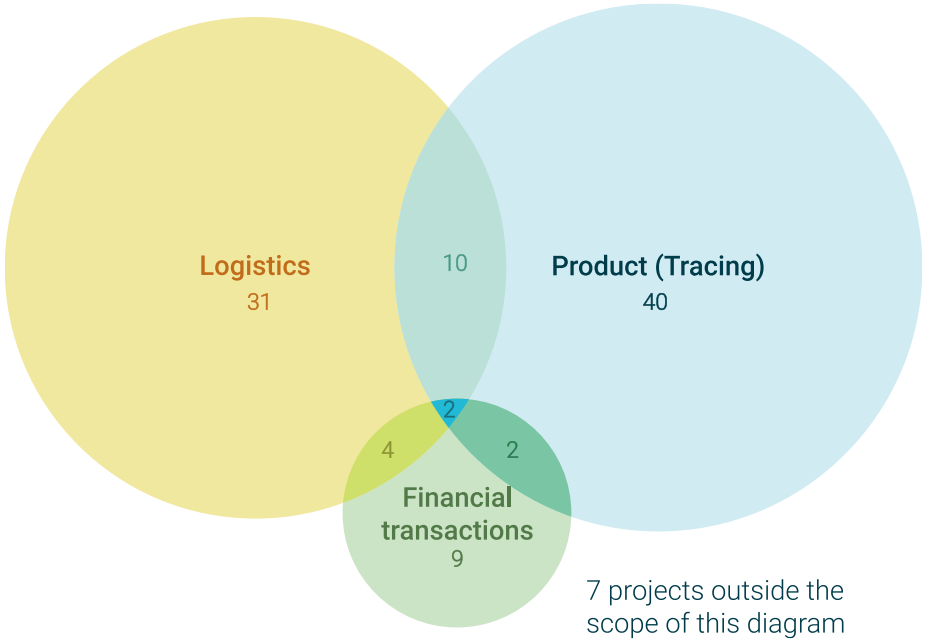


When looking at whether projects are focussed in one or multiple areas, the ranking of focussed projects is also in line with the ranking of the total number of projects. Respectively 74%, 66% and 53% of projects are focused in only one application area with respect to tracing, logistics and financial transactions. Half of all projects in the financial transactions area are also operating in other application areas.

Product tracing and logistics have the largest crossover

A more detailed breakdown of project application crossover can be seen in Figure 13. The largest crossover is between the product and logistics areas. This is to be expected as these are the largest application areas. Only two projects are present in all three of the main application areas.

Figure 13: Projects by application crossover (number of projects).

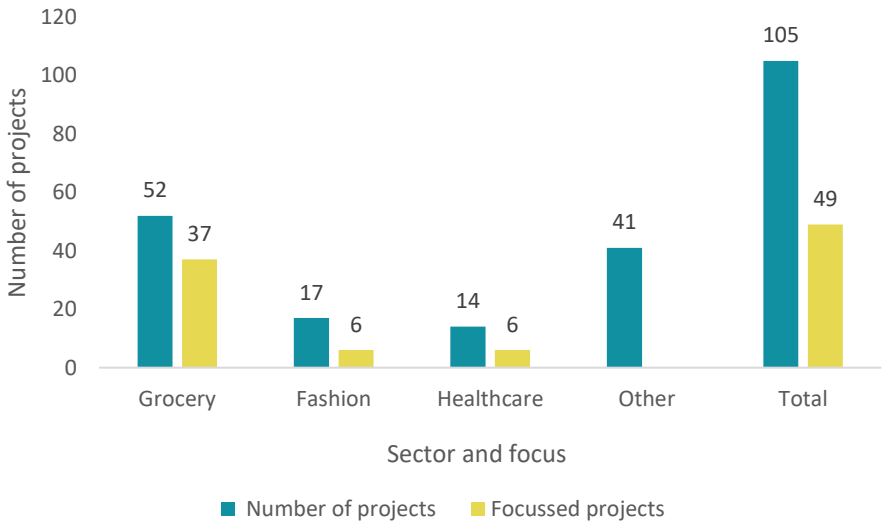


Sector Analysis

The Grocery sector shows the greatest activity amongst projects. Nearly half of all projects analysed are operating within this sector. Fashion and Healthcare are similar in magnitude with approximately 15% of the projects in these sectors respectively. The breakdown of projects in different sectors is shown in Figure 14.

The Grocery sector has the greatest activity amongst projects

Figure 14: Projects by sector and focus (number of projects).



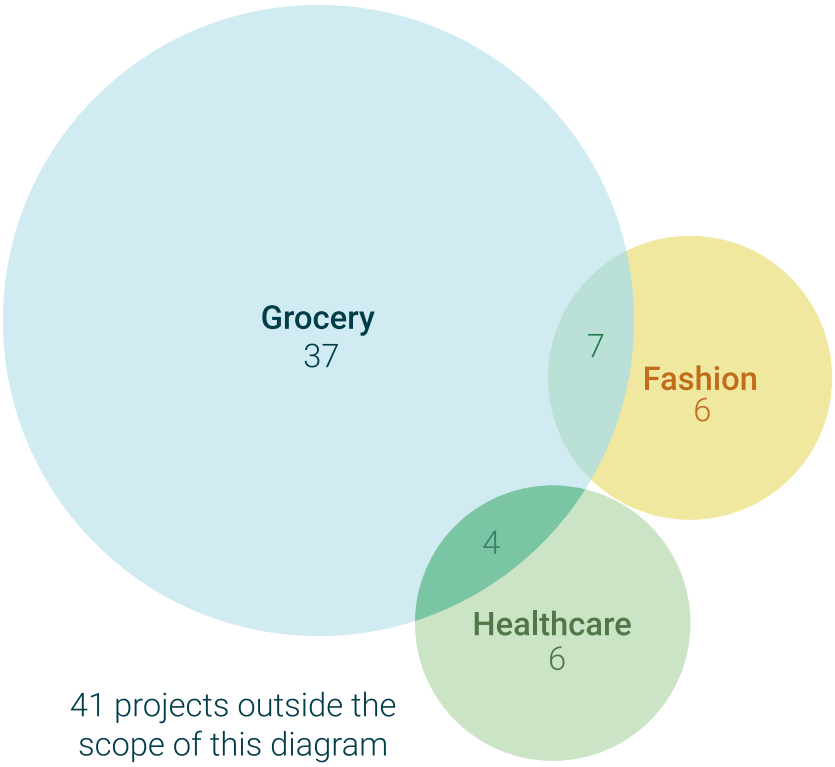
Regarding the crossover of projects amongst different sectors, many of the projects are sector focussed with 71%, 35% and 43% concentrating only in their operating sectors in the Grocery, Fashion and Healthcare arenas respectively.

Sector crossover differs to that seen in application area crossover

In contrast to analysis of projects by application area, with regards to sectoral analysis, approximately 39% of projects fall under other sectors. This reflects many non-sector specific projects which either relate to functional specialisations (e.g. in logistics and supply chain) or industry agnostic projects which are focused on a use case which could apply across multiple industries.

Figure 15 shows the overlap of projects by their operating sectors. Unlike the overlap that was observed within the application areas, with regards to the sectors, no single project spans across all the sectors. Grocery projects overlap with both the Healthcare and the Fashion sectors, but no Fashion projects overlap with Healthcare and vice versa. The overlap between Grocery and the other sectors may be partially explained by the progress in the Grocery sector and number of projects involved, predominantly in the application area of tracing that is the leading usage in each sector.

Figure 15: Projects by sector crossover (number of projects).

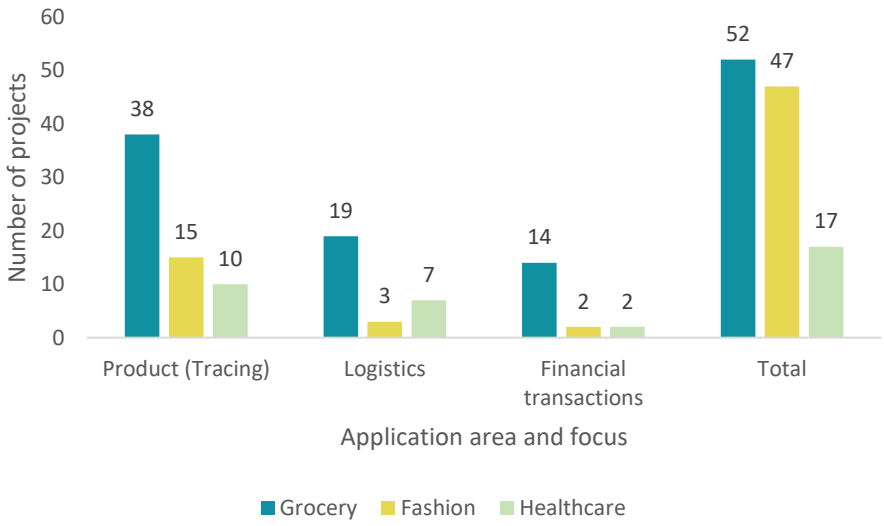


Usage/Application Area and Industry Area Analysis

Combining analysis for both application area and sectors, Grocery sector projects are concentrated in tracing (38 projects), logistics (19 projects) and financial transactions (14 projects). Within Healthcare, tracing (10 projects) and logistics (7 projects) are again the most significant. Fashion has several projects in the tracing space (15 projects, primarily relating to anti-counterfeit) with two to three projects relating to each of the other four use cases. In all three examples we see very limited activity in the retail operations and circular economy areas and thus for analysis purposes these are excluded.[28] Figure 16 shows projects by application area and sector.

Product tracing is the leading application area in each of the sectors

Figure 16: Projects by application area and sector (number of projects).



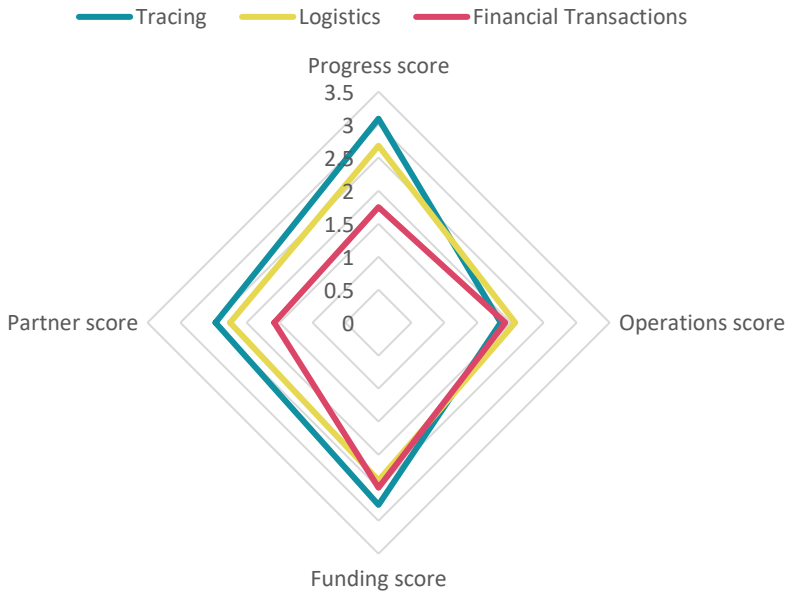
Note that this is a snapshot of the development activity to date. It is dynamic and might evolve – for example, once a use case is proven in its primary target sector (e.g. using blockchain for returns / refund management within retail operations for the grocery sector), then it may well be expanded to secondary target sectors (e.g. to manage returns of medicines within healthcare, or vice versa). Also note that the sum of the projects does not necessarily equal the total: some projects might be relevant to all industries; some might be relevant only to the total.

The scoring of start-up projects is used to evaluate their relative progress and scale within the largest application areas (tracing, logistics and financial transactions).

[28] For the Retail Operations and Circular Economy area, there are less than five projects for each of these areas. These are relatively new and emerging areas for the exploration of DLT and are expected to see further activity soon.

The average scores of the start-ups on each of the scoring areas is shown in the spider chart in Figure 17 for each of the application areas. Examining the operations score first, in each of the application areas the scores are similar. On an operations level (scored on the number of employees at a start-up) most projects are utilising a similar number of employees on average, but with logistics having slightly more than those involved in financial transactions and tracing.

Figure 17: Project average scores by application areas.



Looking next at the funding scores, these again are similar across many of the projects indicating that on average the amount of funding raised in each of the application areas is quite similar. Nevertheless, tracing projects on average have the most funding, followed by financial transactions and logistics.

Scores skew on the partner and progress domains for tracing and logistics projects

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Where differences begin to emerge between projects is in the different application areas on the funding and progress scores. Examining each of these scores, the tracing and logistics applications show that on average projects have significantly higher scores than for the financial applications area. Looking at the partners score, the quality of partners engaged in projects are on average better in the tracing area, followed closely by the logistics area and then financial transactions. Finally, examining the progress score, the greatest level of progress for projects is seen in the tracing area, followed by logistics and financial transactions.

Tracing projects dominate in terms of the amount of progress and the quality of partners involved

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In summary, based on our scoring we see that although funding and operations on average amongst start-up projects are similar across all application areas, there is a divergence in

progress and partners. Here tracing and logistics projects see a greater level of development than that in the financial transactions area. The analysis that is presented in this section is expanded on within each of the pertinent application areas in the following parts of this report.

4. USAGE AREA: PRODUCT (TRACING)

4.1. Business Challenges and Blockchain Solutions

Supply chains today are increasingly complex and agile. This brings many advantages in terms of efficient sourcing of goods. However, it also presents significant challenges to businesses who increasingly require full traceability of product origins. Whereas in the past product provenance may have been relevant only at the "back end" (e.g. for supply managers), today it is often demanded by external stakeholders (e.g. customers who want to know where the product comes from or regulators who need to vet product origins).

Whilst supply chains have seamlessly integrated across multiple geographies for physical goods, the information associated with products hasn't

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The problem is whilst supply chains have seamlessly integrated across multiple jurisdictions and geographies for physical goods, the information associated with the product has not yet caught up. With goods often passing through dozens of intermediaries from the point of production to the point of sale, product data is captured on multiple systems in different formats. The information is effectively siloed and piecing the full product journey together is at best difficult and at worst impossible.

By storing product provenance events on a distributed ledger, counterfeit goods can effectively be identified at any point in the supply chain, which is particularly relevant for the fashion industry

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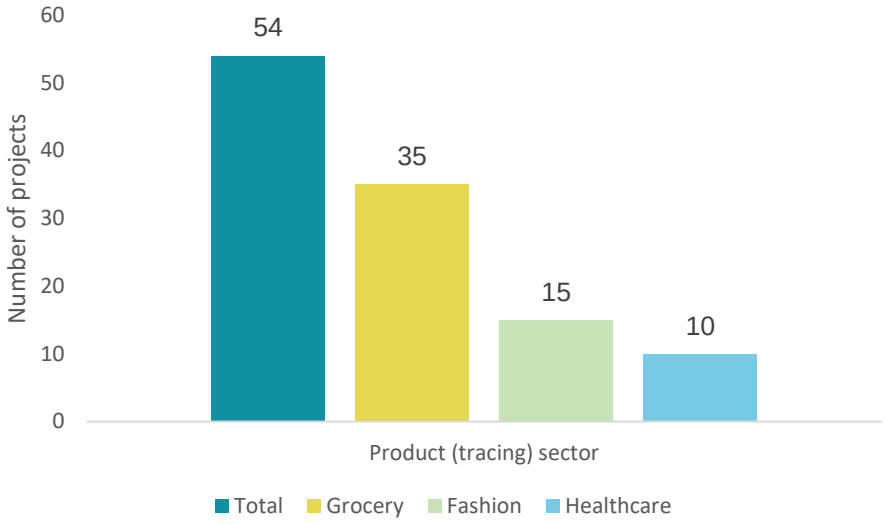
In the absence of effective data to prove product origins, counterfeit goods can proliferate and destroy value for companies and brands. By storing product provenance events on a distributed ledger, counterfeit goods can effectively be identified at any point in the supply chain. Today, value leakage from counterfeit, grey or stolen products is significant and is particularly relevant for the fashion industry.

Finally, in recent years supply chain management has benefitted from the rollout of digital "track and trace". This benefits not only businesses along the supply chain who can plan more effectively and optimise working capital but also consumers who have better visibility of where their product is and by when they can expect order fulfilment. However, in today's world with centralised and often siloed information systems this "track and trace" functionality is not always easy to implement or maintain. In a distributed information system such as blockchain, this becomes much easier to manage as it is part and parcel of how the data is put together. With appropriate permissions in place, real time visibility becomes a systemic feature. This systemic transparency can enable not only live track and trace but also opens the door to more efficient ways of working (e.g. deliveries could be managed directly by the transport provider rather than through a company's transport scheduling department, receivables financing could be arranged through smart contracts directly with the bank rather than through the internal treasury function). The potential for such new ways of working are considered later in this report.

4.2. Research Highlights

This category is the largest single usage area, with a total of 54 out of the 105 projects surveyed. The majority of these (34 projects) are start-ups. Figure 18 shows the distribution of projects based on their sectors.

Figure 18: Tracing projects by sector (number of projects)



The top-rated start-ups which are relevant to this use case are as seen in Table 4.

Table 4: Selected tracing projects by the sectors they operate in.

Project	Grocery	Fashion	Healthcare
Ambrosus	✓		✓
Artory			
Chronicled (part of Mediledger)	✓	✓	✓
Devery	✓		
Everledger	✓	✓	
Farmatrust			✓
GrainChain	✓		
Modum	✓		✓
OriginTrail	✓	✓	✓
Owlting	✓		
Provenance	✓	✓	
Statumn			
Techrock / TaelPay (formerly Walimai / WaBI)	✓	✓	✓
TE-Food	✓		

Everledger[29] is a leading project in this space but with an initial focus on the diamond industry and therefore is not considered in our sector analysis. However, for many of the start-ups in the space the technology which they are deploying is likely to be transferable from the initial focus industry to wider applications. For instance, as Everledger is gaining traction in the diamond industry it is looking at other functionally linked sectors (e.g. for grocery (wine provenance) or fashion (leather provenance)).

4.3. Project Features

Grocery

Today, food provenance is an increasingly hot topic for the industry and distributed ledgers can enable the industry to overcome the existing data siloes which make end to end product provenance so hard. Both start-ups and corporate projects are working to develop DLT-based solutions, and substantial progress has already been made.

Corporate projects have gained significant traction within the grocery space, particularly IBM's Food Trust[30] initiative which counts Walmart, Carrefour[31], Albertsons[32], Unilever[33] and Nestle[34] among its members.[35] Walmart notably announced in September 2018 that it would require all of its leafy greens suppliers in specific regions of the USA to adopt the platform by January 2020.

The buying power of the members of the Food Trust platform is unquestionable and is such that they may be able to oblige their suppliers to "comply or die". However, any blockchain solution needs to work for all participants in the retail value chain and that requires flexibility in product development and a marketing effort to help all stakeholders buy into the benefits of adoption.

Proof of provenance can add value to brands in markets where consumers want to know the full product journey

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Producers are also investing in blockchain projects, recognising that improved proof of provenance can add value to their brand in markets which increasingly value authenticity with consumers who want to know the full product journey. For example, Italian olive oil producer Certified Origins[36] has leveraged blockchain to further distinguish its product in the marketplace. As of today, bottles of the company's olive oil are fully traceable to the specific point of origin via a customer app which obtains the product journey information from the blockchain ledger on Oracle's cloud[37].[38]

Also consider the example of the Dutch market-leading supermarket chain Albert Heijn[39] which has implemented a blockchain traceability pilot for its orange juice sales, in partnership with its supplier (commodity major Louis Dreyfus[40]). Customers buying orange juice can scan

[29] Everledger - https://www.everledger.io/
[30] IBM Food Trust - https://www.ibm.com/uk-en/blockchain/solutions/food-trust
[31] Carrefour - http://www.carrefour.com/
[32] Albertsons - https://www.albertsons.com/
[33] Unilever - https://www.unilever.co.uk/
[34] Nestle - https://www.nestle.co.uk/
[35] Allinson, I. (2019) World's Second-Largest Grocer Joins IBM Food Trust Blockchain. *Coindesk.* Available at: https://www.coindesk.com/worlds-second-largest-grocer-joins-ibm-food-trust-blockchain [Accessed July 2019].
[36] Certified Origins - https://www.certifiedorigins.com/
[37] Oracle - https://www.oracle.com/index.html
[38] Oracle (2019) *Certified Origins Italia Enhances Supply Chain Traceability and Trust with Oracle Blockchain.* Available at: https://www.oracle.com/it/customers/certified-origins-1-blockchain-story.html [Accessed July 2019].
[39] Albert Heijn - https://www.ah.nl/
[40] Louis Dreyfus - https://www.ldc.com/global/en/

a Quick Response (QR) code to not only find out where the orange juice came from but also to do a "Like2Farmer", where they can send a message directly to the fruit pickers at the source.[41]

DLT can improve consumer trust in relation to labels such as "organic", "local" or "responsibly sourced"

Start-ups are also making strides in the space. For example, TE-Food[42] partnered with French supermarket giant Auchan[43] to test its blockchain-based solution in Vietnam since 2016.[44] Auchan subsequently announced its intention to roll out the project across France, Spain, Italy, Portugal and Senegal in late 2018. OriginTrail[45] is another start-up working in the provenance space and in January 2019 announced a partnership with UK standards company BSI[46]. BSI has recognised the potential of DLT to improve consumer trust, particularly in relation to health and ethics labels such as "organic", "local" or "responsibly sourced".[47]

Healthcare

Within healthcare, from a provenance requirements perspective there is significant crossover with the grocery sector, and the ability to trace where medications come from on demand is an increasing area of focus for industry regulators. Indeed, regulation is a major driver for adoption of provenance-related uses, with legislation such as the U.S. DSCSA coming into force incrementally through to 2023. The Act essentially requires firms to be able to track and trace drugs throughout the supply chain electronically, from the raw materials to the manufacturing stage, and through the supply chain to the consumer. Enterprise blockchain solutions are among the fastest and most transparent ways to do that.

One example of a blockchain start-up seeking to solve these issues is Chronicled[48], which is working with industry players including Pfizer, Genentech[49] and Gilead[50] to develop its Mediledger product. Mediledger (which is due to launch commercially later in 2019) validates each transaction in the supply chain onto the blockchain, with the provenance of each item verified at every step. In addition, it enables automated business actions based on Internet of Things (IoT) monitored conditions.

Whilst Chronicled is a healthcare-industry led project, another cross-industry group is currently working on a Food and Drug Administration (FDA)[51] DSCSA pilot programme designed to bring together supply chain technology experts from six selected leaders in their field. The pilot team comprises Systech International (supply chain security consultancy)[52], T-Systems (global IT and telecoms player)[53], FarmaTrust (specialist blockchain solutions provider for

[41] Louis Dreyfus (2018) *LDC and partners use blockchain to achieve full traceability.* Available at: https://www.ldc.com/global/en/our-stories/in-field/juice-you-trust/ [Accessed July 2019].
[42] Te-Food - https://tefoodint.com/
[43] Auchan - https://www.auchan.fr/
[44] Te-Food (2018) European Retail Giant Auchan Implements Blockchain Based Food Traceability on International Scale. *Medium*. Available at: https://medium.com/te-food/european-retail-giant-auchan-implements-blockchain-based-food-traceability-on-international-scale-5bd958b68192 [Accessed July 2019].
[45] OriginTrail - https://origintrail.io/
[46] BSI - https://www.bsigroup.com/
[47] BSI (2019) BSI partners with OriginTrail to develop blockchain-enabled solutions. *Press Release.* Available at: https://www.bsigroup.com/en-GB/about-bsi/media-centre/press-releases/2019/january/bsi-partners-with-origintrail-to-develop-blockchain-enabled-solutions/ [Accessed July 2019].
[48] Chronicled - https://www.chronicled.com/
[49] Genetech - https://www.gene.com/
[50] Gilead - https://www.gilead.com/
[51] FDA - https://www.fda.gov/home
[52] Systech International - https://www.systech-int.com/
[53] T-Systems - https://www.t-systems.com/gb/en

healthcare supply chain)[54], RXTransparent (pharmaceuticals supply chain experts)[55], Cryptowerk (blockchain as a service provider)[56] and CalQLogic (real time analytics and automation technology provider)[57].

Under the scope of the pilot, this diverse team will collaborate for six months (running from Q2 to Q4 2019) to develop a fully interoperable solution that can be used to identify, track and trace prescription pharmaceuticals throughout the U.S. supply chain. The pilot follows collaboration between the parties over several years to address the DSCSA requirements.

The collective approach is designed to meet and excel regulatory requirements with a solution that includes:

- Utilizing a digital e-Fingerprint® layer of security to create an immutable track and trace ledger that improves visibility and enhances counterfeiting detection at the product level.
- Capturing IoT and Cold Chain information to leverage data for additional consumer insight and analytics.
- Deploying blockchain as the infrastructure to enable interoperability providing a reliable foundation for trust in data that has been elusive with other technologies.[58]

In addition, Farmatrust has also worked with Systech on a separate track and trace project. Following requests from Systech's pharmaceutical clients, the collaborative project integrated Systech's previously cloud-based serialisation, traceability and authentication product (Systech360) onto Farmatrust's blockchain core, with a smartphone app interface for end users.[59]

Fashion

The push towards "fast-fashion" has been relentless over the past few years, and the growth of online fashion outlets only served to increase demand for dynamic supply chains which can adapt to consumer demand in the shortest possible timeframes and at the lowest cost. However, consumers today care about the provenance of their clothes and retailers who can effectively provide consumers with the story of where their garments come from are likely to be at a competitive advantage.

Retailers who can provide consumers with the story of where their garments come from are at a competitive advantage

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Provenance[60] is one example of a start-up in this space which, although initially focused around food, is also targeting adoption in the fashion industry with a provenance software service for apparel retailers. Fashion designer Martine Jarlgaard was among the first to adopt the product last year though it is yet to be deployed at mass market scale.[61]

[54] FarmaTrust - https://www.farmatrust.com/
[55] RXTransparent - https://www.rxtransparent.com
[56] Cryptowerk - https://cryptowerk.com/
[57] CalQLogic - https://www.calqlogic.com/
[58] T-Systems (2019) *T-SYSTEMS NORTH AMERICA IS SELECTED FOR FDA DSCSA PILOT PROGRAM*. Available at: https://www.t-systems.com/us/en/newsroom/press-releases/detail/t-systems-north-america-is-selected-for-fda-dscsa-pilot-program-889850 [Accessed July 2019].
[59] Enterprise Times (2018) *Systech and FarmaTrust partner for pharma supply chain authenticity.* Available at: https://www.enterprisetimes.co.uk/2018/09/12/systech-and-farmatrust-partner-for-pharma-supply-chain-authenticity/ [Accessed July 2019].
[60] Provenance - https://www.provenance.org/
[61] Provenance (2018) *Increasing transparency in fashion with blockchain.* Available at: https://www.provenance.org/case-studies/martine-jarlgaard [Accessed July 2019].

4.4. Adoption Challenges

Tagging

One major challenge for adoption at scale is around tamper proof tagging. The challenge is twofold. First, if a tag is the key to unlock the full tracing of any given product, that tag needs to be completely secure in order to prevent cloned tags or removed tags from masquerading as the authentic product. In other words, whilst the blockchain ledger can create an entirely secure set of data, the "on ramp" from the physical product to the product information is a potential weak link which has the potential to undermine the trust in the entire blockchain solution. Projects to date have used a range of tags from simple QR codes to Radio-Frequency Identifications (RFID) to leveraging Near-Field Communications (NFC) technology, but as yet there is no perfect solution.

Second, in most supply chains the product unit will evolve from the point of origin to the point of consumption. The greater the changes are, the more this can present a tagging challenge. Let's consider four examples, from the most straightforward to the most difficult from a tagging perspective shown in Table 5.

Table 5: Tagging scenarios

Scenario	Example	Example case	Tagging approach	Tagging difficulty
Single Product	Diamonds	Once processed and cut, there is no change in the product unit from factory to consumer (traceable to a single diamond)	Tag at the diamond level	Lowest – need to tag diamond directly
Single Source Product	Tuna steaks	Cut from a single tuna fish, with limited processing (traceable to single fish)	Tag at the source level (i.e. the tuna fish), linking all packed steaks to the same source fish	Low – need to tag fish at point of catch and link cuts to the fish (e.g. through RFID tagged packs)
Single point of origin	Single malt whisky (e.g. Macallan 10 years old)	Whisky is produced from multiple casks but a single distillery	Tag at the cask level and link all bottled whisky back to the source casks	Medium – requires linking bottles to multiple casks
Proof of non-contamination	Beef burgers	Prove that burgers are 100% beef origins through certified tracing	Tag all source materials in the entire supply chain	Most difficult – tagging all input materials (not practicable)

Driving Adoption at an Impactful Scale Across the Supply Chain

Whilst there have been many 'proof of concepts' done over the past few years to demonstrate the technological possibilities of using blockchain to trace products, deployments at an impactful commercial scale have been much harder to come by. For the more complex supply

chains which can have dozens of participants along the journey from production to consumption, it takes time, education and investment to arrive at a point where the technology is making a meaningful difference to operations.

This isn't just an education issue (though that is undoubtedly an important part of the equation). It is also a technical one as blockchain requires some integration of systems across all participants so that they can "speak the same language" when referring to any given unit of product – from a shipping container right down to a single Stock Keeping Unit (SKU). Connecting new distributed systems to parallel company Enterprise Resource Planning (ERP) systems is not a straightforward task and will take time to get right.

Furthermore, there is also a more general challenge around the interoperability of blockchain systems themselves. In many industries, there are today competing solutions vying for critical mass. We are not yet at a stage where any single blockchain protocol reaches acceptance as the single way of working. Development of decentralised blockchain solutions has (ironically) been rather siloed to date. This is where consortia can play an important role to bring industries together and look at driving adoption through industry level decision making, achieved through discussion, workshops and consensus.

4.5. Outlook

Tracing of products is among the best developed use cases for blockchain technology, and we expect activity in this domain to progress significantly through 2019-2020 with deployments at scale. In the grocery sector, provenance applications of blockchain bring benefits to a whole range of stakeholders. Buyers can manage procurement more effectively, food safety can be tightened through better visibility on sourcing, brands can benefit from telling their "sourcing story" and customers enjoy better access to the reality of where their food comes from. For healthcare, regulation will continue to be an important catalyst for adoption as the industry looks to blockchain to help solve some of the challenges posed by new rules. Within fashion, as responsible sourcing becomes increasingly important (particularly for younger consumers) there are opportunities for brands and retailers to distinguish themselves by sharing the provenance story of the clothes they sell.

The macro forces driving adoption forward are clear, but the devil will be in the detail and there is some painstaking work to be done before we can arrive at decentralised industry level blockchain solutions which put the product first and enable new levels of traceability. There has been a natural tendency up to now among start-ups and corporate projects to focus on getting their specific solution right and promoting uptake. That is normal and will continue.

From an industry perspective there is a need for collaboration and agreement on what is needed from the technology and how to prioritise

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However, from an industry perspective there is a need for collaboration and agreement on what the industry wants from the technology, and how to prioritise. Industries can also benefit from understanding what is possible from other industries, and how they compare. For example, it may be that the most viable blockchain product tracing solution is developed within one industry (e.g. mining) and becomes the tracing use case solution of choice across all industries.

Regulatory involvement and support will also be an important driver for adoption of traceability use cases at a commercial scale. In April 2019, the FDA announced that it will hold a public

engagement later in 2019 to discuss blockchain's future role in food safety and how it as an industry regulator can help to promote standards and interoperability, including consensus mechanisms.

5. USAGE AREA: LOGISTICS

5.1. Business Challenges and Blockchain Solutions

Logistics is of course a very broad category and a business can face any number of logistical challenges to effectively manage the physical supply chain of their products.

For groceries, logistics is a major part of the product cost and with high volumes and thin operating margins even small savings in distribution or storage costs can provide significant uplift to the bottom line. For healthcare, effective logistics is further complicated by supply chains which include drug manufacturing within limited production capacities. This means that pharmaceutical companies often face real challenges to manage supply and demand and avoid stock-outs of drugs which their patients rely on.

Supply chains need to be digital and dynamic, reducing buffers without compromising performance. Blockchain, IoT and Artificial Intelligence are making this a reality.

At a broad level, blockchain looks an excellent fit to help solve logistical challenges since it provides an auditable digital trail which records the product journey and can be shared across supply chain participants as needed. Whilst supply chains are linear with often paper-based processes documenting as a product batch or shipment moves down the chain, today's supply chains are increasingly digital and dynamic, enabling companies to optimise by reducing "buffer" without compromising performance. Digital technology, including blockchain (often in conjunction with other emerging technology such as IoT and Artificial Intelligence (AI)) helps to make this dynamic dream a reality in what Deloitte[62] has called "Digital Supply Networks": supply chain as a network which is "always on", and capable of adapting to different supply and demand scenarios.[63] Whilst in a traditional linear supply chain an issue at one point in the chain (e.g. a compliance breach or contamination) creates knock-on issues further down, Digital Supply Networks can react in real time and make optimal supply decisions within defined parameters. Later in this section, we drill further into specific examples of how this works in practice and how blockchain can underpin the Digital Supply Network.

IoT integration offers the potential for "trustless data"; especially important for cold chain management

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Managing dynamic supply chains becomes even more challenging when it concerns environmental parameters. For example, cold chain goods such as fresh or frozen foods or temperature sensitive medical goods are highly susceptible to damage. Currently detection of any exceptions to temperature requirements typically relies on a trusted partner checking that parameters are respected. This approach doesn't always work, particularly in more remote locations where infrastructure may be lacking. Used in conjunction, IoT technology sensors can monitor parameters throughout a product journey and any deviation from required conditions is recorded on the ledger for all participants to see. This IoT integration offers the potential for "trustless data", generated in a fully automated way from the sensors and devices handling the product. This is an important area of development in the blockchain world today,

[62] Deloitte - https://www2.deloitte.com
[63] Deloitte (2017) *When Two Chains Collide: Supply Chain Meets Blockchain.* Available at: https://www2.deloitte.com/content/dam/Deloitte/pt/Documents/blockchainsupplychain/IE_C_TL_Supplychain_meets_blockchain_.pdf [Accessed July 2019].

with several start-ups seeking to bring together blockchain and IoT to bring cold chain management to a new level of compliance. With the two technologies combined, smart contracts can be used to "auto-enforce" conditions and ensure that any breaches are automatically weeded out when required (and only in cases of actual breach, removing unnecessary losses).

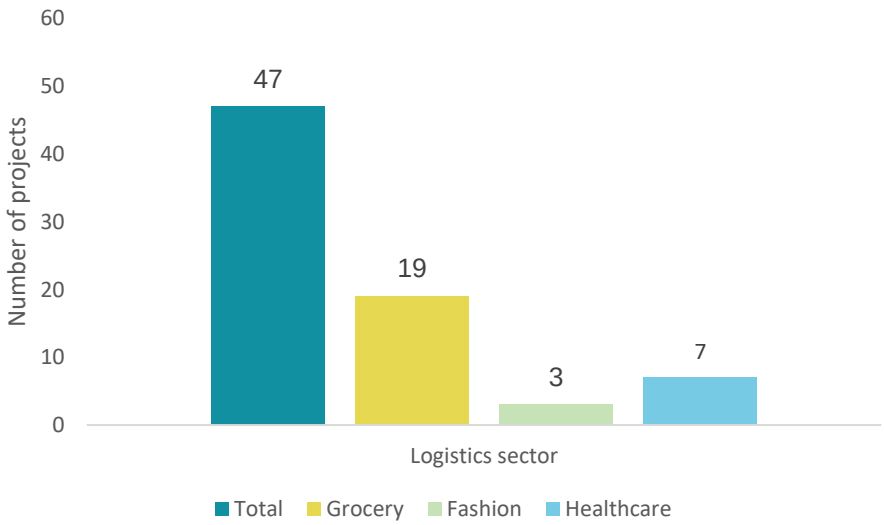
"Digital paper" and blockchain-based solutions can provide enhanced security and simultaneously enable faster processing of shipments

Outside of the supply chain management function, blockchain technology is gaining traction as a form of "digital paper" which can replace hitherto paper-based regulatory and governmental certification and clearance processes. For example, port authorities traditionally requiring physical paper copies of shipping documents such as a bill of lading are deploying blockchain-based solutions which can provide enhanced security and simultaneously enable much faster processing of shipments. This would seem a relatively "quick win" for blockchain deployments as the value of expediting shipments is clear and the number of participants in port customs clearance processes are typically relatively limited (e.g. by involving the largest shipping companies, a port authority could quickly achieve a critical mass to quantify the impact of their blockchain deployment).

5.2. Research Highlights

This is the second largest usage area within the data gathered, with a total of 47 of the 105 projects including functionality which is relevant to logistics. However, it should be noted that there is substantial crossover with the tracing use case – 12 of the projects surveyed offer both product tracing functionality and facilitate with logistics and supply chain management. Figure 19 shows the distribution of projects by their respective sectors.

Figure 19: Logistics projects by sector (number of projects).



The top-rated start-ups which are relevant to this use case are shown in Table 6.

Table 6: Selected logistics projects by sector.

Projects	Grocery	Fashion	Healthcare
Ambrosus	✓		✓
Agridigital blockchain project	✓		
BanQu	✓		
CargoX			
dexFreight			
GrainChain	✓		
Modum	✓		✓
OpenPort			
OriginTrail	✓	✓	✓
Ripe	✓		
Shipchain			
Slync			
T-Mining			
TradeLens			
VeChain Thor			
WaltonChain	✓	✓	

Note that many of the projects don't relate to a specific industry application but rather are generic to supply chain applications across industries.

5.3. Project Features

Grocery

Within grocery, a good deal of the projects discussed earlier in the provenance and tracing chapter are also relevant to logistics and supply chain enhancements. For example, OriginTrail's platform provides increased transparency on provenance and product tracing but it also extends further to provide supply chain participants with better visibility on product movements. However, some projects are specifically dedicated to improving supply chain management within the food industry.

For example, Silicon Valley start-up ripe.io[64] is working on establishing a blockchain-based food quality network, where food quality will be assured by an associated digital data bundle. Exact use cases are still in development, however if accompanied by IoT sensor integration (which we will discuss at greater length in the healthcare section) this could provide proof to stakeholders that the food has complied with necessary standards (e.g. temperature, time in transit, etc).

Ripe.io are partnering with another foodtech start-up outside of the blockchain space called FoodWiki, which uses digital taste profiling to replace traditional sensory panels. Through this

[64] Ripe.io - https://www.ripe.io/

partnership, their intention is to develop a product which enables tracking of how food tastes through the supply chain, such that products can reach their most flavour at the point of sale.[65]

Healthcare

The development of logistics management solutions for environmentally controlled supply chains (e.g. for temperature or humidity) has primarily focused on the healthcare industry although clearly there is significant overlap with the requirements from the grocery industry. Two Swiss start-ups are particularly prominent in the space: Modum[66] and Ambrosus[67]. Let's consider how they work.

First, one or multiple environmental sensors (e.g. temperature and humidity meters) and / or measuring devices (e.g. weighing scales) record the condition of the product. This data is then encrypted, signed and written both to a tagging device such as an RFID and to the blockchain ledger. This effectively creates a distributed duplicate of the defined product conditions, which is maintained as needed. Subsequent data could be recorded at defined time intervals (e.g. every hour) or at specific events (e.g. on receipt into a warehouse, or upon loading into a delivery vehicle). The distributed copies of the data are available to all participants based on defined permissions – for example, warehouse staff might be able to check a full product history, but a customer might only see a summary view of key milestones in the product journey.

Modum have tested their technology in partnership with Swiss Post for transportation of temperature-controlled pharmaceutical products. A pilot was completed in Q1 2019 with Swiss Post[68] using temperature-controlled boxes specifically designed for transporting temperature sensitive products, with sensors monitoring the temperature inside the box using Modum's IoT solution, called MODSense.[69] Chronicled's Mediledger project (referred to in the tracing use case section) also includes a portable smart sensor that can store temperature readings on a blockchain with a "CryptoSeal" which can be scanned and verified against the blockchain registry at each stop in the supply chain.[70]

Whilst it is still in development, this IoT integration with blockchain might also be helpful in guarding against counterfeit or substandard products, and biopharmaceutical manufacturers could use it to capture and record interactions with regulators.

Port and Customs Clearance Processes

This use case is generic to all industries importing and exporting goods. Despite the digitisation of many supply chain processes, customs clearance and shipping documentation continues to rely heavily on physical paper documents. This is because the existing centralised digital architecture cannot satisfactorily overcome the trust barrier. This makes for an ideal use case for blockchain technology whereby the information and status relating to each shipment can be stored on a distributed ledger for all participants to view and process as per the defined permissions. In fact, the shipment can be stored in a fungible token, with the capacity for direct transfers of ownership – subject to approvals through the defined consensus mechanism.

[65] Forbes (2017) *The Blockchain of Food.* Available at: https://www.forbes.com/sites/themixingbowl/2017/10/23/the-blockchain-of-food/#1b6ba30775fd [Accessed July 2019].
[66] Modum - https://modum.io/
[67] Ambrosus - https://ambrosus.com/
[68] Swiss Post - https://www.post.ch/en
[69] SAP (2019) *SAP Helps Swiss Post and Modum Build Blockchain Solution for Temperature-Controlled Logistics.* Available at: https://news.sap.com/2019/03/swiss-post-modum-blockchain-solution-temperature-logistics/ [Accessed July 2019].
[70] Chronicled (2016) *How and Why We Invented the CryptoSeal.* Available at: https://blog.chronicled.com/how-and-why-we-invented-the-cryptoseal-6577d8633a2 [Accessed July 2019].

There are several pilots in this category which are underway. For example, the Abu Dhabi led Silsal project is running a cargo clearance pilot in partnership with the Port of Antwerp, replacing paper processes to process all shipment documentation on blockchain. [71] Furthermore, it should be noted that most of the world's largest distribution companies such as DHL[72], UPS[73] and Fedex[74] are actively working on integrating blockchain technology into their own shipment processes.[75]

5.4. Adoption Challenges

Logistics is among the most talked about use cases for blockchain technology, and with good reason. By putting assets at the heart, the technology opens a wealth of possibilities for seamless collaboration along supply chains. However, since supply chains typically involve many and varied participants it is also among the most complex use cases to implement. As with all blockchain deployments, benefits are only realised at scale once critical mass is obtained. Consequently, whilst a raft of proof of concepts have been completed over the past three years, rollout at scale is still a work in progress. This is challenging because it requires a collective approach with industry level engagement.

Interestingly UPS, DHL and Fedex in April 2019 called on the government to use regulation in order to align distribution companies around standard blockchain practices. This came out of the three companies' collaboration in a blockchain distribution consortium, Blockchain in Transport Alliance (BiTA) [76].[77] The technological solutions are there and have been proven to work. The challenge is aligning a wide group of stakeholders around implementation – which is particularly challenging in the case of complex logistics and dynamic supply chains.

There is a role for regulators to help to independently create common practices

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Whilst specialist logistics companies have quickly recognised the potential value of blockchain technology for their industry, for logistics professionals within grocery there is more work to be done to move their suppliers across to blockchain solutions. Again, there is a need for standardisation, particularly in the context of increasingly dynamic supply chains where suppliers are unlikely to want to lock themselves into a specific commercial relationship purely for technological reasons. Consequently, there is a role for regulators to help to independently align the industry around common practices – but in order to bring this about, collaborative forums will be needed.

With regards to environmental sensors and the IoT integration use cases, gaining critical mass is again challenging and it is unclear whether blockchain specific start-ups will succeed in building a presence at scale across pharmaceutical or perishable food supply chains. Furthermore, with heavy reliance on expensive sensory hardware and systems integration, the capital expenditure for start-ups in the space might be prohibitive without additional funding.

[71] Partz, H (2018) Abu Dhabi Ports Subsidiary Tests International Blockchain Pilot with Port of Antwerp. *Cointelegraph.* Availabe at: https://cointelegraph.com/news/abu-dhabi-ports-subsidiary-tests-international-blockchain-pilot-with-port-of-antwerp [Accessed July 2019].
[72] DHL - https://www.logistics.dhl
[73] UPS - https://www.ups.com/
[74] Fedex - https://www.fedex.com
[75] Tabak, N. (2019) FedEx, UPS, DHL executives see eye-to-eye on blockchain. *Freight Waves*. Available at: https://www.freightwaves.com/news/blockchain/fedex-dhl-ups-execs-blockchain-revolution [Accessed July 2019].
[76] Blockchain in Transport Alliance - https://www.bita.studio/
[77] Tabak, N. (2019) FedEx, UPS, DHL executives see eye-to-eye on blockchain. *Freight Waves*. Available at: https://www.freightwaves.com/news/blockchain/fedex-dhl-ups-execs-blockchain-revolution [Accessed July 2019].

5.5. Outlook

Logistics will be a major area of interest, particularly for the grocery and healthcare sectors. However, whilst the tracing use case is a first step, the full benefits from logistics deployments are likely to follow once tracing capabilities are in place. The potential is very significant, but the first step is the hardest – implementing blockchain systems which can track the assets from source to end use. Once this is in place there are a wealth of potential benefits.

For example, sustainability is a hot topic for supermarkets and their customers and blockchain is a potentially important enabler to improve performance in this regard. By providing real time visibility along the supply chain, product wastage can be significantly reduced through more efficient markets which can enable producers to anticipate market dynamics and respond to fluctuations such as supply gluts or demand surges. This could be used with other emerging technologies such as electronic shelf edge labelling, leveraging integrated supply chain data to optimise pricing based on supply and demand (likely in conjunction with AI).

Real world adoption of digital paper is well underway and we expect that this will accelerate over the coming years. This is a particularly compelling area of development as the incremental value is very clear – it is a step change from manual, paper clearance processes which are often little changed in the last century, to fully digitised distributed certificates. However, the epicentre of development in this specific use case is likely to sit with port and customs authorities as well as international shipping companies.

Having a certifiable history of a product's journey can also open up new potential business models

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In the case of environmental sensors integrated with blockchain, the business benefits of having a certifiable history of a product's journey are clear. Reducing product wastage is the first step, but it can also open new potential business models. For example, if a medical product's storage history is known and certifiable, it might be reused or resold whereas in existing setups it would be discarded since one company is not able to trust third party storage data. The blockchain start-ups in this space are likely to face competition from traditional sensor hardware incumbents and may struggle to achieve adoption at scale due to heavy capital expenditure requirements for the hardware element. However, this could be overcome either through partnerships with hardware manufacturers or additional funding.

6. USAGE AREA: FINANCIAL TRANSACTIONS

6.1. Business Challenges and Blockchain Solutions

The payments use case is certainly the most talked about in blockchain, especially following the cryptocurrency boom of 2017 (led by Bitcoin) which saw a wave of ICOs, through 2018. However, cryptocurrencies are only a small part of the story when considering blockchain implications for financial transactions. They are not a focus of this report, and cryptocurrencies are unlikely to be a significant area in the short to medium term in DLT supply chain solutions. Finance-specific blockchain applications are considered here where they relate purely to finance and accounting processes. Projects are leveraging blockchain in financial processes:

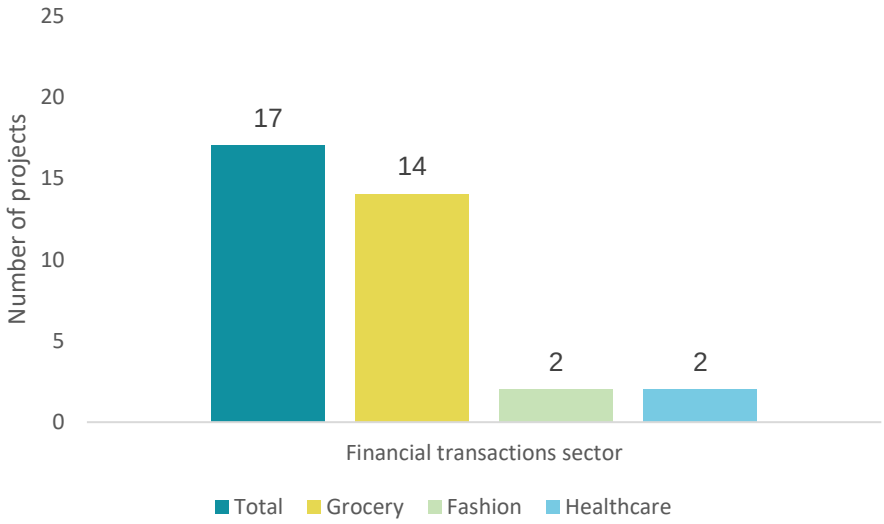
- to make payments through smart contracts.
- to sell directly to retailers or consumers.
- to use payment tokens to optimise working capital deployment.

For the supply chain to function smoothly, payments should follow the movement of goods according to agreed payment terms. However, the reality is often different with the potential for working capital constraints at one point in the chain leading to late or missed payments and supply disruption further down the chain. There is also reliance on third party credit facilities which adds further complexity and potential for disruption. Transactions via blockchain can help reduce complexity by replacing third party bank payments with direct supplier to retailer payments. Payments can also be executed using smart contracts – such that the conditions for payment are predetermined.

6.2. Research Highlights

The financial transactions use case is among the use cases with fewer projects within the data gathered, with a total of 17 of the 105 projects including relevant functionality. Grocery is the most strongly represented industry, with a number of projects relating to direct payments or sales of farmed produce. Figure 20 shows the distribution of projects in this particular use case by sector.

Figure 20: Financial transaction projects by sector (number of projects).



The top-rated projects which are relevant to this use case are shown in Table 7.

Table 7: Selected financial transactions projects by sector.

Projects	Grocery	Fashion	Healthcare
Agridigital blockchain project	✓		
Albert Heijn orange juice project*	✓		
Chainvine	✓		
Eximchain	✓	✓	
GrainChain	✓		
Remedichain			✓
Skuchain	✓		
Techrock / TaelPay (formerly Walimai / WaBI)	✓	✓	✓
TradeChain: Commonwealth Bank of Australia (CBA)*	✓		
Vinsent (formerly VinX)	✓		

*Indicates non-start-up projects

6.3. Project Features

From the research, it is found that the majority of projects in this space are relevant to the grocery industry. Texas-based start-up GrainChain[78] can be explored further to see how blockchain can help improve financial transactions for the sector.

GrainChain is specifically targeting the production end of the chain by offering farmers a blockchain-based platform through which they can buy and sell produce direct. By removing middlemen and connecting farmers with end consumers, GrainChain connects supply with demand. This in turn can help reduce inefficient buffers in the supply chain (e.g. the familiar “grain mountains”) and promote more sustainable farming practices.

GrainChain provides a blockchain based transaction platform including corn, sorghum, wheat, and soybeans – with more than 80,000 transactions already settled on the platform, initially in the USA but now expanding to Mexico. The platform includes integration with grain sensor equipment to automate inventory certification, invoice settlement and reporting to buyers and sellers. Contracts between buyers and sellers are negotiated through the portal which is then stored on the blockchain with an agreed payment held in escrow until delivery.

The platform also utilises tokens to carry out direct payments, with the sellers receiving a dollar-backed Grainpay stablecoin which enables instant settlement of the transaction. Once the contract is filled the tokens are converted into hard (fiat) currency and the corresponding token is burned, with GrainChain charging a commission on the transaction.

Similar platforms and products exist elsewhere – for example the innovative start-up Agridigital[79] is today helping farmers in Australia to leverage blockchain technology in order to simplify their supply chain and to facilitate the matching of payments to physical goods.

[78] GrainChain - https://www.grainchain.io/
[79] Agridigital - https://www.agridigital.io/

6.4. Adoption Challenges

One significant challenge for financial transaction use cases is the often-negative preconception of tokens. This is largely the result of a misunderstanding of how blockchain can help to facilitate payments processes through direct settlement which presents a clear advantage in some scenarios versus existing practices. Unfortunately, with the technology still at an early stage and the high level of visibility of Bitcoin and cryptocurrencies paired with the generally low understanding of blockchain, management and boards are often reluctant to examine how blockchain and potentially tokenised payment models could help simplify their supply chain financing and reduce hard currency working capital requirements. This is a hurdle that will be overcome over time and the onus is on the business to demonstrate the value of blockchain solutions for management and boards to support such projects.

Regulation and legal implications of innovating payment models using blockchain effect adoption in supply chains

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Another adoption challenge in the financial transactions space is around regulation and legal implications of innovating payment models using blockchain. With the technology still very new, regulators and legal experts are still exploring how blockchain needs to be treated from a legal and fiscal perspective which can present challenges for companies seeking to innovate in the space. For example, whilst GrainChain might seek to execute transactions using a stablecoin which is then immediately converted into hard currency, there could be a legal question over how to treat this transfer of value – is it a single transfer of value, with the token as a purely representative means of accounting for the transfer, or is it two transfers of value with a purchase, sale and another purchase event? Note: this is a purely figurative example, but the key point is that the legal context in which to frame crypto assets is far from defined, and there are significantly different approaches taken in different jurisdictions.[80]

6.5. Outlook

With blockchain, data becomes “asset centric” rather than “organisation centric” and each asset or product has a log of ownership history. This characteristic lends itself to new ways of treating financial transactions, removing the need for middlemen or third-party arbiters of trust and it is why blockchain is often referred to as “the internet of value”. The long-term transformation through blockchain applications in financial transactions for supply chain are likely to be among the most impactful.

DLT based solutions involving financial transactions are initially most developed in the commodities sector

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However, it bears repeating that the technology is at an early stage and transformation is likely to be step by step. Financial transactions follow physical assets, and once the physical assets are effectively tracked through blockchain, opportunities for streamlining financial transactions follow. Hence why in this use case we can see from the research that there is an initial focus on commodities, where asset tracking is less complex. For consumer-packaged goods, in our view the first step is solving traceability to then unlock opportunities for financial transaction innovation.

[80] For further information on crypto assets see: FCA (2019) *Cryptoassets: our work*. Available at: https://www.fca.org.uk/firms/cryptoassets

7. USAGE AREA: RETAIL OPERATIONS

7.1. Business Challenges Blockchain Solutions

Whilst the use cases considered so far are primarily concerned with the product journey up to the point of sale, this category explores how blockchain can help improve post sales processes in retail. It covers two main categories:

- product after sales (e.g. refunds, warranties and recommerce)
- customer information (e.g. loyalty and rewards, customer identification)

For product after sales processes, DLT can simplify cumbersome manual, paper-based processes which are currently prone to error or fraud

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In both categories, the potential advantage of blockchain is to create a single instance of each product or customer and to log their history (activity, transactions, etc) on a distributed ledger rather than on a centralised server or database. For product after sales processes, this can simplify cumbersome manual, paper-based processes which could currently be prone to error or fraud (e.g. product returns and refunds). For customers, loyalty and rewards programmes could become significantly easier to manage, becoming easier for users to spend. For retailers, it becomes easier to track and activate consumers, often at lower costs and with enhanced security.

7.2. Research Highlights

Retail operations is currently a much less active use case area with 4 of the 105 projects. The projects which are relevant to this use case are shown in Table 8.

Table 8: Retail operations projects by sector.

Projects	Grocery	Fashion	Healthcare
Chronicled (part of Mediledger)	✓	✓	✓
Monochain		✓	
Oracle Warranty & Usage Tracking			
Techrock / TaelPay (formerly Walimai / WaBI)	✓	✓	✓

It should be noted that the research only includes projects which are specifically linked to the physical supply chain in retail. There are several other start-ups that are purely focused on tokenising loyalty programmes which are not in the scope of the research.

7.3. Project Features

Techrock[81] is a Chinese start-up with a twofold value proposition: product authenticity and loyalty management. The company offers retailers a loyalty platform to incentivise consumers to purchase authentic products, and to track the lifecycle of the authenticated goods recorded on the platform via NFC tags. The initial focus was on infant formula, helping consumers to buy with confidence in the wake of the fake baby formula issues which affected the Chinese market. However, today the platform is offered to retailers in both the grocery and fashion

[81] Techrock - https://rock.tech/

industries, and in April 2019 it announced a partnership with Japanese e-commerce market leader Rakuten. The deal enables Chinese customers to purchase from Rakuten via Techrock.[82]

Techrock also offers its own certified products, which are available for sale in offline retail outlets as well as through the dedicated WeChat store. The company has a narrow range of products where authenticity is important. Additionally, Techrock customers participate in a blockchain loyalty token called Tael[83]. Users earn Tael by touching the Techrock label to verify authenticity, purchasing products and referring friends. Merchants can also purchase tokens to provide promotions through the platform, which is built on IBM's Hyperledger Fabric[84] – one of the most prominent permissioned blockchain protocols.

7.4. Adoption Challenges

Although some specific use cases such as loyalty and warranty management are attracting significant interest, blockchain solutions are yet to be adopted at scale for retail operations. Let's consider a few barriers to adoption as of today.

There is no requirement for consumers to know that they are using a blockchain solution, so long as the solution works seamlessly in the background

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Firstly, the technology is new, and consumers are not familiar with blockchain solutions which can partly explain why a lot of the activity in retail to date is at the pre-sales stages (from production to point of sale). However, this needn't be a major blocker for adoption – there is no requirement for consumers to know that they are using a blockchain solution, so long as the solution works, and there is a good user experience.

Legislation is another potential headwind, specifically with data regulations (notably GDPR) meaning that only limited information can be stored on a shared network. This has the potential to reduce the benefits of loyalty data – however blockchain can also be a significant help here by helping control how customer data is shared and with whom.

Finally, scalability is a potential hurdle, particularly when considering the largest grocery incentive programmes could handle thousands of transactions per second. For public protocols such as Bitcoin's, an average of around seven transactions processed per second clearly falls short of the requirements for mass scale loyalty programmes. However, this is also a surmountable challenge if the solution is built on a permissioned platform.

7.5. Outlook

Blockchain can add value to existing retail operations by moving paper based and manual processes onto blockchain. In a decentralised world, consumers could hold warranties in a wallet where their aftersales protection is immediately accessible via a secure token issued with the product. This would provide customers with increased transparency on after sales coverage and consequently greater confidence to purchase.

[82] Tael (2019) Rakuten Partners With Techrock to Bring Verifiable Authentic Japanese Products To China. *Medium.* Available at: https://medium.com/@Taelpay/rakuten-partners-with-techrock-to-bring-verifiable-authentic-japanese-products-to-china-57b3bfd9edfd [Accessed July 2019].
[83] Tael - https://taelpay.com/
[84] IBM Hyperledger Fabric - https://www.ibm.com/blockchain/hyperledger

In conjunction with IoT, the possibilities become more exciting, particularly for big ticket items or appliances. For example, it is possible that a sensor-enabled appliance (e.g. a washing machine) might be able to self-diagnose the fault and automatically execute the warranty service via a smart contract (e.g. pump fault -> covered under warranty -> execute warranty / order spare part / book engineer).

Beyond traditional warranty for initial purchase, DLT based solutions could lead to "product as a service" business models

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Beyond the traditional warranty on initial purchase, this model can evolve into "product as a service". Clearly this would require an integration of emerging technology across multiple partners and is likely to be some years away; but the first step of warranties on a blockchain is ready now. Adoption in retail has been relatively slow in this area, however companies can look to the insurance sector (which is already seeing significant uptake of blockchain to manage insurance policies) for best practices and templates for implementation.[85]

For loyalty and rewards programmes, real world deployments are already in place, albeit not at a major scale in retail. However, other industries have rolled out at scale – for example Singapore Airlines[86] launched KrisPay[87] in 2018 to enable customers to manage and redeem their points via a digital wallet, including at retail partners. There is additional potential value for retailers, particularly in fashion, to use loyalty to help address fake goods and the "grey" market and we expect to see significant progress in this area over the next twelve months.

[85] CBInsights (2019) *How Blockchain Could Disrupt Insurance.* Available at: https://www.cbinsights.com/research/blockchain-insurance-disruption/ [Accessed July 2019].
[86] Singapore Airlines - https://www.singaporeair.com
[87] Krispay - https://www.singaporeair.com/en_UK/us/ppsclub-krisflyer/use-miles/krispay/

8. USAGE AREA: CIRCULAR ECONOMY

8.1. Business Challenges and Blockchain Solutions

Traditionally our economy is linear, which means raw materials are used to make a product, and then after consumption any waste is thrown away. This economic model is reaching its physical limits. In the last few years we have seen a shift towards circular economic models, with major retailers launching their initiatives including Adidas[88], Neiman Marcus[89], IKEA[90], Galleries Lafayette[91], Audemars Piguet[92], Richemont[93] and others.

This **circular economy** is described with reference to the 3Rs:

1. **reducing** materials need and waste
2. **reusing** products; and
3. **recycling** materials

"Brands are starting to realize that the amount they save by not having sustainable practices is outweighed by the detrimental cost of all the negative press. In fashion it's always about money. That's why we've seen brands start to take it seriously." [94]

In the past, the company approach to the end of their products' life wasn't important for consumers. However, there is a switch in the consumer mindset and behaviour towards more ethical brands. Retailers perceive sustainability as an exercise in damage limitation and have practices in place to react and respond to any bad press or consumer sentiment. Others see an opportunity to innovate and differentiate. The fast growth of sustainable brands such as Allbirds [95] and Veja [96] combined with the growth of consumer interest has prompted mainstream retailers such as Adidas and IKEA to innovate with their product lines. The pressure to innovate and adapt to a circular economy is starting to build on retailers and will only increase as sustainability becomes more important.

How can companies manage this new market? How can they demonstrate their sustainability credentials through reducing waste, reusing raw materials and recycling? How can a brand distinguish itself by supporting a secondary market for their products, without cannibalising their own sales and destroying value? These are some of the new business problems that companies are having to tackle in order to adapt and flourish in today's market.

[88] Addidas - https://www.adidas.co.uk/
[89] Neiman Marcus - https://www.neimanmarcus.com/
[90] Ikea - https://www.ikea.com
[91] Galeries Lafayette https://www.galerieslafayette.com/
[92] Audemars Piguet - https://www.audemarspiguet.com/
[93] Richemont - https://www.richemont.com/
[94] Walters, M. (2019) IS SUSTAINABILITY THE FUTURE OF FASHION? *GAMEPLAN A*. Available at: https://www.gameplan-a.com/2019/05/is-sustainability-the-future-of-fashion/ [Accessed July 2019].
[95] Allbirds - https://www.allbirds.com/
[96] Veja - https://www.veja-store.com

8.2. Research Highlights

According to the research, the circular economy is the least active use case area with 3 of the 105 projects. The projects which are relevant to this use case are shown in Table 9.

Table 9: Circular economy projects by sector.

Projects	Grocery	Fashion	Healthcare
Circular Service (CISE) platform		✓	
Monochain		✓	
Remedichain			✓

Of the three, two are start-ups (Monochain[97] and Remedichain[98]) and the Circular Service (CISE) platform[99] is a consortium.

8.3. Project Features

Within fashion, Monochain is London-based start-up which converges the primary and resale markets to enable the circular economy whilst simultaneously reducing counterfeiting. The company is part of Fashion for Good[100], which is a platform for sustainable fashion innovation which is looking to implement its solution with its corporate partners including Adidas, Kering (Gucci, Balenciaga, Saint Laurent etc)[101], PVH (Tommy Hilfiger, Calvin Klein)[102], C&A[103], Galeries Lafayette, Target[104] and Zalando[105]. MonoChain is currently working with one of the world's leading brands to bring their solution to the market. This is in the process of ramping up and today there are over 2,000 end customer certificates issued on their blockchain platform proving the item's provenance, guaranteeing authenticity and facilitating reselling.

In healthcare, Remedichain is a small start-up which is seeking to reduce pharmaceutical waste by enabling unused valid medication to be redistributed to other patients. This is a significant problem: it is estimated that $100 billion of medication is destroyed in the USA. each year whilst approximately 32 million Americans cannot afford the medication they need[106].

The Memphis-based company is using blockchain to retrieve unused, high-value medications from patients and pass them on to economically disadvantaged patients who would not be able to regularly afford them. Blockchain's transparent, secure and immutable ledger allows for a safe and confidential distribution of medical information. It is currently piloted in Memphis for high cost oncology medications, with plans to roll out nationally. The model is designed to support non-profit pharmacies which distribute the donated medications without competing with the commercial pharmacy channel – preventing margin erosion for the pharmaceutical companies.[107]

The Circular Service (CISE) platform is a Netherlands-based consortium which is collectively seeking to facilitate cooperation and coordination in circular service networks. The platform

[97] Monochain - http://mono-chain.com/
[98] Remedichain - https://www.remedichain.com/
[99] The Circular Service Platform - https://www.circle-economy.com/circular-service-platform/
[100] Fashion For Good - https://fashionforgood.com/
[101] Kering - https://www.kering.com/
[102] PVH - https://www.pvh.com/
[103] C&A - https://www.c-and-a.com/
[104] Target - https://target.com
[105] Zalando - https://www.zalando.co.uk/
[106] Statistics from https://www.remedichain.com [Accessed June 2019]
[107] Boxler, D. (2019) Remedichain to Connect Patients with Costly Meds. *Drug Topics.* Available at: https://www.drugtopics.com/technology/remedichain-connect-patients-costly-meds [Accessed July 2019].

brings together a whole range of partners from the Sustainable Finance Lab[108] and Circle Economy[109] to banks (ABN AMRO[110], ING[111], Rabobank[112]) and law firms (Allen & Overy[113]).

The blockchain-based platform functions as an open and community-maintained facility for anyone that has the ambition to contribute to a circular economy. It unburdens circular service network participants by automating administration and improving coordination and trust in the network.

8.4. Adoption Challenges

Circular economy applications present compelling use cases for retailers, however adoptions at scale are still few and far between. One reason for this is that whilst blockchain undoubtedly can help transition retailers towards an effective circular economy that works for consumers and companies alike, it is usually required in parallel with other emerging technology such as IoT as well as changing business models such as selling products as services. Secure tagging is also a challenge, although within fashion progress is being made towards tags which are integral to the clothing or apparel itself.

8.5. Outlook

The outlook for circular economy use cases in fashion looks extremely bright, with increasing traction and recognition from major players in the industry that the circular economy must be embraced – notably in the last two years when leading industry players including IKEA, Adidas, PVH (Tommy Hilfiger & Calvin Klein) and global luxury group Kering (Gucci, Saint Laurent, Balenciaga) announced their commitment to foster the circular economy in a concerted effort to improve sustainability in fashion. That said, blockchain is just a piece of the puzzle and there is a whole raft of measures that retailers are taking to help improve their sustainability.

[108] Sustainable Finance Lab - https://sustainablefinancelab.nl/
[109] Circle Economy - https://www.circle-economy.com/
[110] ABN AMRO - https://www.abnamro.com/
[111] ING - https://www.ing.com/
[112] Rabobank - https://www.rabobank.com/
[113] Allen & Overy - http://www.allenovery.com/

SECTION C: CONCLUSION

Future Outlook

Blockchain enterprise transformation is product-led rather than organisationally led and removes the silos of existing data structures, creating a secure and auditable product history which can be accessed in near real-time. This is a major step forward for retail operators managing physical supply chains from source to shelf (and indeed in after-sales).

From this research it is clear that blockchain is set to transform how physical supply chains are managed and engaging with blockchain initiatives is a business imperative. The concepts are well proven from a technological perspective – however, there is a great deal to be done in terms of ways of working to implement decentralised systems at scale. The benefits from an implementation at a company or internal level are generally limited; collaborative forums need to be established to realise benefits at scale (beyond proof of concepts or restricted pilots). Equally, regulators need to be engaged proactively to help establish standards which industry operators can use as templates for blockchain adoption. This cannot be done by working in siloes.

The blockchain start-up ecosystem is undoubtedly maturing and the era of scam companies looking to make quick money out of token sales with highly ambitious and unsubstantiated claims is waning. As elsewhere, quality teams with a track record and industry knowledge are likely to win the day. Start-ups have a major role to play to develop solutions which work for corporates. Corporates should partner with start-ups but at “arm’s length” – there is a risk if any solution appears to be too close to a particular player (particularly if it is a market leader) that competitors will be reluctant to come on board.

The applications and potential for value creation once product-led blockchain is in place are numerous, with improved features for customers (authentic product history) and new business models becoming possible (e.g. monetising the circular economy). The physical supply chain and product tracking implementations are only a first step.

Although through this research we see the most progress is in the tracing and logistics sectors, as tokens and smart contracts gain more traction, the financial transactions usage area will also see significantly more progress. Already since research for this report was completed, more attention is being shone on the retail operations and circular economy areas. Top fashion houses have begun to experiment with DLT and so one would expect that soon much of the industry will follow suit. As discussed in the beginning of this report, DLT adoption will very much first come into play as a means of replacing shared infrastructure. The more interesting, dynamic and disruptive aspects of the technology facilitating new business models will emerge as adoption and acceptance grows.

Gaps for Adoption

There are some important gaps which require attention in order for blockchain adoption to successfully scale across increasingly complex supply chains. First, in terms of data quality, the old adage of “garbage in garbage out” still applies: blockchain overcomes trust issues through decentralisation but it is still reliant on the quality of data which goes in. This is where other emerging technologies can play a role (AI and IoT) to create “trustless data” which is generated automatically, for example using integrated sensors.

Secondly, the on and off ramps between the digital, blockchain-enabled world and the physical world are yet to be fully defined. Currently, tags are the critical interface, but these often bring their own security concerns (e.g. replication, removal, other tampering).

Finally, the new co-opetition model of consortia is not an easy one to implement. It requires a new way of working for companies and also is potentially challenging from a regulation and anti-trust perspective. New collaborative forums can play an important role here to bring stakeholders together and drive industry level adoption.

Future Reports

As this research shows, DLT is being adopted within the Supply Chain. What remains to be seen is how it will evolve beyond providing a data sharing infrastructure. How quickly will the more disruptive aspects of the technology, namely new business model development through smart contract and token utilisation, begin to appear? Certainly, based on the levels of experimentation and gradual movement of projects to production it may be sooner than many would anticipate. Given the lack of digitisation in certain supply chain processes, the leap frogging effect of moving directly from manual, paper-based processes to DLT ones will streamline the implementation of the technology. Companies who choose to ignore the benefits of adopting DLTs in their supply chains may be at competitive disadvantages to those who embrace them.

This report on DLT in the Supply Chain is the first in a series of reports that the UCL CBT is producing on various aspects of DLT adoption in the retail value chain. Future reports will explore in further depth the topics of track and trace, digital twinning, digital identity, and regulation, certification and compliance.

APPENDIX 1: GLOSSARY OF TERMS

Artificial Intelligence (AI): The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.

Bitcoin: The first decentralised, open source cryptocurrency that runs on a global peer to peer network, without the need for middlemen and a centralised issuer.

Block: A package of data that carry permanently recorded data on the blockchain network.

Blockchain: A shared ledger where transactions are permanently recorded by appending blocks. The blockchain serves as a historical record of all transactions that ever occurred, from the genesis block to the latest block, hence the name blockchain.

Coin: Representation of a digital asset built on a new blockchain.

Consensus: The status when all participants of the network agree on the validity of the transactions, ensuring that the ledgers are exact copies of each other.

Cryptocurrency: A digital currency in which encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds, operating independently of a central bank (see also coin and token).

Decentralised application (Dapp): An application that is open source, operates autonomously, has its data stored on a blockchain, incentivised in the form of cryptographic tokens and operates on a protocol that shows proof of value.

Decentralised Autonomous Organisation (DAO): A company running without any human intervention and surrendering all forms of control to an incorruptible set of business rules.

Decentralised: The concept of a shared network of dispersed computers (or nodes) that can process transactions without a centrally located, third-party intermediary.

Digital asset: Any text or media that is formatted into binary source.

Digital signature: A mathematical scheme used for presenting the authenticity of digital assets.

Distributed Ledger: A ledger in which data is stored across a network of decentralised nodes. A distributed ledger does not have to have its own currency and may be permissioned and private.

Distributed Network: A type of network where processing power and data are spread over the nodes rather than having a centralised data centre.

Digital Signature: A digital code generated by public key encryption that is attached to an electronically transmitted document to verify its contents and the sender's identity.

Ethereum: A public blockchain system developed as an open-source project, its architecture running remotely on the Ethereum Virtual Machine. It uses 'ether', a cryptocurrency, as its token and supports the storage and execution of 'smart contracts'.

Fiat: Government-issued currency – e.g. USD, EUR, CNY, JPY, GBP, etc.

Hash: The result of applying an algorithmic function to data in order to convert them into a random string of numbers and letters. This acts as a digital fingerprint of that data, allowing it to be locked in place within the blockchain.

Hyperledger: An umbrella project set up by the Linux Foundation comprising various tools and systems for building open-source blockchains.

Immutable: "Unable to be changed". Data stored in a blockchain cannot be altered (not even by administrators).

Initial Coin Offering (ICO): The form in which capital is raised to fund new cryptocurrency ventures. Modeled after traditional Initial public offerings (IPO) but initially unregulated. Funders of an ICO receive coins or tokens.

Internet of Things (IoT): The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.

Mining: The act of validating Blockchain transactions. Requires computing power and electricity to solve "puzzles". Mining rewards coins based on your computing power.

Near Field Communication (NFC): A technology allowing the short-range wireless intercommunication of mobile phones and other electronic devices for purposes such as making payments.

Node: A copy of the ledger operated by a participant of the blockchain network.

Non-Fungible Token (NFT): A special type of cryptographic token that is a representation of a unique digital asset that is not interchangeable. This is in contrast to cryptocurrencies like Bitcoin, and many network or utility tokens that are fungible in nature.

Participant: An actor who can access the ledger and read records or add records to it (usually an operator of a node).

Peer to Peer (P2P): Refers to the decentralized interactions between two parties or more in a highly-interconnected network. Participants of a P2P network deal directly with each other through a single mediation point.

Peer: An actor that shares responsibility for maintaining the identity and integrity of the ledger.

Permissioned Ledger: A ledger where actors must have permission to access the ledger. Permissioned ledgers may have one or many owners. When a new record is added, the ledger's integrity is checked by a limited consensus process. This is carried out by trusted actors — government departments or banks, for example — which makes maintaining a shared record much simpler than the consensus process used by permissionless ledgers. Permissioned blockchains provide highly-verifiable data sets because the consensus process creates a digital signature, which can be seen by all parties. A permissioned ledger is usually faster than a permissionless ledger (see also private blockchain).

Permissionless Ledger: A ledger which has no single owner (e.g. Bitcoin). The purpose of a permissionless ledger is to allow anyone to contribute data to the ledger and for everyone in possession of the ledger to have identical copies. This creates censorship resistance, which

means that no actor can prevent a transaction from being added to the ledger. Participants maintain the integrity of the ledger by reaching a consensus about its state.

Private Blockchain: A closed network where blockchain permissions are held and controlled by a centralized entity. Read permissions are subject to varying levels of restriction.

Private Key: A unique string of data that represents proof of identification within the blockchain, including the right to access and own that participant's wallet within a cryptocurrency. It must be kept secret: it is effectively a personal password.

Proof of Stake: A consensus distribution algorithm that rewards earnings based on the number of coins you own or hold. The more you invest in the coin, the more you gain by mining with this protocol.

Proof of Work: A consensus distribution algorithm that requires an active role in mining data blocks, often consuming resources, such as electricity. The more 'work' you do or the more computational power you provide, the more coins you are rewarded with.

Public Blockchain: A globally public network where anyone participate in transactions, execute consensus protocol to help determine which blocks get added to the chain, and maintain the shared ledger.

Public Key: A unique string of data that identifies a participant within the blockchain. It can be shared publicly.

Radio-Frequency Identification (RFID): A technology whereby digital data encoded in RFID tags are captured by a reader via radio waves.

Scalability: A blockchain project's ability to handle network traffic, future growth and capacity in its intended application.

Smart Contracts: Automatically executed contracts governed by business rules embedded in blockchain code. Actions executed through smart contracts are enforced by the participants of the network. Closely associated with Ethereum which was the first blockchain protocol to incorporate this functionality.

Stablecoin: Any cryptocurrency pegged to a stable asset, like fiat or gold. It theoretically remains stable in price as it is measured against a known amount of an asset not subject to change.

Token: Representation of a digital asset built on an existing blockchain (see also coin).

Transaction Block: A collection of transactions on the bitcoin network, gathered into a block that can then be hashed and added to the blockchain.

APPENDIX 2: PROJECTS INCLUDED IN THIS REPORT

- 14bis
- ADNOC oil & gas supply chain
- Agridigital blockchain project
- Albert Heijn orange juice project
- Ambrosus
- Anyledger
- Arc-Net (Distilled ID project)
- Arianee
- Artory
- AT&T blockchain solutions
- BanQu
- Bean to Cup (Starbucks)
- BeefLedger
- Better Cobalt
- Bext360
- BiTA
- Block Array
- Blockchain Food Safety Alliance
- Blockfreight
- Blockshipping (GSCP)
- Blockverify
- BlocRice
- CargoX
- Chain of Things
- Chainvine
- Chainvine
- Chronicled (part of Mediledger)
- Circular Service (CISE) platform
- Circularise
- Circulor
- Inbev, APL, Accenture, Kuehne, Nagel (Consortium)
- Cryptowerk
- CrystalChain
- Deloitte, Kerry & Cargosmart
- Devery
- dexFreight
- Diamsledger
- DMG (Supply Chain)
- eHarvestHub
- Everledger
- Eximchain
- Farmatrust
- Food Trust Framework (Alibaba)
- Global Shipping Business Network
- GoGo Chicken
- GrainChain
- Hijro
- IBM Food Trust Solution
- IOHK coffee supply chain project
- iSolve
- Kerala food supply blockchain
- Minehub
- Ministry of Science and ICT
- Ministry of Agriculture, Food and Rural Affairs
- Mizuho / Hitachi project
- Modum
- Monochain
- ONE Blockchain

- ONE Blockchain
- OpenPort
- OpenSC
- Oracle Intelligent Cold Chain
- Oracle Intelligent Track & Trace
- Oracle Lot Lineage & Provenance
- Oracle Warranty &Usage Tracking
- OriginTrail
- Owlting
- Pacifical / Gustav Gerig
- Pavo
- Provenance
- PWC Air Trace
- Remedichain
- Resonance
- Ripe
- SAP anti-drug counterfeiting project
- Seal
- Shipchain
- Shooftech
- Silsal
- Skuchain
- Slync
- Spiritus
- StaTwig
- Stratumn
- SUKU
- Sweetgreen sourcing project
- SyncFab
- Techrock / TaelPay
- TE-Food
- Temco
- T-Mall
- T-Mining
- T-Provenance
- TraceLink blockchain project
- Tracr
- TradeChain: CBA pilot
- TradeLens
- Tradeshift blockchain project
- TrustChain (IBM)
- U.S. Customs & Border Protection / BluJay Solutions
- Vanig
- VeChain Thor
- Viant
- Vinsent (formerly VinX)
- WaltonChain
- Wave (previously OGYDocs)
- XAIN
- ZERV

ABOUT THE UCL CENTRE FOR BLOCKCHAIN TECHNOLOGIES

The UCL Centre for Blockchain Technologies was founded in 2016 to research the effects of DLT and blockchain into our socio-economic systems and to promote the safe and organic development and adoption of blockchain-based platforms.

The centre is the nucleus for DLT and blockchain research and engagement across eight different departments at UCL and for its Research and Industry Associate network. Our Research and Industry Associate community consists of over 180 researchers and practitioners from UCL, other academic institutions and companies utilising DLT.

Some of the initiatives that the UCL CBT engages in are:

- The P2P Financial Systems Workshop.
  - Widely regarded as the premier conference for Peer to Peer financial systems discussions and attended by top academics and central bankers.
  - Running for the fifth time, in 2019 it was held at the ECB in Frankfurt, Germany.
  - Learn more at https://www.p2pfisy.com
- ISO Standards on DLT.
  - Faculty members of the UCL CBT Collaborate with ISO TC307 on blockchain standards.
- DLT & Fintech Executive Education Programmes.
  - Launching the first in-person Blockchain Executive Education Programme in 2018, over 70 individuals have since then successfully taken our programmes in Blockchain and Fintech literacy.
- Blockchain technology for Algorithmic Regulation And Compliance (BARAC) Project.
  - BARAC investigates the feasibility of using blockchain technology for automating regulation and compliance producing a proof-of-concept platform and facilitating knowledge transfer by means of a bottom-up cross-disciplinary approach developed together with industry and regulators.
  - Learn more at https://gtr.ukri.org/projects?ref=EP%2FP031730%2F1
- International Token Standardization Association (ITSA).
  - UCL CBT is a founding member of the ITSA.
  - Learn more at https://itsa.global/
- Call for Proposals.
  - The first UCL CBT Call for Research Proposals disbursed over £200,000 to nine proposals with the outcomes of these proposals expected to be showcased in early 2020 (6-month length projects starting from July 2019). Major areas of project focus are Smart contracts, Cryptocurrency market, Blockchain security, Blockchain use cases and Regulation and Policy and Fiscal policy in tokenomics.
- Regular events and workshops.
  - The UCL CBT holds seminars and workshops free to the public about DLT.

The UCL CBT is always looking for individuals to engage in our research initiatives and corporates and institutions to collaborate with. Please get in touch with us through our website if you are interested in working with us.

UCL Centre for Blockchain Technologies
66-72 Gower Street, London, WC1E 6EA, UK
http://blockchain.cs.ucl.ac.uk/

ABOUT THE RETAIL BLOCKCHAIN CONSORTIUM

The Retail Blockchain Consortium (RBC) explores and advances the use of DLT within the retail value chain. It facilitates collaboration, the pooling of resources and platforms, knowledge transfer, and mitigation of risks in the adoption of DLT for its members.

The consortium is a global collaboration led by academic partners (University College London Centre for Blockchain Technologies), corporate partners (Oracle and Luxoft/DXC Technology), and start-up partners (Monochain and Farmatrust).

Mission and Vision

The aim of the RBC is to share knowledge of blockchain technology to foster adoption in the retail value chain. This will enable key players to understand the practical challenges of the deployment of blockchain technology at scale across the globe. The consortium will provide resources for academic and commercial partners to leverage this innovative transformational technology for specific retail value chain use cases.

How Will You Benefit from Joining?

As a retailer, brand, supply chain provider, or partner you can become a member of the RBC and benefit from the following:

- Access to workshops run by industry thought leaders.
- Intensive educational and technical accredited courses run by experts.
- Participation in members-only events and committees on blockchain applications within the retail value chain.
- Helping to drive corporate social responsibility and improve the environment through relevant use of blockchain.
- Access to the latest academic retail-focused research on blockchain from the world's leading universities.

Get Involved – Join the Executive Forum

The biggest opportunity within the RBC, is to work with likeminded Executives, who are working in and interested in how blockchain technology will revolutionize the retail value chain.

If you are an Exec within the value chain, and you want to understand how blockchain technology can improve your business, this is the place to be.

The RBC will educate, support, advise and develop your knowledge and understanding of enterprise blockchain, so that you can be confident you make the right blockchain technology decisions to drive your business forward.

Please see the website for how to get involved in this exciting consortium and be a part of shaping the future of blockchain technology www.retailblockchainconsortium.org.

UCL Centre for Blockchain Technologies
http://blockchain.cs.ucl.ac.uk/