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Abstract

The purpose of this paper is to assess the possibility of using blockchain technology in the realm of public procurement within the EU, particularly in connection with the award of public contracts. In this context, blockchain is used as an umbrella term covering IT technologies and cryptographic solutions used to generate consensus on a distributed ledger.

The paper starts by elaborating how blockchains and distributed ledgers work in general, including the drawbacks of different blockchain models and implementations, before looking into recent developments for distributed consensus that may herald some potential.

As for public procurement, blockchain has been used in three real use cases in Aragon (Spain), Colombia and Peru, with the first two not passing from the pilot stage and the latter being deployed in production. These use cases are analysed with an emphasis in what can be learned from the difficulties faced by each project.

Finally, this paper will posit two specific areas of EU public procurement practice that might benefit from the use of blockchain technology. The first is on data management and accessibility where current solutions have been unsuccessful, such as cross-border certification data as required by the European Single Procurement Document (ESPD) and e-Certis or the difficulties with contract data collection and publication. The second, on situations of clear lack of confidence on public powers, where the downsides of blockchain technologies and the costs they entail are an advantage. Even considering these potential scenarios, the overall perspective is that the benefits of blockchain solutions do not really provide much value in the context of public procurement for now.

I. Introduction

Blockchain can be defined as an umbrella term which encapsulates a number of different IT technologies and cryptographic solutions allowing for agents to collaborate in situations where they have no reasons (or ways) to trust them.[2]

In more technical terms, blockchain amounts to the recording of entries in a distributed ledger

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2. For a more elaborate definition and description of distributed ledger systems see, Michel Rauchs, Andrew Glidden et al, *Distributed ledger technology systems: a conceptual framework*, (Cambridge Centre for Alternative Finance 2018).

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with each participant keeping a copy of every transaction registered in the network. Each transaction is processed, timestamped and added to the ledger if and only if it achieves the consensus of the majority of participants in the network. Consensus - and the trust associated - is thus decentralised and achieved via a consensus mechanism which, in its first iteration, consists on the performance of cryptographic puzzles by the network participants, colloquially known as 'proof of work'. Only the first node solving the puzzle can add new entries to the ledger and once added such entries are immutable, trading privacy for transparency.[3] The puzzles are computationally intensive, requiring significant computing power to solve and establishing trust in the participating nodes via the certain cost and uncertainty associated with the computational tasks. In the lack of censorship and external mechanisms of trust/validation lies the key difference between blockchain and more traditional database systems. This is different in conceptual terms from a distributed database[4] even though as it will become evident some distributed databases are indeed passing off as blockchains.

Bitcoin is the first example of blockchain being deployed as a network able to generate consensus using a proof of work mechanism. At the time its whitepaper was published online by Satoshi Nakamoto[5] it proposed a way to solve a fundamental problem with online currencies or tokens, that is how to guarantee that a given token is not spent multiple times. The consensus mechanism afforded by proof of work and the immutability of entries on the bitcoin ledger guaranteed that it was mathematically impossible for a given unit of that cryptocurrency to be duplicated.

Whereas Bitcoin's single purpose is the creation of a cryptocurrency to be traded as such, since then numerous other attempts in other areas have been made to use the core idea of an immutable ledger with entries accepted by consensus. Ethereum[6] is the leading example with a network designed to work as a distributed computer, with its own programming language[7] and ability to execute smart contracts.[8] While it shares some characteristics with bitcoin, namely proof of work as a consensus mechanism and the use of a token (ether) for transactions, it has been designed

3. As argued by Michele Finck and Valentina Moscon, 'Copyright law on blockchains: between new forms of rights administration and digital rights management 2.0' [2019] International Review of Intellectual Property and Competition Law 90.

4. With an opposing view, Raquel Carvalho, 'Blockchain and public procurement' [2019] Euroepan Journal of Comparative Law and Governance 189 and Pawel Nowicki, 'Deus Ex Machina? Some remarks on public procurement in the Second Machine Age' [2020] EPPPL 56.

5. Satoshi Nakamoto, 'Bitcoin: A Peer-to-Peer Electronic Cash System' (31 October 2008) https://nakamotoinstitute.org/bitcoin/ accessed 14 July 2022.

6. Vitalik Buterin, 'Ethereum whitepaper' (2014) https://ethereum.org/en/whitepaper/ accessed 14 July 2022.

7. The programming language is called Solidity and it is available at: https://soliditylang.org/ accessed 14 July 2022.

8. On the origins of smart contracts, Nick Szabo, 'Smart Contracts: Building Blocks for Digital Markets', Extropy nr. 16 (1996) https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh. net/smart_contracts_2.html accessed 14 July 2022.

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from the ground up to allow for applications to be built upon it, such as asset tokenisation, financial assets, stablecoins, identity systems, distributed file storage, decentralised autonomous organisations (DAOs)[9] or non-fungible tokens (NFTs)[10]. While Ethereum relies at the time of writing on proof of work as a consensus mechanism, it will migrate soon to proof of stake instead. Under proof of stake, consensus is achieved via the nodes staking an amount of ether on a smart contract. Once the amount is staked it is at risk and if the behaviour of the node is deemed untrustworthy such capital will be destroyed, thus ensuring the safety of the network.[11]

II. Endogenous issues and limitations

The approach above describes public blockchains which can also be categorised as a maximalist view of blockchain, that is an implementation of an immutable ledger, based on a distributed consensus mechanism where anyone can participate as a node with read/write privileges. This final element of lack of censorship makes that approach less interesting to commercial applications in comparison with traditional databases since anyone can have access to and potential write into the ledger. It is no surprise thus that most projects and implementations of this maximalist approach have happened in so-called crypto projects: cryptocurrencies and cryptoassets, for the most part segregated from the economy at large. It is fair to say its most defining features also work as a constraint on the value blockchain may have for wider application and the reality remains that use cases for the technology outside its core crypto world are limited even after more than a decade of development.

Proof of work as a consent mechanism is also problematic despite being the current gold standard. Proof of work requires significant computing power to be allocated to the task where most of that work is wasted since it is not rewarded with adding new entries to the ledger. This is so by design since it is this investment in computing power (and the risk associated with it) is required to ensure the safety of the network and the trustworthiness of the nodes. However, this leads to two major problems with proof of work blockchains. First, the energy costs are significant and tend to grow over time and in some instances exponentially to maintain the difficulty of the cryp-

9. On DAOs see, Chainalysis, 'Dissecting the DAO: Web3 Ownershup is Surprisingly Concentrated (27 June 2022) https://blog.chainalysis.com/reports/web3-daos-2022/ accessed 14 July 2022.

10. On these see, Andres Guadamuz, 'The treachery of images: non-fungible tokens and copyright' [2021] Journal of Intellectual Property Law & Practice 1367-1385.

11. For more information see, Ethereum, 'Proof-Of-Stake' https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/ accessed 14 July 2022.

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tographic puzzles, to the point that bitcoin currently uses over 131TW/h, a similar amount of energy to Argentina.[12] In consequence, today each transaction on a proof of work blockchain requires incomensurably more energy than say a similar transaction on a traditional credit card network. Second, proof of work is energy innefficient by design thus meaning it depends on the allocation of scarce resources to establish the trust in the nodes. In a world with plentiful and 'free' energy, proof of work blockchains would either be insecure due to the ease of muster such resources or, in alternative, require a never-ending arms race to find the boundary at wich energy becomes scarce once more. Proof of work is so energy innefficient as a consensus mechanism that it is one of the reasons why Ethereum is moving from it and to proof of stake as a consensus mechanism instead by the end of 2022.[13]

Whereas proof of stake is supposed to solve the issue of energy consumption in addition to improving the scalability of the Ethereum network, it may introduce new risks. So far proof of stake is not a tested solution, at least neither in production nor at scale, a drawback Ethereum developers recognise themselves. Therefore, anyone wanting to use Ethereum to deploy some sort of blockchain-enable solution will be taking on the uncertainty of using a new consensus algorithm.

Public blockchains also suffer from what can be described as the blockchain trilemma. Out of being distributed, secure or scalable they can only achieve two of these objectives and at least for both bitcoin and ethereum the choice is to achieve the first two objectives at the expense of scalability for the network. This is why they are - until now - unable to scale in terms of transactions per second, with Ethereum being limited to simply 30 transactions per second even after a significant upgrade to the network, and even then it usually averages 15 transactions per second.[14] This means as well that transaction processing can be very expensive which, as will be detailed when discussing the issues of using public blockchains in public procurement.

It is expected that the move to proof of stake in the future will solve the scalability issue with a potential of up to thousands of transactions per second once sharding is introduced as well.[15] Whether this will solve the conundrum mentioned above or instead move the compromise to either its secure or distributed nature, remains to be seen.

12. Digiconomist, 'Bitcoin energy consumption' https://digiconomist.net/bitcoin-energy-consumption, accessed 14 July 2022.

13. Ethereum Foundation Blog, 'Ethereum's energy usage will soon decrease by 99.95%' https://blog.ethereum.org/2021/05/18/country-power-no-more/, accessed 14 July 2022.

14. Blockchair, 'Ethereum transactions per second' https://blockchair.com/ethereum/charts/transactions-per-second accessed 14 July 2022.

15. Coinshares, 'The compromises and benefits of Ethereum switching to a Proof of Stake network' https://coinshares.com/research/compromises-and-benefits-ethereum-proof-of-stake-network accessed 14 July 2022.

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III. Exogenous issues and limitations

Public blockchains also give rise to exogenous issues and limitations, namely in their connection with the wider economy and the legal rules that govern it. While it is true that various ideas in the blockchain space are indeed novel, it is a myth that they happen in a legal vacuum and no legal rules apply. In time, rules will be designed to take them into account specifically, but legal concepts are elastic and mutable so for now one needs to apply existing laws using interpretation and analogy techniques. The first example of these are the application of data protection rules, particularly the GDPR. GDPR was not designed with blockchains in mind and its design considerations are based on orthogonal premises to those of blockchains, but the fact of the matter is that GDPR does apply in this context as it would to any other technology involving personal data. That in turn means some difficulties in applying specific GDPR concepts and princiles such as data controller, joint controllers or how to handle the right to be forgotten when entries in the ledger are immutable.[16]

Another issue affecting current public blockchains surrounds with the existence of fiduciary duties from the teams leading them.[17] Even though the use of a public blockchain in uncensored and distributed, allowing for anyone to participate in it, this freedom does not apply to the individuals managing the underlying code.[18] In general these are a small team who may or may not involve the wider community in the decision-making, but that at the end of the day make the decisions about what code runs and what does not, thus giving them an outsized influence on how a given blockchain operates. At the end of the day, blockchain is code and whomever controls the repository where it sits, controls its future. This lack of accountability can be assessed from a traditional agent/principal perspective but also one of fiduciary duties that may be or not owed by those individuals towards stakeholders. And if fiduciary duties are present, personal liability follows.

The personal liability of blockchain developer teams is connected with the lack of legal personality and a corporate veil wrapping a given public blockchain development.[19] At most, the developer team amounts to a partnership and these tend to not provide any sort of protection vis-a-vis personal liability.

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16. Michele Finck, 'Blockchain regulation and governance in Europe' (Cambridge University Press 2018) and specifically when dealing with the public sector, Alexander Rieger, Alexander Stohr, Annette Wenninger, Gilber Fridgen, 'Reconciling Blockchain with the GDPR: Insights from the German Asylum Procedure' in Christopher G. Reddick, Manuel Pedro Rodríguez-Bolívar, Hans Jochen Scholl (eds) *Blockchain and the Public Sector. Public Administration and Information Technology*, vol 36 (Springer 2021) 73-97.

17. Angela Walch, 'In coders we trust: software developers as fiduciaries in public blockchains' in Phillip Hacker, Ioannis ianos, Georgios Dimitropoulos and Stefan Eich (eds) *Regulating blockchain. Techno-Social and Legal Challenges* (Oxford University Press, 2019) 58-80.

18. Angela Walch, 'Deconstructing 'Decentralisation': exploring the core claim of crypto systems' in Chris Bummer (Ed) *Crypto assets: legal an monetary perspectives* (Oxford University Press 2019) 39-68.

19. Florian Moslein, Blockchain applications and company law, [2020] Legal Technology Transformation in Practice.

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IV. Enterprise and hybrid blockchain models

To alleviate some of the issues mentioned above, in the last few years we have seen a number of enterprise or hybrid blockchain models appearing. These are usually developed and managed by specific companies and tailored for their own needs and missing one or more of the characteristics of public blockchains mentioned earlier. These may be missing the free read or write access, immutability or consensus mechanism. For the most part they can be described as distributed databases and not really blockchains, despite the branding which, as things stand in 2022 tends to be downplayed somewhat. A good example is that of Tradelens, jointly developed as a hybrid blockchain by Maersk and IBM to improve the processing of information for shipping goods. While originally the mention of it being a blockchain solution was front and centre in its messaging, with time this changed and nowadays the page for the project does not even mention it at all.[20] Meanwhile, IBM disbanded most of its blockchain team.[21]

Another example is that of the Helium which uses 'proof of spectrum' as its consensus mechanism. In this network, participants are rewarded by making spectrum available for use in the Helium network.[22] Once the appropriate equipment is installed and turned on, nodes are rewarded for making the spectrum available to the network, first for a low bandwidth IoT-specific protocol and more recently to 5G. This shows how the core idea of a distributed ledger can be used beyond its cryptocurrency origins and related space as to achieve what was not possible beforehand, showing an avenue for where blockchain solutions might be relevant in the future.

This is to say that so far hybrid (or private) blockchains appears for the most part to be an oxymoron and a solution looking for a problem. They tend to require trust in the parties or at least one party and if that is the case there is really no need for an expensive or cumbersome consensus mechanism. Therefore, they are more distributed databases, which while offering specific advantages, do not need to be called blockchains. That does not mean in the future this will remain the case for certain.

V. Existing use cases in public procurement

As for public procurement, there have been calls for blockchain to be deployed and suggestions on how to do so, but the fact of the matter is that until now there are only three known examples

20. Tradelens, https://www.tradelens.com/ accessed 14 July 2022.

21. Yahoo News, 'IBM blockchain is a shell of its former self after revenue misses, staff cuts' (01 February 2021) https://finance.yahoo.com/news/ibm-blockchain-shell-former-self-175818192.html accessed 14 July 2022.

22. Helium, https://www.helium.com/ accessed 14 July 2022.

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of attempts to deploy the technology in practice, in Aragon (Spain), Colombia and Peru. The first two were simply proofs of concept, whereas in Peru blockchain was deployed in production. Overall, these three use cases show what can be done with blockchain in public procurement but more importantly show the limitations of the technology as well as providing with food for thought if blockchain is really a technical solution worth pursuing in the context of public procurement.

There are also references to potential pilots or deployments of blockchain solutions for other countries such as Chile (2018)[23] and Thailand (2019)[24] but it was not possible to find any hard evidence that these pilots were ever deployed or what their current status might be. As such, these have not been analysed for the purposes of this paper.

1. Aragon

The Spanish region (autonomous community) of Aragon has its own public procurement law[25] which complements the Spanish law.[26] In 2018 the Region approved a law on the Strategic Use of Public Procurement in Aragon, with a provision allowing for the use of blockchain technologies,[27] thus paving the way for their deployment. Therefore, since 2018 the Regional Government has been using the hybrid blockchain Hyperledger which was designed for enterprise use and is managed very differently from the public or maximalist blockchains described on section **X** above. In effect, the Hyperldeger blockchain is much closer to a distributed database than a maximalist blockchain[28] since access to the various features is subject to permission and it does not rely on a consensus mechanism either.

As of late 2020, Aragon used the Hyperledger blockchain to register 30 proposals[29] as well as to

23. ChileCompra, 'ChileCompra inicia proyecto piloto para el uso de la herramienta blockchain en compras publicas' https://www.chilecompra.cl/2018/02/chilecompra-abordo-el-uso-del-blockchain-aplicado-a-la-probidad-y-transparencia-en-compras-publicas/ and https://www.chilecompra.cl/2018/07/chilecompra-inicia-proyecto-piloto-para-el-uso-de-la-herramienta-blockchain-en-compras-publicas/ accessed 14 July 2022.

24. Ledger Insights, 'Thai government to use blockchain for VAT refunds, bonds, procrement' https://www.ledgerinsights.com/thai-government-blockchain-vat-bonds-procurement/ accessed 14 July 2022.

25. Law 3/2011 (On Aragonese public procurement measures).

26. Law 9/2017 (Public Sector Contract Law).

27. On this, Miguel Ángel Bernal, 'El desarrollo autonomico de la normativa sobre contratos públicos' [2019] Monografias de la Revista Aragonesa de Administración Pública 91-138.

28. As mentioned on Hyperledger's whitepaper, "An introduction to Hyperledger', 4.

29. Observatorio Blockchain, 'Miguel Angel Bernal, de la indentidad digital blockhain, a la residencia digital para Aragon' https://observatorioblockchain.com/blockchain/miguel-angel-bernal-de-la-identidad-digital-blockchain-a-la-residencia-digital-aragonesa/ accessed 14 July 2022.

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award a contract for the purchase of face masks via a smart contract. This contract was registered on Ethereum and available for anyone to see.[30]

The purpose of this proof of concept appears to have been twofold. First, to log the submission of tenders and using the cryptography to guarantee that a given proposal had been submitted on time and had not been tampered with, like, for example being opened before the deadline which would indicate an integrity risk for the procedure. Second, to speed up the procedure administrative overhead, at least in the example of the face mask smart contract since the award was done automatically via the rules inscribed in the smart contract itself.

Regarding that first objective, it is self-evident that a blockchain solution and the cryptographic approach it entails can provide the transparency and anti-tampering benefit that Aragon was looking for. Having said that, and assuming that the hashes themselves are indeed tamper proof as they should be for cryptographical reasons. Since Aragon opted for a hybrid blockchain there is always the uncertainty of the underlying code being controlled by a private party and as such subject to discrete modifications that would affect the security of the system. This is mostly an unreasonable fear, but one that could play a factor on economic operators that already distrust a submission system and may keep the same approach even when a more transparent approach is taken. In addition, it can be said as well that the security offered by hashing submissions by economic operators is possible to do with traditional electronic platforms and databases, so the real technical security benefit is not exclusive to a blockchain solution. In fact, it is arguable that it might probably be cheaper and easier to incorporate such a solution on existing systems instead of building a completely new one from scratch, while achieving the same stated goal of providing transparency and security to the market.

As for the second objective of speeding and automating contract awarding decision-making, it is possible to do so with a smart contract and a blockchain, but also with traditional procurement mechanisms. At the end of the day, if the specifications are detailed enough there is no reason why they could not be deployed on a traditional electronic procurement platform and achieve the same result. In other words, there is nothing specific on a blockchain solution that would make it impossible to achieve this goal without it. This realisation takes us to what is the key take home message of the Aragon blockchain pilot: it is still being used to duplicate what can be achieved by traditional technical approaches and not even doing so in a way that would make it more efficient or 'better' to achieve its stated goals.

In October 2021, a new contract worth almost €450,000 was awarded to keep developing the

30. Available at: https://etherscan.io/tx/0x960cb1613f4c33db4f6eca9f360b2a0d823795a28a88f5d5dcd44ada9ae29daa accessed 14 July 2022. Simply registering this contract on the Ethereum blockchain costed $6.80.

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blockchain procurement system of Aragon for 18 months.[31] One would assume this is to be achieved by iterating the current solutions and choices and not by moving to a completely new technical setup.

2. Colombia (World Economic Forum)

The World Economic Forum led the pilot of a blockchain project in public procurement in Colombia to assess its usefulness as part of a wider anti-corruption body of work which included as well complementary measures and social engagement.[32] The actual pilot procedure was for the award of school meals[33] and it included a proof of concept for software to test a number of different solutions and technical choices. Contrary to Aragon, the WEF pilot decided to use a public blockchain, in this instance Ethereum. The blockchain proof of concept had 5 main objectives:

- Permanent and tamper-evident record-keeping

- Real time transparency and auditability

- Automated functionalities with smart contracts

- Reduced reliance on the discretionary decision-making of centralised parties and authorities

- Enhanced citizen engagement

Unfortunately, though not unexpectedly, the proof of concept faced significant challenges and at the time of writing (July 2022) there was no indication it had ever been implemented and not recent updates were found. More specifically, due to the use of the Ethereum blockchain it faced uncertain costs for running the procedure and even for tender participation. This is due to the fact that each operation (bid submission, selection, evaluation, award) has to registered on the blockchain and each of these 'transactions' incurs a financial cost called 'gas'. This cost is variable and depends on the load on the Ethereum network at any given time, fluctuating significantly and very quickly, partially because of the limited number of transactions per second (15) that can be processed on the network. For example, in the summer 2021 the costs of each transaction on Ethereum were above $50 whereas at the time of writing it is now down to below $1.[34] This means that every single operation connected with a procurement procedure using Ethereum would cost

31. Contract information available at: https://www.infopublic.net/concursos/contrato-desarrollo-evolucion-sistema-licitacion-electronica-tecnologia-registro-distribuido-blockchain-comunidad-autonoma-aragon-2863428 accessed 14 July 2022.

32. The original proposal, Carol Cortés, Alejandro Guzmán, Camilo A. Rincón-González, Catherine Torres-Casas, and Camilo Mejía-Moncayo, 'A Proposal Model Based on Blockchain Technology to Support Traceability of Colombian Scholar Feeding Program (PAE)' [2019] Applied Informatics 245–256.

33. BID and WEF, 'Insight Report - Exploring Blockchain Technology for Government Transparency: Blockchain-Based Public Procurement to Reduce Corruption' (2020).

34. According to Gasprice.io, https://www.gasprice.io/ accessed 14 July 2022.

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money and more crucially cost an uncertain amount, thus introducing uncertainty into the process. In addition, whereas the development software and tools for Ethereum are stable and well known by now, the user interface and experience for non-expert users is still very lacking and not as easy as using online banking or an ATM. Therefore, basing the proof of concept on Ethereum meant significant additional uncertainty and complexity for participating economic operators and also for public body which would have been expected to cover these additional costs incurred by them.[35]

3. Peru (Peru Compras)

Peru Compras, the central procurement agency of Peru deployed a blockchain solution in a production environment in public procurement since 2019[36] using LAC-Chain, a permissioned blockchain developed by the Inter-American Bank for Development.[37] LAC-Chain was designed to kickstart a blockchain ecosystem in South America and the Caribean, improving financial inclusivity, fight corruption and increase transparency. LAC-Chain uses the Stamping.io as backend platform for the registration of digital assets.[38]

The system was deployed in April 2019 and by late 2020, 176,608 purchase orders had been registered in the system and 'verified', amounting to S/ 1,824,244,357, that is close to USD 500M.[39] In total, the cost for Peru Compras to process these purchase orders was S/ 32,000 (circa USD 8,500).[40] However, since December 2020 the only update found referred to 370,000 purchase orders by mid 2021 without disclosing the amounts of either the contracts or the costs involved.[41]

The system deployed by Peru Compras seems to include both bid registration and contract award. The latter is done via a BATCH process based on lowest price as awarding criteria which subsequently generates a purchase order connected with the process.[42] The purchase order is

35. For a more detailed look at the difficulties see, BID e WEF, Insight Report - Exploring Blockchain Technology for Government Transparency: Blockchain-Based Public Procurement to Reduce Corruption p 28-30.

36. Peru Compras, 'PERU COMPRAS ingresa al ecosistema digital de la blockchain' (16 April 2019) https://www.gob.pe/institucion/perucompras/noticias/80243-peru-compras-ingresa-al-ecosistema-digital-de-la-blockchain accessed 14 July 2022.

37. LAC Chain, 'Ordenes de compra de PERU COMPRAS con blockchain' https://www.lacchain.net/projects/%C3%93rdenes-de%20compra%20de%20PER%C3%9A%20COMPRAS%20con%20Blockchain accessed 14 July 2022.

38. Stamping.io, 'Primera orden de compra tokenizada en la blockchain' (5 April 2019) https://medium.com/@stamping.io/perucompras-tokenizar%C3%A1-las-%C3%B3rdenes-de-compras-en-la-blockchain-5bf6d9db0715 accessed 14 July 2022.

39. Exchange rate at the date of writing in July 2022.

40. Peruvian Economy and Finance Ministry, 'Evaluation of modified IT plan 2017-2019' (2019).

41. Peru Compras, Noticompras, Edicion 14, July - August - September 2021 (2021).

42. Stamping.io, 'Primera orden de compra tokenizada en la blockchain'.

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registered as a unique token and generates a QR code that is to be scanned by the receiver of the goods purchased using an app on a smartphone to assess the authenticity of the order. Effectively, each purchase order is subsumed to a non-fungible token which is registered in the LAC-Chain blockchain.

As for the information contained in the registration, on the technical side it includes the URL for the PDF with the purchase order including its hash and a hashlink guaranteeing bids have not been tampered with. As for data, it includes the information about the winner and contracting authority, order number and contract details.

Furthermore, while Peru Compras states that it has deployed a blockchain solution on a production environment, it turns out that LAC-Chain is in of itself a testnet with a limited number of nodes. A mainnet to succeed LAC-Chain called LACNet has been already developed. This new chain is a paid for system which at the time of writing (July 2022) costs between USD170 and 1,250/month and is based upon the Hyperledger Besu Ethereum client.

Bearing in mind that Peru Compras used a testnet as well as the lack of detailed updates since late 2020, it is impossible to conclude if the project has been successful[43] or what are the country's plans to take it from there. Furthermore, it is important to note as well that Peru decided to use an enterprise or hybrid, permissioned blockchain, which is described as a 'public-permissioned blockchain' instead of a public blockchain such as Ethereum. Peru is probably the best example of blockchain being deployed in a production environment in public procurement even though from a technical perspective there seems to be no reason to use a blockchain to achieve what Peru Compras set forth to achieve.

4. Reflection on existing use cases

These three examples clearly show how far away blockchain technology is from being in a state that warrants wider adoption and that significant challenges remain until that level is reached, even to replace pre-existing approaches or methodologies. What was achieved with blockchain in the three use cases analysed could have been achieved as well with more traditional IT solutions.

In that critique lies crux of using blockchain in public procurement thus far which is that we have not been able to transcend the traditional mental models or objectives and are simply using it to do the same thing using a different technical solution which is not necessarily even the best for

43. Although by late 2019, the country had signed a MoU with Chile to share their knowledge and best practices, Diario Bitcoin, 'Convenio de cooperacion entre ChileCompra y Peru Compras podria impulsar adopcion Blockchain en contratacion publica (07 September 2019) https://www.diariobitcoin.com/tecnologia/blockchain/convenio-de-cooperacion-entre-chilecompra-y-peru-compras-podria-impulsar-adopcion-blockchain-en-contratacion-publica/ accessed 14 July 2022.

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the purposes at hand. It is no surprise then that blockchain solutions are unable to add value to these operations. Blockchain as an overarching technology or approach to technology will only be useful once it finds areas where it solves currently unsolved existing problems or where it allows for something to be done that could not be so previously.

In addition, it is telling as well that despite significant interest and information publicly available for these projects in 2019 and 2020, from 2021 onwards and up to the date of writing (July 2022) no new information has been made available. This indicates at least a lack of interest from the public authorities involved in promoting the work they have been doing with the technology.

VI. Potential use cases in EU public procurement

Any potential use case for blockchain in public procurement needs to fit around existing EU legal constraints, namely the prescriptive rules of Directive 2014/24/EU. Bearing in mind how electronic procurement is mandatory in the EU and every Member State has invested in its own systems already to comply with the obligations, it is very unlikely as well that we will see any sort of 'cradle to grave' procurement system inside the EU based in full on a blockchain solution. Furthermore, we need to bear in mind that the true value of the crypto space in general seems to be to enable completely new ideas and business models not possible with traditional technology solutions and that public procurement in the EU tends to be conservative and lagging on the adoption of new technologies.

Nonetheless, it is possible to conceive two broad areas where at least in theory blockchain might be useful as a solution: i) in situations where lack of trust in public bodies overrides other considerations and ii) where no pre-existing technical solution for a given problem exists or has been successfully deployed.

1. Lack of trust in public bodies

It is arguable that for countries where a severe lack of trust in public bodies arises that there may be a need to choose a procurement system that is not only transparent and secure but also is shown to be as such. In a sense, it is the procurement equivalent to the idiom that Caesar's wife must be above suspicion. Since public blockchains excel at manufacturing trust whereby default multiple parties have no reasons to trust each other, this characteristic makes them a valuable solution for those situations where trust in public bodies has disappeared and needs to be restored. In this scenario, public blockchains drawbacks such as their radical transparency, free and open access and cumbersome consensus mechanism are advantageous. This is because they provide a clear signal public bodies are serious about change by binding themselves to what may be a

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sub-optimal technical solution, but it is clearly the best solution to signal such seriousness. Perhaps it is possible to frame the Peru Compras project in this light, even though there is no evidence of extreme corruption or trust issues arising in the country used as a justification for its blockchain use case. And as mentioned earlier, what Peru achieved with a blockchain could have instead been done with a more traditional technical solution.

Slovakia[44] and Ukraine[45] have significantly changed their electronic procurement systems as to be more transparent, thus increasing accountability on public spending due to perceived lack of trust in public bodies. Both did so using traditional IT solutions and not blockchain related ones.

Even though Ukraine undertook a complete root and branch change of their procurement system after the Maidan revolution in 2014, it seems very unlikely the same will happen in the future, more so for any country inside the EU. Therefore, there may be moments and opportunities where perhaps a government may feel pressured to improve transparency and decides to move part of the procurement cycle into a blockchain solution. It is unlikely this would be a wholesale change of a national procurement system since those tend to follow the procurement Directives, but instead a more targeted and focused change to improve trust in public procurement. For example, it might be by increasing the transparency of procurement decisions (and decision-making processes) via their inclusion in a public blockchain. It is self-evident the same transparency might be achieved with a traditional database system but the added value for a public blockchain solution arising from the impossibility of tampering with entries in the ledger and the radical transparency it offers, provide a better solution to the need of restoring trust in public bodies.

2. Lack of pre-existing technical solution

The second area within the EU public procurement framework where it is possible to consider a blockchain solution is for those situations in which a given need as not been fully solved with recourse to existing technical solutions. If and when these are identified, then blockchain can be assessed in equal terms with other technical solutions that may have to be developed to solve such need.

Looking at the current practical issues arising from Directive 2014/24/EU, there are two areas where the existing technical solutions have been lacking. These are contract (and contract

44. GovLab, 'Open contracting and procurement in Slovakia' http://odimpact.org/case-open-contracting-and-procurement-in-slovakia.html accessed 14 July 2022 and OECD, 'Development and implementation of a national e-procurement strategy for the Slovak Republic' (2017).

45. Known as the ProZorro e-procurement system. On this see, OECD Observatoyr of Public Sector Innovation, 'eProcurement system ProZorro' (29 June 2016) https://oecd-opsi.org/innovations/eprocurement-system-prozorro/ accessed 14 July 2022.

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changes) registration and the ESPD/e-certis information exchange system. Furthermore, it is possible to conceive the usefulness of smart contracts to be used in the context of electronic auctions for simple goods contracts.

a. Contract and contract modifications registry

Currently, contract award notices and modifications are sent manually to the OJUE to comply with the requirements of Article 84 of Directive 2014/24/EU. In consequence, compliance with those requirements is certainly less than perfect. This is due to a misalignment of incentives between the manual obligation and the lack of consequences for non-compliance. In short, if a contracting authority does not fulfil this obligation, it faces no serious consequences for the failure in comparison with the procurement notice at the beginning of the procedure since missing that one out would affect the validity of subsequent decisions. For contract award and modifications, however, there is no such risk for breaching Article 84.

It is fair to say, however, that the current problem with Article 84 is not a technical one but one of compliance with existing rules. As such, it is perfectly possible to consider how a non-blockchain solution would work in this context - after all, countries like Paraguay[46] and Ukraine have 'end to end' procurement systems and capture that information without any need for a blockchain solution and even the UK is designing a central register of suppliers which will capture the relevant information from suppliers.[47] Yet, once more some of the technical disadvantages of a public blockchain solution (cost, lack of control, potentially cumbersome consensus mechanism) enhance the case for the transparency that is achieved by keeping this data on a blockchain. Plus, the advantage of it being immutable and censorship resistant at least for public blockchains make it a better solution overall than a centralised database, since it enhances the transparency objective by eliminating opportunities for data tampering. Having said that, this may be an area where a hybrid or enterprise blockchain might be helpful, albeit at the price of compromising some of those benefits. This is so because hybrid blockchains can be configured so that only contracting authorities are authorised to write into the ledger, unless the objective would be to allow for civil society to interact with the data directly in the blockchain by, for example, commenting in the ledgers themselves. However, the critique made earlier that hybrid blockchains have more in common with distributed databases than real blockchains, remains valid here as well.

46. Open Contracting, 'Paraguay's transparency alchemists' (02 October 2017) https://medium.com/open-contracting-stories/paraguays-transparency-alchemists-623c8e3c538f accessed 14 July 2022.

47. Cabinet Office, 'Transforming public procurement - our transparency ambition' (30 June 2022) https://www.gov.uk/government/publications/transforming-public-procurement-our-transparency-ambition/transforming-public-procurement-our-transparency-ambition accessed 14 July 2022.

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b. ESPD/e-Certis repository

A second area where perhaps a blockchain solution might be useful is as a repository for the information connected with the ESPD and e-Certis[48] since both have significant issues that are difficult to overcome within the current legal and technical frameworks.[49]

Regarding the ESPD, under the current rules the contracting authority is under the obligation to find exclusion information which is freely available in the internet or that it already has access to. Therefore, accessibility to foreign economic operator information by contracting authorities is one of the practical issues surrounding the use of the ESPD. The use of blockchain for the ESPD has been proposed already with the automation of exclusion grounds and selection criteria, possibly via a smart contract.[50] This suggestion seems far-fetched and lacking understanding of how both exclusion and selection work in practice as well as the underlying technology as well.

It is certainly conceivable that a hybrid blockchain containing the economic operator information relevant for the ESPD would help the contracting authority, assuming it is given authorisation to access the data. However, this solution could only work for specific situations such as those covered by Article 57(1) of Directive 2014/24/EU, that is the mandatory exclusions grounds since these are binary exclusions and as such can be subsumed to a yes/no assessment. Nonetheless this would only be possible if all public bodies in the EU holding the data relevant for Article 57(1) would include such data on that blockchain, something that looks as of today to be simply impossible to achieve. Otherwise, if one is dependent on the economic operators uploading the evidence themselves (and in an appropriate data format no less) we're once again falling into the oracle problem[51] and magical thinking traps based on an assumption that technology will just work. In addition, whereas the cross-border nature of the ESPD is not really working today, the downstream decision-making process of exclusion and selecting works, even though it could be improved. Therefore the value proposition for a blockchain solution is very different for each.

Having said that, and with the limitations from the oracle problem notwithstanding, a more reasonable ambition might instead be to use the blockchain registry as an archive for the data, for example updating the concept of the 'virtual company dossier' that exists (in theory) under the ESPD model but whose practical usefulness to date appears very limited.

48. As suggested before in 2020, Pedro Telles, 'Blockchain em contratação pública' in *Actas das II Jornadas de Direito dos Contratos Públicos (30 de Setembro a 2 de Outubro de 2020, FDUL)* (2021).

49. On these see, Pedro Telles, 'The European Single Procurement Document' Upphandlingsrättslig Tidskrift, (1 2017) 1-21 and Pedro Telles, 'Article 59: The European Single Procurement Document', in Rocberto Caranta and Albert Sanche-Graells (Eds) *Commentary on Directive 2014/24/EU* (Edward Elgar, 2021).

50. Nadia-Ariadna Sava and Dacia Dragos, 'The legal regime of smart contracts in public procurement' [2022] Transylvanian Review of Administrative Sciences, No 66E/2022 104.

51. On this see, Caldarelli, G., 'Understanding the Blockchain Oracle Problem: A Call for Action' [2020] Information 11 509 and Law Commission of England and Wales, "Smart legal contracts: advice to the government' (2021) 21-22.

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The same logic applies to the e-Certis repository of information. As it stands e-Certis is not a canonical source of information that can be relied upon by contracting authorities and economic operators. As such, the system does provide either party with legal certainty about the information it contains since there is no guarantee the information is correct. It is obvious the solution for this issue is mostly one of legal nature and the liability associated with the fidelity of the information contained. While it is not directly solvable by technical means, it is conceivable that a blockchain solution could be deployed to guarantee what information had been made available when, effectively raising the probability of discovery for Member States who do not have up-to-date information in the system. However, as with all other ideas proposed thus far, there is no technical reason why this can only be done with a blockchain and not a traditional IT solution.

c. Smart contracts for simple goods contracts

The final area of interest to look at as potential use cases is that of smart contracts. In particular, these may be relevant for simple goods contracts[52] that might be tendered via electronic auctions as appears to have been the case in the Aragon pilot. While the topic of smart contracts in public procurement warrants a paper of its own, at least some points can be highlighted here.[53]

Smart contracts can be subsumed to IF > THEN(THAT) conditions whereby if the premise is fulfilled then the contract is executed automatically, with the defining feature being this automation of contractual clauses. In short, contractual clauses are to be converted into computer code that can be self-enforced,[54] with this automation of performance being one of their key defining features.

As mentioned in the examples of Aragon and Peru it is indeed possible to use smart contracts in the context of public procurement. However, their usefulness is limited to very simple contracts particularly those involving commodities (like facemasks) which can be reduced to price only.[55] This is because smart contracts are inflexible[56] and rely on binary yes/no conditions that make them difficult to operate beyond these simple conditions. In other words, they can be useful in the context of complete contracts, that is those contracts where the clauses capture all and every single variable connected with it. Nonetheless, beyond simple goods contracts the vast majority

52. With a similar view Raquel Carvalho, 'Blockchain and public procurement', European Journal of Comparative Law and Governance (2019) 189.

53. On how smart contracts may be regulated, Roger Brownsword, 'Samrt contracts: coding the transaction, decoding the legal debates', in Phillip Hacker, Ioannis ianos, Georgios Dimitropoulos and Stefan Eich (eds) *Regulating blockchain. Techno-Social and Legal Challenges* (Oxford University Press, 2019) 311-324.

54. Sergi Nin Sanchez, 'Decentralised ledger technologies for public procurement' [2019] EPPPL 186.

55. Which, in accordance with Article 67 of Directive 2014/24/EU is no longer the default award criteria.

56. Jeremy M. Sklaroff, 'Smart contracts and the cost of inflexibility' [2018] University of Pennsylvania Law Review 263-303.

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of public contracts are by their own nature incomplete,[57] thus meaning they require some flexibility for adaptation to changing circumstances that could not be foretold when the contract was being drafted.

Furthermore, it is fair to say as well that while smart contracts are routinely connected with blockchains they do not depend on distributed ledgers to exist. In fact, they were conceptually described in the 1990s by recourse to a vending machine as an example, therefore well before any talk surrounding blockchain or distributed ledgers.[58] As such, it is perfectly possible to achieve the same level of automation by simply using traditional technologies, foregoing the need for any sort of blockchain technologies and in fact it already happens on a day to day basis beyond the example of the vending machine.[59] For example, giving instructions to an online broker to buy stocks in a certain company at a certain price would amount to a smart contract whose performance would happen automatically if and when the conditions imposed by the client were met.

VII. Conclusion

This paper has shown that despite the hype around the use of blockchain beyond the field of cryptocurrencies, when it comes down to public procurement the examples of its use are few and far between. Furthermore, only one example could be found of it being used in production and even then using a testnet and not a mainnet deployment solution, whereas the other examples are clearly simply pilots. In addition, the evidence from these examples shows that public or maximalist blockchains where trust is manufactured by consensus are for now, unusable for public procurement. This leaves hybrid or enterprise blockchains as the ones available for use, but these are not fundamentally different from distributed databases or other traditional IT solutions.

Having said that, the potential scope for the use of blockchain solutions is to be found on what cannot be done via traditional means or where these traditional means have failed so far, even though in theory they could be made to work, for example for contracts registries or updated versions of the ESPD and e-Certis. This is more so the case in situations where external factors may change the balance of importance and relevance for a blockchain solution vis-a-vis a traditional solution, ie whereby its reduced efficiency is considered a plus, for example for projecting an image of integrity and transparency that supersedes other objectives which would be better served

57. On incomplete contracts in general see, Jean Tirole, Incomplete contracts: where do we stand?, Econometrica July 1999 vol 67 issue 4 p.741-781.

58. Nick Szabo, “Smart Contracts: Building Blocks for Digital Markets”, Extropy nr. 16 (1996) https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh. net/smart_contracts_2.html accessed 14 July 2022.

59. As argued as well by the Law Commission of England and Wales, 'Law Commission smart legal contracts: advice to the government' (2021) 13.

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with a more efficient system.

As such and as things stand, it seems unlikely that there will be a significant scope for take up of blockchain in public procurement in the context of EU public procurement and that it will remain mostly a theoretical endeavour worthy of exploring in some small-scale pilots.

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