Blockchain in transport and logistics – paradigms and transitions

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Editorial:

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Introduction

Blockchain – also known as *distributed ledger* – technology is set to revolutionise data and business process management and transactions. Blockchain adoption, pioneered initially as a financial technology (*fintech*) then as a supply chain technology (Underwood, 2016), has expanded to public administration, transport, and logistics. Use cases in the former have been reported, but little is understood on its disruption in transport and logistics – including freight and passenger dimensions.

There is rising importance for a frictionless process where mobility of goods and services flow seamlessly between borders. There is a need for closer alignment between transport infrastructure including customs, airports, ports, rail and road. A digital infrastructure including clouds, intelligence management, payment systems, and pass-porting, to support these needs is paramount. This integration can enhance trade relations and transform the global supply chain. It can also transform how resources and capabilities in this environment can become more collaborative in the machine economy.

Industry, government or academic led studies can provide novel insights to advance transformational impact in addressing *challenge-led* problems in public and private manufacturing and services. There is a need for research in a multi-modal transport and logistics environment, especially those incorporating legacy and future systems.

Within this context, there are also various global social and economic shifts occurring. Major globally impactful transitions such as One Belt-One Road led by China (Ferdinand, 2016), increasing importance of airport resilience and operational efficiency (Rotundo, 2019), Brexit—Global Britain (Tielmann and Schiereck, 2017; Toly, 2017), Shift2Rail (shift2rail.org), and other broad socio-economic transitions also relate to technological evolution of blockchains.

The transdisciplinarity of this issue is evident; multiple disciplines and a variety of stakeholders need to cooperate for taking full advantage of blockchain and related technology. Multiple methodologies for investigation are needed. Empirical research as well as new theoretical grounding, concepts, models and methods are likely necessary. Demonstration of blockchain adoption in related supply chain, manufacturing and service sectors for transport and logistics such as automotive, aviation, shipping, rail network, taxi hailing service, forwarding, delivery service, travel require elaboration and synthesis.

This position paper aligned with the *International Journal of Production Research* Special Issue on Blockchain in Transport and Logistics aims to provide a foundation for the cutting-edge leading cases of the adoption of blockchain in transport and logistics, and chart the next wave of blockchain's transformational role in transport and logistics. This position paper presents key concepts and methods informing the paradigms in blockchain for transport and logistics, and summarises various future directions and scenarios for blockchain transitions.

Paradigms

Cross-border management

Cross border trade cargo flow is one of the most complex operations to manage in transport and logistics. This cargo flows typically involves transactions and data exchanges including tariff, tax and import/export duty checks, security checks (if applicable), goods validation and logistics service providers (LSPs) checks within outgoing and incoming ports. A typical container with smooth operation could range anywhere from 30 minutes to hours for processing at a port. For passenger flow management between borders, similar processes and time requirements also occur. Efficient cross border cargo and passenger flow management are critical for commerce.

Various advanced technologies have been introduced and implemented for cross-border transport management. Technologies include face recognition, artificial intelligence (AI), biometrics, robotics, laser and infrared technologies. For instance, face recognition has been used in certain major airports for passengers check-in and aircraft boarding (Chouliaraki and Georgiou, 2019); whilst laser and infrared technologies have been used to trace goods in containers (Li, 2013).

Blockchain is rapidly evolving in helping to improve traceability of cargo trade flow across borders (Pournader et al, 2019). It is not meant to replace advanced physical technologies, but to serve as a decentralized distributed ledger that administers the data transaction and authentication of goods and services across borders. Blockchain is relevant in such operations due to the ability to show clear line-of-sight and chain-of-custody for each transaction. It does this through proof of work and smart contracts (Dolgui et al, 2019); especially when multiple transport modes, logistics services and companies are involved. As a result, it will facilitate the process to comply with the custom rules and regulations for the geography. In addition, because it is immutable, the authentication of the goods and services receipts can be efficiently executed.

For cross border trade flow management, goods of high value are usually subject to close monitoring. Blockchain can play a key role in such instances of high value goods transport. Alternatively, goods that are of easy target for counterfeiting – for example, medical and pharmaceutical products – can benefit from blockchain too. Multiple cases can be found, e.g. the use of blockchain for diamond supply chain (Underwood, 2016) and the adoption of blockchain in airports (Di Vaio and Varriale, 2019) and seaports (Philip et al., 2019).

The need for more efficient cross-border management has driven demand for blockchain in transport and logistics application; this demand is in consort with other advanced technologies. The blockchain supported cross-border management paradigm is one of the major directions for future blockchain research and upscaling.

Trust

Blockchain has been described as a trustless system (Cole, et al., 2019). Trustless means that you don't have to trust specific participants in a transaction for the transaction to occur. A transaction will occur because of specific set rules and algorithms – protocol – of a blockchain platform. The trustless paradigm scatters the role of transaction approval across multiple actors in a network. It makes trust irrelevant. But trust does not just end with this characteristic; it is one of the most basic and popular features of blockchains. There are many other characteristics that can help contribute to building trust in blockchain supported supply chains, transportation and logistics. The other trust dimension is to build or increase trust.

Transparency characteristics, especially in the supply chain, are also part of building trust through blockchain technology. Although transparency may not be supported by competitive markets who may view information asymmetry as a competitive advantage, there are situations where transparency builds trust and can be competitively advantageous.

Affective trust has a number of dimensions including authentication trust, resource access trust, delegation trust, provision trust, and infrastructure trust (Galvez, et al., 2018).

The 'we have nothing to hide' perspective can build trust with customers, clients, and supply chain members. For example, showing how well a transportation organization does on environmental resources and emissions management with information accessed publicly and by partners, can build trust on whether the company is performing well on environmental factors and not 'greenwashing'. Transparency, the reliability of information, and its immutability together contribute to trust – all these theoretically exist in modern blockchain systems.

Traceability, through a history of blocks – with time stamps, as an example – can build trust and transparency (Francisco and Swanson, 2017). In transportation and logistics, along with goods flow is related documentation – such as bills of lading and ship notifications – information flow that passes from agent to agent in the supply chain. These forms and notifications flows may be subject to loss, counterfeiting, and theft. They are also stored on paper for long period of time. Holding paper inventory, requiring hardcopy, shipping documents, and filing can cost billions of dollars; not including the various fraudulent activities that can siphon away valuable property.

Food products are subject to fraud as they are processed in their supply chain. Seafood is especially problematic as cheaper fish are passed off for more expensive varieties. In this case it is the product that is subject to fraud. Having provenance and traceability can greatly reduce fraud and adulteration of goods. Fraud in the food industry costs over $10 Billion annually (Yiannas, 2018). Even a small percentage of fraud reduction can justify blockchain investments.

Another information technology and data warehousing characteristic necessary for logistics and transportation management – as is true for all organizational processes and activities – is the trust ideal of a single version of the truth (SVOT). Organizational decision-making needs this characteristic for well-defined and well-understood decisions and actions. Inconsistent, unreliable, and fragmented information that result from missing SVOT, builds distrust in managerial decisions, processes, and communication. Time is wasted on debating the veracity of these activities and information with a dubious consensus as an outcome; while disparate members of the supply chain work on different activities due to various versions of the truth. Lack of SVOT along the supply chain makes for greater inefficiencies.

Blockchain can improve SVOT, making, planning, decision-making, and action more efficient (Aste et al., 2017). Of course, other improvements to communication and information systems can also contribute to SVOT and trust, but blockchain with its designed security and consensus systems, along with traceability and transparency can set the foundation.

As can be seen, there is substantial business value in building trust through blockchains. There is efficiency, reputation, time-to-market, responsiveness, and materials savings – to name a few – that can occur with building trust through transparency, reliability, consistency, and traceability of information through blockchain technology. Yet, burdens and barriers do exist: whether the promises can be delivered, the scalability of the solutions, the integration or removal of legacy systems, investment requirements, and inter-organizational change management are only some of the barriers that exist to blockchain adoption (Saberi et al., 2019a; b).

The research on this topic can be quite extensive. For example, in economics, information theory can be used to evaluate how information asymmetry is altered and mitigated in blockchain environments. Information asymmetry provides opportunities for informational rents that can build organizational profitability (Shen et al., 2019). With greater transparency from blockchains these informational rents are likely to be reduced, if not eliminated. A basic research question is whether organizations will be willing to give up informational rents to accrue blockchain efficiency and other value benefits. There are many such tradeoffs and relationships that may be investigated in this new paradigmatic environment.

Transparency and traceability can build trust by meeting stakeholder needs, curbing illicit business practices, improving sustainability performance, increasing operational efficiencies, enhancing supply chain relationships and information flow, and providing better information about market forces and trends (Hastig and Sodhi, 2019). These benefits and values need to be balanced against the tradeoffs and limits of blockchain adoption.

Standards, governance and operations

Blockchain governance is a two-way street. Blockchain technology requires appropriate governance for it to operate. It also influences governance of transportation, logistics and supply chains.

An important aspect for blockchain governance targets blockchain industrial ecosystem, providers, platforms, developers, and users to have a common language. Currently, academically and practically, blockchain technology is a *contested concept* (Kouhizadeh, et al., 2019a;b). The contested concept means that various stakeholders – within the same and different stakeholder groups – have their own definitions, perspectives, and definitions of blockchains and its elements.

This lack of overall consensus – except maybe a consensus on blockchain's potential and hype – has been a critical blockchain adoption barrier. Lack of consensus arises across a variety of issues ranging from building immutability through proof-of-work activities to industrial use case adoption. Thus, standards efforts have emerged within and across industries. Two major initiatives for blockchain standards include those by the International Standards Organization (ISO) and the IEEE Society.

The ISO technical committee ISO/TC 307 is the group in charge of developing standards for blockchain and distributed ledger technologies. Currently there is a number of ad hoc and working groups. The six working groups are developing standards on: Foundations; Security, privacy, and identity; Smart contracts; Governance, and Use Cases. Each of these areas, as evidenced by our articles and articles in the special issue, overlap and can be quite extensive from organizational, policy, and technical perspectives.

The IEEE Society has been working on blockchain standards to establish some very specific standards for activities related to cryptocurrencies and industries (see Table 1). They also have anti-corruption standards such as security measures and anti-money laundering activities. There are some special interests involved in these standards definition and the IEEE society provides a medium for industry standard developments. Relatedly to transportation are connected and autonomous guided vehicles. This effort can revolutionize the transportation and logistics industry if this co-methodology infrastructure develops along with other technologies and processes such as IoT.

P2140.1 - Standard for General Requirements for Cryptocurrency Exchanges P2140.2 - Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges P2140.3 - Standard for User Identification and Anti-Money Laundering on Cryptocurrency Exchanges P2140.4 - Standard for Distributed/Decentralized Exchange Framework using DLT (Distributed Ledger Technology) P2140.5 - Standard for Custodian Framework of Cryptocurrency P2141.1 - Standard for the Use of Blockchain in Anti-Corruption Applications for Centralized Organizations P2142.1 - Recommended Practice for E-Invoice Business Using Blockchain Technology P2143.1 - Standard for General Process of Cryptocurrency Payment P2143.2 - Standard for Cryptocurrency Payment Performance Metrics P2143.3 - Standard for Risk Control Requirements for Cryptocurrency Payment P2144.1 - Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management P2144.2 - Standard for Functional Requirements in Blockchain-based Internet of Things (IoT) Data Management P2144.3 - Standard for Assessment of Blockchain-based Internet of Things (IoT) Data Management	P2418.1 - Standard for the Framework of Blockchain Use in Internet of Things (IoT) P2418.2 - Standard Data Format for Blockchain Systems P2418.3 - Standard for the Framework of Distributed Ledger Technology (DLT) Use in Agriculture P2418.4 - Standard for the Framework of Distributed Ledger Technology (DLT) Use in Connected and Autonomous Vehicles (CAVs) P2418.5 - Standard for Blockchain in Energy Access the P2418.5 Working Group website P2418.6 - Standard for the Framework of Distributed Ledger Technology (DLT) Use in Healthcare and the Life and Social Sciences Access the P2418.6 Working Group website P2418.7 - Standard for the Use of Blockchain in Supply Chain Finance P2418.8 - Standard for Blockchain Applications in Governments P2418.9 - Standard for Cryptocurrency Based Security Tokens P2418.10 - Standard for Blockchain-based Digital Asset Management P825 - Guide for Interoperability of Transactive Energy Systems with Electric Power Infrastructure (Building the Enabling Network for Distributed Energy Resources)

Table 1: Active IEEE Standards Projects (Source: IEEE – https://blockchain.ieee.org/standards -- last accessed December, 2019).

Many of these standards are currently in early stages of development, representing few established and agreed-upon standards; and thus limited structured governance. The original goals of blockchain enthusiasts was to not have any overseers governing blockchain technology and developments; thinking it would stifle development or maybe even corrupt the system. Regulatory bodies would put controls on blockchain activities, such as cryptocurrencies that originally sought to replace these regulatory and controlling bodies.

IEEE and ISO represent industry, governmental, and other stakeholder bodies; private industry associations have also sought to set standards. The Blockchain in Transport Alliance (BiTA; https://www.bita.studio/standards) has its own standards group for transportation and logistics. Only one established BiTA standard exists for blockchain as of January 2020 – the "Location Component" standard. This standard is used to define the location of any type of object or entity including fixed entities – a building, port, or rail station; or a mobile entity – a vehicle or shipping container. These standards include data requirements and entity relationships in blockchain information blocks. It is expected that BiTA will be building from this initial standard and has a process in place.

How these standards affect blockchain adoption in the transportation and logistics industries along with improvements and alterations of various operational practices and efficiencies requires investigation. Standards diffusion theory can also be parlayed to industries who have not seen this type of issue since the days of electronic data interchange (EDI) and electronic commerce standards.

Blockchain technology can help determine and set governance norms and rules for transportation, logistics, and supply chain industries and activities. Using a norms and rules perspective of governance sets the boundaries for blockchain managed supply chains and industrial practices. For example, given transparency and traceability goals, open information sharing rules will need to be established. What is expected and allowed to be shared and the level of openness would be concerns in a governance situation.

One important aspect of governance is determining agreements and when successful transactions are expected to occur. Traditionally, contractual agreements, monitoring, and activities occur through actual transformations based on rules such as how much to deliver, when to deliver, and payment agreements. In a blockchain situation, there are platforms, such as Ethereum and Hyperledger Fabric that have their own smart contract protocols and languages which may delimit the rules and approaches that may be used.

Legal contracts have been a standard approach since laws and torts have existed. E-contracts have existed for decades. The term smart contract actually existed for e-commerce applications arising in the 1990s. The current definition for a smart contract is defined as a self-executing program in a blockchain environment, meant to implement automated transactions agreed by the parties (Governatori, et al., 2018).

Smart contracts electronically govern processes in a blockchain governed supply chain. Process transactions within a blockchain have rules established through consensus and potentially updated by various agents in the supply chain – depending on whether the overall governance is private or public blockchains. This governance may include specifications and rules for the exchange of goods, services, and capital. They may also have various existing performance requirements as part of governance.

Goods that meet expected characteristics may be exchanged when certain aspects are met. This may include any bill of lading. A bill of lading is a contract signed between a party consigning the goods and the carrier of the goods from that point forward. It's both a contract, and a receipt. It binds the carrier to the service promised – that the carrier will transport the goods in compliance with the commercial contract. It also serves as proof that the service was promised. In this way, the smart contract can be the bill of lading where it can show ownership of goods and when the goods have met the contractual obligations as transactions occur, across a distributed ledger, where all can observe and even approve a transaction.

Governance and rules across a supply chain are difficult to manage as partners in a supply network are not typically governed, managed, and traced effectively. For example, the provenance on whether products or materials are from a forbidden source, such as conflict minerals and blood diamonds, is not an easy rule to be governed. Blockchain characteristics allow for more effective governance. What was impractical, infeasible, or not trustworthy allows for greater ethical governance rules to be put into place.

These are all conceptually potential from a governance perspective, actual implementation will still require development and study.

Business model

Whilst blockchain technologies mature along the adoption curve, innovative business models that support blockchain delivery have started to flourish too (Chong et al., 2019; Nowinski and Kozma, 2017). In the context of transport and logistics, such innovative business models can be categorized into three types: (a) cloud and enterprise platform service, (b) blockchain as a service, (c) digital mobility as a service.

A cloud and enterprise platform service business model aims to collect multiple services together on a single platform supported by cloud computing technology to deliver discrete and end-to-end services to final customers. For instance, through the Microsoft Cloud platform, original equipment manufacturers (OEMs), automotive supply chains and logistics service providers can manage orders and design transports and logistics operations through private blockchains. Blockchain providers can offer blockchain as a service model to serve public and private users. For instance, public transport services managed by cities can adopt such services to optimise the sharing economy – for example the rental and use management of electric bikes and electric scooters.

Change from a product to a service orientation in our increasingly inter-connected digital eco-system has stimulated major transformation from a classic ownership model to a usership model. Consequently, the business approach in transport and logistics have evolved towards digital mobility as a service model. Blockchain plays a crucial role in such a revolution. For example, charging facilities infrastructure alignment with electric vehicles, swapping of batteries under an exchange scheme (in-use and end-of-life) for mileage, energy storage and power, and last mile delivery of goods and services via unmanned aerial vehicles (UAVs) – drones – can be supported by blockchain mobility as a service.

These new business model paradigms for blockchain will disrupt classic business models and will further a major shift of society towards a digital future.

Ethics, security and privacy

There are various ethical concerns with blockchain technology (Bertino et al., 2019). Open information, building consensus, access and inequity, security, and governance each have aspects that influence ethical concerns.

Major issues are associated with both individual and organizational privacy (Feng et al., 2019). Depending on information provided in the blockchain, specific individuals and personnel may lose their privacy. Worker rights may degrade depending on the level of detail attached to processes and transactions. Wages, identifying information, and their performance may be publicly available; care should be taken in these situations. Most of these are identity privacy issues.

Organizational privacy may include information related to organizational intellectual property, performance, and costs without a broader picture. Proprietary information would need to be managed carefully in an environment where transparency of information is a goal. Thus, there will be tensions involved in how much and the type of information to be shared. These are usually associated with transaction privacy issues.

Supporting ethical conduct can also be a goal of blockchains. This characteristic was alluded to in the discussion on trust through traceability and transparency. If information is widely available and is reliable, then nefarious and unethical actions will be less likely. These actions can be reduced by shedding light on poor practices that can injure organizational reputation and goodwill. Also, given the immutability of information and traceability, adjudication in court, penalties, can cause organizations to behave more ethically.

Another ethical aspect is that blockchains may also be subject to accessibility concerns. Smaller companies without the knowledge and resources to take advantage of blockchain technology may be at a greater disadvantage and be further disadvantaged. This inequity may occur to organizations, transporters and logistics companies, in less developed regions of the world. This situation may also be true for individual and micro-enterprises, where some blockchain activities may replace lower skilled jobs. These may be aspects of a 'digital divide' that may become larger as greater automation and information technology is used to make processes more efficient.

Alternatively, there are situations where blockchain can also provide vulnerable regions with greater stability and integrate them into the transportation and logistics supply chains. For example, blockchain may help to incentivize and trade in regions of the world where traditional economic systems are relatively unstable. It can also help provide legal rights and contracts to organizations through electronic smart contracts and bills of lading. There may also be fewer situations of exploitative behavior if information is widely available and transparent.

Whether blockchains can make for more ethical transportation and logistics activities is an open question. Similar to most tensions such as privacy versus transparency, exploitation versus integration into modern economic systems, the tradeoffs and paradoxes are likely to remain. Identifying best ethical and responsible practices will need to be investigated as the technology diffuses.

Transitions

Integration with other technologies

The evolution of emerging technologies as described by Gartners hype cycle 2017 is widely reported (Carter and Koh, 2018). Blockchain is one of the emerging technologies – predicted to have a maturity cycle in 5-10 years – on the curve, amongst other technologies ranging from smart dust, deep learning, machine learning, commercial UAVs to virtual reality. There is no doubt that our future society will be increasingly interconnected digitally. Therefore, integration with other technologies including blockchain, Internet of Things (IoTs), Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), edge computing, Cloud, 5G and quantum computing are paramount.

In addition to integration with digital technologies, the boundary between the physical, virtual and digital worlds will be blurred, demanding integration with flexible and cobot (collaborative robots), digital twin, industrial internet, deployable smart factory anywhere and modularization, resource efficient and sustainable technologies (environmental and economic including life cycle assessment), immersive, virtual, augmented and mixed realities, wearables, autonomy and 3D printing-additive manufacturing.

These technologies integration are applicable across fields including autonomous transports and logistics, but also intelligent manufacturing and services. The fourth industrial revolution (Industry 4.0) and Logistics 4.0 will benefit, calling for the race of their innovation.

Following from the key paradigms above, it is essential that these technological transitions must be managed and governed with ethical and secured approaches with acceptable standards.

Integration with other methodologies

Blockchain has the potential to be interlinked with a variety of transportation, logistics and supply chain activities and methods that rely on multiple organizational or multiple process information.

In environmental practices to determine the ecological footprint of various supply chain activities, life cycle analysis (LCA) can be made more effective (Kouhizadeh and Sarkis, 2018). Blockchain technology supports component identification throughout a product's lifecycle. It can greatly streamline the data collection phase for LCA. It can also verify sustainability labels and certifications which require auditing throughout the process.

In managing the economic dimensions of transport and supply chains, issues of efficient scheduling and inventory management methodologies arise. The methodologies and tools to manage this environment include various optimization approaches that can consider the overall information across the supply chain. One of the most pernicious systemic and structural aspects of the supply chain, which includes transportation and warehousing, is the bullwhip effect. The blockchain is capable of sharing information quickly, reliably and accurately across organizations. Having the whole supply chain's direct access to information can help mitigate the bullwhip effect. Part of this effort to help reduce bullwhip effects is vendor managed inventory (VMI). VMI along with blockchain technology and internet capabilities may be a strategy for managing bullwhip affects. Research on developing, implementing and observing such situations is needed.

We discussed how smart contracts help determine what actions or processes can actually complete a transaction. Many times the consensus smart contract agreed upon across the supply chain may not be the most efficient. Knowing the history, the performance, and having this information available across blockchain partners can help identify ways to improve processes, objectives, or goals. Knowing this history can also help trace what worked and what did not work. Thus, methodologically, benchmarking, continuous improvement, and business process improvement within and between organizations can be more effective (Mendling et al., 2018). Research can include: how to design processes for blockchain execution; design blockchain smart contracts to help identify ways to improve inter-organizational business processes; and developing approaches for identifying, discovering, and analyzing relevant processes that can work best using blockchain technology.

Governance models may also change with the blockchain technology. We have mentioned new rules and approaches that can derive from how organizations interact. This situation can help redesign strategic and tactical decisions for organizations. For example, strategically managing and designing supply chain networks that include warehouses, cross-docking, and facility locations may all be influenced by tactical information from blockchains. Thus, not only do business processes get altered, but actual delivery scheduling based on flow information across the blockchain may source, store, and deliver goods differently over time – and even automatically – when blockchain information is linked to artificial intelligence and machine learning systems. There are opportunities in this context to have smart contracts that learn and are dynamic.

Lean, agile, total-quality management, and just-in-time (JIT) methods can be more effectively focused on inter-organizational performance. The data from multiple entities can be evaluated to determine a more global performance. As an example, JIT has been traditionally criticized by shifting supply chain inventory holding risk further down the distribution channel. With blockchain information, data and observations can be made to determine whether such risks do occur and how they can be mitigated.

Some of these methodologies – for example agile organizations and supply chains – are designed to help build resilient and robust supply chains. This resilient design may mean being able to source from different locations rapidly, deliver at different capacities, and be generally flexible to meet unexpected risk events and opportunities. It is not clear that blockchains can effectively do this, but with opportunistic and open information, it is more likely that organizational networks can become more fluid. Whether this issue of agile and virtual enterprises and supply chains evolves with blockchain technology requires investigation.

These integrations would enable further advancement in their research and innovation domain across disciplines, hence creating clear applications impact in the field of production, operations, supply chain (transport and logistic) in the technological era.

Sustainability

Sustainability is a major cross-cutting theme in this evolution (Koh et al, 2017) in future mobility in transport and logistics. This includes electrification such as electric vehicles and electric aeroplane, greener and more efficient fuel such as biofuel and hydrogen, lightweight materials such as advanced composites and polymers, battery energy storage, recycling and circular economy (Awasthi et al, 2019; Kouhizadeh et al., 2019b) including new battery chemistry for longer life with less reliance on critical materials such as lithium.

Connecting these advances into production, operations, manufacturing and services, requires a future digitally connected transport and logistics system and network, able to share resources and respond to demand, thus enabling movement of resources seamlessly between road, rail, air and sea. For instance, future electric vehicle supply chains will be able to show data related to energy and power capacity for batteries in the network, thereby sharing this information amongst users community, supported by batteries swapping authenticated by blockchain and other technologies.

Similarly, large scale LCA of any supply chain can be verified through blockchain and AI technologies, supporting future prediction on potential environmental impact, where this would be particularly useful to advance the analytics of embodied impact in the supply chain.

One major sustainability concern with blockchain and most digital technologies is the amount of energy needed to operate them (Truby, 2018). Although there may be efficiencies and optimization in energy trading and other efficient mechanisms offered by blockchain; a major concern is the amount of energy required to manage the distributed ledger system and proof-of-stake and proof-of-work. Computer technology and software development may be needed to further aid these efficiencies across the transportation supply chain.

Conclusions

Drawing from the paradigms and transitions summarized above, several key research requirements and action points can be concluded.

(1) The rise of digitalization integration into every decision-making in our fabric of society whether this is in public, business or private context are non-deniable. The ability to manage such change efficiently and sustainably will differentiate the future state (Koh et al, 2016). This calls for responsible digitalization integration with environment, social and economic equally embedded in the process, preventing resource scarcity and encouraging a balanced future system with harmonization of resource flow. In particular, blockchain integration with other technologies and methodologies as

discussed in this position paper are expected to support this growth; but a wariness of unexpected consequences of these technologies must be considered.

(2) The change of transport and logistics experience and infrastructure towards an intelligence medium requiring integration between physical infrastructure and digital infrastructure, as well as secured resource flow to enable safe exchange of data and resources between nodes and stakeholders in the supply chain.

(3) The harmonization between policies for energy, climate change, social and economic development, industrialization, environment, sustainability, trade, technology and innovation, finance, manufacturing, supply chain, information, resources and circular economy with strategic policies at national and international scales is crucial in delivering global system transformation for growth that are powered by technology and sustainability together.

(4) Future research and innovation are needed urgently to address the paradigms and evolutions outlined above. This will advance the science and the field, and stimulate advanced cross-disciplinary collaboration.

(5) Integration between science and technological research and innovation in this area, coupled with government policy formulation with industry and academic collaboration are required to drive the paradigms and evolutions forward strategically, effectively and efficiently.

(6) Academically, the theory to understand, explain, and further the successful implementation of blockchain technology is still needed. Organizational change, social interaction, individual acceptance, and global trade theories are all examples of theoretical and academic study needed at multiple levels to fully comprehend and integrate blockchain into transportation and logistics.

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